EU income stabilization tool: potential impacts, financial sustainability and farmer's risk aversion

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Abstract

The Income Stabilization Tool, a risk management scheme introduced within the Common Agricultural Policy (CAP) 2014–2020, could help European Union farmers manage the income risks they face. This study assesses the potential impact of implementing this tool through the maximum level of contribution to the fund which determines an indifference to participate in the fund and its financial sustainability. The study relies on an expected utility approach and assesses the variability of loss ratios over time using a sample of Italian hazelnut farms as a case study. The participation depends on the level of farmers' contributions and their degree of risk aversion. However, the CAP public support makes the scheme financially sustainable.

Keywords: Expected utility, Gross margin, Mutual Fund, Risk management

Introduction

The resilience and sustainability of farms are influenced strongly by their capacity to survive various risks and shocks that affect their income (Lien et al. 2007; Dahms 2010; Mitchell and Harris 2012; Meuwissen et al. 2019; Reidsma et al. 2015). In particular, higher uncertainty reduces the responsiveness of investment to demand shocks, making firms more cautious when either investing or disinvesting (see, for example, Bloom et al. 2007). In the European Union (EU), a large number of farmers face severe income drops; every year during the period 2007–2015; at least 20% of farms in the EU incurred severe losses (i.e. income drops greater than 30% of their average income in the three previous years; European Commission 2018a). The relative share of these farms changes by sector and by economic size class. Farms specialized in horticulture and permanent crops other than viticulture have a high probability of severe economic losses (Trestini et al. 2017).

Risk management can help farmers face potentially disruptive challenges (Meuwissen et al. 2019). Several instruments can be used to do this (Bielza Diaz-Caneja et al. 2008; Meuwissen et al. 2013; Trestini et al. 2018). Risks could be managed through market tools such as the individual ones (insurance, forward and future contracts) or shared with other farmers (mutual funds), cooperatives, producer organisations, or through

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ex-ante public support such UE/Member State as subsidised insurance and mutual funds, and CAP market measures. Such instruments can be used to manage single risks (e.g. production risk of a specific commodity) or the whole farm income risk. However, an innovative way to address downward fluctuations in agricultural income includes the Income Stabilization Tool (IST) which is an interesting tool potentially available to EU farmers. It is a risk management tool financed by the Rural Development Programmes (RDP) and based on a public–private partnership that provides financial compensation to farmers who experience a severe income drop (Bardaji and Garrido 2016). A mutual fund (MF), which is steered by associated farmers, manages the IST. The farmers pay an annual financial contribution to the MF to become eligible for receiving compensations when their whole-farm income decreases over 30% from the expected income [Article 39 of Regulation (EU) No 1305/2013]. However, because risks do not affect all agricultural sectors equally, a sector-specific IST has been recently introduced. Here, farmers' compensation is triggered when their income drop exceeds 20% of their expected income [Regulation (EU) No 2017/2393].

Despite some positive features, the IST is still in a pioneering phase in the EU. According to Moellmann et al. (2018), only one Spanish region (Castile-León) and two Member States (MSs) (Hungary and Italy[1]) have planned an IST but none had been implemented until 2020 (Giampietri et al. 2020). Therefore, historical compensation and liability data are not available to support insurance rate-making procedures or practical aspects of the implementation of this instrument.

While several analyses have shed light on the potential implications of the introduction of IST on the stabilization of farm income, very few of them address the problem of farmers' participation choice in the scheme and its financial sustainability. Farmer's adoption of risk management strategies depends on several factors such as risk perception or risk attitude (Meraner and Finger 2019; Giampietri et al. 2020) and, among others, on the level of the financial contribution they pay to the MF (Capitanio et al. 2016; Trestini and Giampietri 2018). To make the management of an MF sustainable, contributions should be large enough to cover compensations and other loading costs the MF faces (Coble and Barnett 2013). However, high contribution' levels are expected to make the IST unattractive to farmers who have a quite elastic demand for insurances (Smith and Glauber 2012). This calls for establishing under which conditions supply and demand can interact while also considering the availability of public support. The financial sustainability of the scheme is important for its continuation (Capitanio et al. 2016). In particular, the scheme must ensure a sound accounting balance over a reasonable number of years and the annual balance must not reach critical negative levels and threaten the fund's financial position.

Considering this background, the following research questions demand answers. First, what is the potential impact of the IST on income-related risks at the farm level? Second, under which conditions farmers would be indifferent to participate? These questions are investigated under plausible hypotheses based on levels of contribution paid to

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[1] Despite the fact that rural development policy is planned at a regional level in Italy, the risk management toolkit the CAP provides is ruled at the central level through the National Rural Development Programme (Mipaaf 2017) due to the complexity of the toolkit programming. This latter is transposed into the Risk Management Plan for Agriculture (see the latest MD n. 3648 of 08/04/2020, Mipaaf 2020) which rules the sector-specific IST.

the MF, policy support, and farmers' risk aversion. Third, which conditions provide the opportunity for supply and demand to interact with one another? In particular, this work will identify the maximum level of contribution at which farmers are indifferent to participate and the minimum contribution that makes the MF managing the IST financially sustainable. Fourth, which geographical scale (i.e. either national or regional) should be adopted when implementing IST? The opportunity to differentiate the contribution rate by region will be addressed taking into consideration the extent of the financial risk the MF faces caused by fluctuations in the overall amount of compensations the MF pays to farmers over the years.

This paper answers these questions using a sample of Italian farms specialized in hazelnut production as a case study. These farms represent a sector affected by a relatively high level of risk given the variability of yields and the strong price volatility (Zinnanti et al. 2019); in addition, high costs and lengthy implementation time strongly constrain changes in production patterns.

The paper is organized as follows. "Background on income risk management schemes and the IST" section depicts the whole income risk management tools used worldwide and offers a literature review of IST analyses. This roots the analysis within the available literature and indicates its contribution to the current debate. "Material and method" section describes the data and the methods used in this analysis. "Results" section shows the results of the analysis. "Discussion" section closes the paper and provides a discussion of the results.

Background on income risk management schemes and the IST

Income risk management tools

Whole-farm income risk management schemes have attracted the interest of agricultural policymakers worldwide (Thomas 2018). Different income risk management schemes are available in developed countries (European Commission 2017a, b; Thomas 2018; OECD 2019; Cordier 2014). Public agricultural insurance programmes dealing with farm income volatility are heavily used and largely subsidised in the USA and Canada (Cordier 2014).

In the USA, insurance tools are the main public policy mechanism for reducing farmers' exposure to yield and/or price risk (Smith 2018; Mahul and Stutley 2010; Taylor et al. 2017). The 2014 Farm Bill[2] introduced two new risk-management programmes: the *Price Loss Coverage*, a fixed-price support to address sharp declines in a commodity's marketing year average price below the statutory reference price, and the *Agricultural Risk Coverage*, a county- or farm-level[3] revenue-based programme to support farmer's revenue when crop prices fall below 86% of the historical average benchmark revenue, i.e. a five-year Olympic average of past prices multiplied by a five-year Olympic average of yields (AHDB 2016; Cordier 2014; Taylor et al. 2017; Smith 2018; OECD 2019;

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[2] The 2018 Farm Bill, in force through 2023, continues insurance programmes implemented under the 2014 Farm Bill (OECD 2019).

[3] The county-level option is crop-specific; rather than calculating a revenue value across all the crops grown on a farm, the Agriculture Risk Coverage (ARC) enrolment is tied to a particular commodity. The individual-based ARC programs a whole-farm revenue-benchmark coverage while the county-based ARC program is a product revenue-benchmark coverage (Cordier 2014).

Smith and Glauber 2019). Both programmes cover a portion of a farmer's income losses and payments are made on a per acre historical basis (Cordier 2014; Smith and Glauber 2019; OECD 2020). Among the key success factors in managing US income insurance schemes are extensive public support to co-finance premium rates and a large database of historical yields and prices (Cordier 2014).

The Canadian Government has moved away from price and yield stabilization mechanisms, developing several business risk management programmes to address different layers of risk in agriculture (OECD 2020; Thomas 2018). Among these, AgriStability, a whole-farm margin programme, protects farmer's net income, coming into play when margins fall below 70% of the Olympic average of the last 5 years of farmers' net margin (OECD 2020; Slade 2020).

Unlike the above-mentioned countries, the EU still mainly supports farmers' income guaranteeing an annual direct payment (Buckwell et al. 2017). However, a risk management toolkit (Art. 37–39 of Reg. (EU) 1305/2013) has been incorporated in the second pillar of the Common Agricultural Policy (CAP) 2014–2020 (thus becoming optional measures co-financed by the MSs) to help farmers to manage risks. The toolkit includes the IST, which has some desirable features. First, it refers to the whole farm income considering the complex nature of farm risk (not just production risk such as farm insurance) and the correlation between prices and yields and across the profits from different farm activities (Meuwissen et al. 2003; Severini et al. 2016). Second, the IST has the potential to also cover systemic risks (specifically price risk) that are not covered by the available commercial insurances, hampering the principles of risk pooling (Meuwissen et al. 2003). Third, in contrast with traditional insurance products offered by insurance companies, the IST based on MFs managed by groups of farmers (Cordier and Santeramo 2019). Fourth, it can be supported by agricultural policies in agreement with World Trade Organization green-box requirements (Mary et al. 2013).

In 2017, considering the critical issues that emerged in the first application of the IST, Reg. (EU) No 2017/2393 also introduced the sector-specific IST and expanded opportunities for farmers.

Literature review on the IST

Researchers have addressed several issues including the potential implications of the introduction of the IST on income variability and average income level. Several studies demonstrate the income stabilizing effect of the IST on agricultural income stability by offering direct protection against low incomes (Castañeda-Vera and Garrido 2017; Liesivaara et al. 2012; Mary et al. 2013; Severini et al. 2019a, b). Due to the provided public support, the IST also improves the average level of income of the farmer population. Using a Certainty Equivalent approach, Castañeda-Vera and Garrido (2017) have assessed the efficiency of this tool in pursuing the two goals of income stabilization: increasing farm lower incomes and decreasing income variability. Furthermore, Finger and El Benni (2014a) and Severini et al. (2019b) have shown the effects of the IST on reducing income inequality in agriculture.

A large strand of literature has focused on estimating the probability of receiving compensations and their extent as well as influencing factors (El Benni et al. 2016; Pigeon et al. 2014; Trestini and Giampietri 2018). These analyses provide useful insights

for defining the contributions farmers are asked to pay to the MF. To address this issue, researchers have tested possible implications of implementing alternative rating approaches and reference income levels (Finger and El Benni 2014b; Severini et al. 2019a; Trestini and Chinchio 2018).

Further issues have garnered limited attention, such as the geographical dimension on which the scheme should be operated and the financial sustainability of the MF. Trestini and Giampietri (2018) compare the hypotheses of a national IST with that of developing five different macro-regional schemes. In the first case, it is possible to pool the risk of single regional funds and to differentiate the level of contribution accordingly to the level of income risk of each region. Hence, Trestini and Giampietri (2018) found that opting for a national scheme can reduce the financial risk the MF faces but that is advisable to set different contribution levels for farmers belonging to different macro-regions.

Finally, several analyses have not studied farmers' participation choice, assuming mandatory participation in most of the cases. This appears to be a strong limitation especially in assessing whether the new scheme could garner a participation rate large enough to succeed. However, several factors affect farmers' demand for agricultural risk management tools including farmer's risk attitude and risk perception; off-farm income and direct payments; expected indemnity for insurance; direct and indirect experience with insurance; farm and farmer's characteristics (Finger and Lehmann 2012; van Winsen et al. 2016; Liesivaara and Myyrä 2017; Santeramo 2018; Meraner and Finger 2019; Giampietri et al. 2020). In addition, Giampietri et al. (2020) demonstrated the higher the perceived barriers to adopt, the lower the intention to participate in a mutual fund highlighting the role of farmer's trust on the intention to adopt subsidised risk management tools. Castañeda-Vera and Garrido (2017) have shown that risk-adverse farmers are expected to participate in the IST. However, their results are referring to the considered case study and cannot be automatically extended to other areas and sectors.

Material and method

Data and study area

The aforementioned research questions were answered using a sample of Italian farms specialized in hazelnut production. Perennial crops are very important in Italy; more than half of Italian farms specialize in them (Istat 2018). In the international context, Italy boasts significant production of tree crops, including hazelnuts, for which it is the second-largest producer in the world (14.3%) after Turkey (CREA 2018; FAOstat 2018). The hazelnut sector is developing fast in response to an ever-growing demand for products derived from hazelnuts, (Liso et al. 2017; Dobhal et al. 2018) pushing toward a high level of product specialization and, in turn, a high level of income risk.

The income risk hazelnut farmers in Italy face is high and comes from different sources, including limited control over product quality (Zinnanti et al. 2019).

The Italian hazelnut production is geographically concentrated in four regions: Lazio (in the center), Piedmont (in the north), and Campania and Sicily (in the south; Istat 2018). Because the different geographical location of production across the country influences the crop economic outcome, this analysis focuses on hazelnut production in these four regions. Data used in this study were obtained from the Italian Farm

Table 1 Farm sample (number of observations)

Year	Campania	Lazio	Piedmont	Sicily	Total
2008	13	10	63	4	90
2009	15	11	81	4	111
2010	20	18	82	4	124
2011	19	30	82	5	136
2012	13	29	84	4	130
2013	14	31	81	5	131
2014	17	24	86	5	132
2015	20	23	84	5	132
2016	17	22	82	5	126
2017	14	22	54	5	95
Total	162	220	779	46	1207

Accountancy Data Network (FADN) and refers to the period 2008–2017 (European Commission 2018b).

The preliminary sample consisted of 1,973 observations of the crop unitary gross margin (GM) (€/ha). This is a commonly used activity-based indicator of economic performances of crops given by the difference between crop revenues and crop-specific explicit costs for purchased inputs such as fertilizers, crop protection products, other specific crop costs excluding overheads and labour cost (European Commission 2018a; Castañeda-Vera and Garrido 2017). Data were subsequently filtered taking into consideration two aspects. First, only observations referring to plantations older than seven years were included because there is either no or negligible production in the period before this age, and so it can be considered as being the crop establishment period. Second, farms with a number of observations fewer than three years within the considered period have been eliminated because these observations were considered too limited to provide a reliable representation of inter-year variability of economic results. The resulting sample consists of 1207 observations distributed among regions and years (Table 1).

Methods

Implementation of the IST

The analysis assumes farm deflated unitary GM as the income indicator used to apply the IST.[4]

This choice is in line with the definition of income given by the Regulation (EU) No 1305/2013, later modified by the Regulation (EU) No 2017/2393, and the Italian Ministry of Agriculture (MIPAAF 2017, 2020) where income refers "… to the sum of revenues the farmer receives from the market, including any form of public support, deducting input costs" (Regulation [EU] No 2017/2393).

In the case of the sector-specific IST, farmers are indemnified if their income drops by more than 20% of the average income level.

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[4] EU regulations do not provide specific indications regarding whether the income figures should be deflated. The choice of using deflated series seems coherent with the standard practice used within the risk analysis literature (e.g. Hardaker et al. 2015). This choice, compared to that of not deflating data, has effects on the assessment of income risk. When a significant trend exists the probability to observe an income drop is lower if deflated data are used.

EU Regulations No. 2013/1305 and No. 2017/2393 define the average income of a farmer over a three-year period or "based on the preceding five-year period excluding the highest and lowest entry" (2013, 2017). In this study, however, the average income is farm-specific and is considered over the whole period 2008–2017. In fact, using only the three previous years and the Olympic average of the preceding five years resulted in a too limited number of observations from FADN database.

Given these assumptions, for each farm hypothetically participating in the IST scheme: $x_{i,t}$ is the deflated value of the unitary GM of the ith farm at the tth year; and.

$\bar{x}_i$ is the average of the $x_{i,t}$ realized in the period considered (2008–2017) in the ith farm.

To allow better comparability of the variability of economic results among farms, GM has been standardized by dividing each GM observation by the farm-specific mean of GM. In this way, each regional GM distribution is centred to unity. Formally: $xs_{i,t}$ is the standardized value of the unitary GM of the ith farm at the tth year, obtained as $xs_{i,t} = \frac{x_{i,t}}{\bar{x}_i}$.

The relative reference income that triggers the indemnification in the tth year is a and it is fixed at 80% by assuming that the minimum trigger allowed by the EU Reg. (EU) no. 2017/2393 is used (i.e. 20%). This simply means that farmers experiencing a drop of GM less than 20% of their average GM are not going to receive any indemnification. Furthermore, farmers who experience a severe drop in income will receive compensation equal to only a share of the occurred loss. Formally, the indemnification the MF pays to the ith farm in the tth year is:

$$y_{i,t} = \begin{pmatrix} 0 & \text{if} & xs_{i,t} \geq a \\ (\bar{x}_i - x_{i,t}) \cdot b & \text{if} & xs_{i,t} < a \end{pmatrix} \tag{1}$$

where the parameter b is set at 0.7, which is the maximum relative level of indemnification of the losses allowed by the EU Regulation. This partial compensation is supposed to reduce the effects of moral hazard in the case of the IST. In other words, because they will be only partially compensated, farmers are expected not to change their behaviour in the case they subscribe to an IST. To participate in the IST scheme, farmers must pay an annual contribution to the MF managing the IST that is conceptually similar to the premium paid in insurance scheme. This analysis assumes that farmers pay financial contributions that are proportional to their expected income (Severini et al. 2019a). Hence, large farms pay larger absolute contributions than small farms.

After being deflated and standardized, the observed distributions of GM (now called *baseline*) were analysed and compared with those derived from the application of the IST. However, because the farmers' contribution rates have not been defined yet, the following three scenarios of application of the IST were considered: no contribution (IST$_{0\%}$); contribution rate at 5% (IST$_{5\%}$); and contribution rate at 10% (IST$_{10\%}$). The first scenario is hypothetical because it assumes that farmers do not pay any contribution to the MF. This scenario is used as a benchmark to assess the impact of the contribution rate. The other two scenarios refer to situations in which farmers pay contributions that are set, respectively, at 5% and 10% of the farm GM mean.

Because each region is relatively small and homogeneous regarding climatic and soil characteristics, it was assumed that all farms in a region face the same relative income risk (Zinnanti et al. 2019). This means that the farms within a region face the same distribution of the standardized GM ($xs_{i,t}$).[5] However, as observed, the absolute average GM levels differ among farmers also within the same region. This allows accounting for the existence of farm-specific individual effects that explain such absolute differences in average values.

Assessing the potential impacts of the IST

The potential impact of introducing the IST was assessed by observing the average profitability and the income-related risk. The level of profitability of hazelnut production was analysed by considering the first moment of the distributions (μ) of GM both without and with the IST in place.

To assess the riskiness of the activity, the distributions of the standardized GM both without and with the IST have been estimated for each region. From discrete distributions of data, the Probability Density Functions (PDFs) by region were estimated by using the *BestFit* tool provided by Version 7.6 of the @Risk™ software—Palisade Corporation, Newfield, New York. The Akaike Information Criterion statistics test was chosen to rank the PDFs. This test provides a measure of how closely the fitted distribution matches the data distribution, defining the best density function from the log-likelihood function and accounting for the number of parameters of the fitted distribution.

The risk analysis relies on the Value at Risk (VaR) that was calculated on the estimated PDF of the unitary GM. According to Dowd (2007), VaR is the maximum loss that may be expected over a given horizon period at a given confidence level. It was calculated as follows:

$$\text{VaR} = \overline{x}_i - V^* \tag{2}$$

where $\overline{x}_i$ is the average GM[6] and V^* is the value of GM at a confidence level of 95%. This indicator is calculated using the standardized GM and then converted into absolute values. Focusing on the worst distribution outcomes, large values of VaR suggest high risk. Any risk-reducing strategy reduces the level of VaR so that the effectiveness of different risk management strategies can be analysed by assessing how much they reduce the VaR. To facilitate the comparison among the regions considered, the relative VaR (Var%) is reported, given by the ratio between VaR and the average GM, indicating how much below the average it is possible to lose in relative terms.

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[5] The lack of long enough individual farm income series does not permit to explore farm heterogeneity within the region but only differences between regions. Future research could explore further this issue by considering farm heterogeneity also within each region.

[6] The classic VaR formula refers to a profit/loss function with a mean equal to zero: VaR = Value P/L at 95% c.i. of the distribution. However, in this analysis, the formula refers to a central value of the income distribution different from zero (x_i).

Comparing farmers' indifference to participate in the IST

This section compares farmers' wellbeing with and without IST in place to provide insight regarding the conditions under which farmers will be indifferent to participate in the IST.

The analysis assumes farmers are rational agents, an absence of informational asymmetry, and rules-out adverse selection and moral hazard (Hardaker et al. 2015). This latter assumption may not be verified since insured farmers could undertake riskier activities than not-insured farmers, resulting in higher indemnifications to farmers (see for example Horowitz and Lichtenberg 1993 for an empirical assessment of the effect of insurance subscription on farmers' behaviour). However, in the considered case, the extent of moral hazard should not be large because of two main reasons. First, farmers receive compensations that only partially compensate for the faced losses (i.e. a maximum of 70% of the losses). Second, the perennial nature of the crop and the high specialization of the considered farms reduces the chance of changes in production practices (e.g. pest control).

The likely impact of introducing the IST on farmers' wellbeing has been analysed comparing risky alternatives with uncertain outcomes (Hardaker et al. 2015). In this study, values of GM are assumed to be stochastic and the risky alternatives correspond to non-participation in the IST (i.e. baseline) or participation in the IST considering increasing contribution rates (e.g. $IST_{0\%}$, $IST_{5\%}$, and $IST_{10\%}$).

The outcomes for n risky alternatives can be compared using the cumulative distribution function (CDF) of GM, denoted by $F_1(w)$, $F_2(w)$,..., $F_n(w)$. Alternatives were graphically ordered allowing differentiation among efficient (undominated) and inefficient (dominated) choices (Hildebrandt and Knoke 2011). However, the result depends strongly on the level of risk aversion of the agent considered. Indeed, for a very risk-averse person, the less risky alternative may be still preferred: such a risk-averse agent weighs negative outcomes more heavily than positive outcomes (especially when the contribution rate is relatively high).

Following these considerations, comparing risky alternatives using the expected utility ($E(U)$) approach is more convenient (Ritchie et al. 2004; Hildebrandt and Knoke 2011). This method assumes that agent behaviour depends on the maximization of the expected utility deriving from the stochastic outcomes. Following the general reasoning of Masten and Saussier (2002), it is possible to formalize the farmer's decision to either accept or reject the IST scheme (y^*) as a discrete decision-making problem:

$$y^* = \begin{cases} y = 0 & \text{if} \quad U(V^0) \geq U(V^1) \\ y = 1 & \text{if} \quad U(V^0) < U(V^1) \end{cases} \tag{3}$$

where in this study, V^0 and V^1 represent the net benefits associated with not participating and participating in the IST scheme, respectively.

Therefore, assuming a specific utility function and setting reference levels of risk aversion is required. Despite this imposes some restrictions on farmers' behaviour, empirical analyses often use the negative exponential form (Hardaker et al. 2015):

$$U = 1 - \exp(-cw), \quad c > 0 \tag{4}$$

where w is the levels of the economic variable of interest (i.e. hazelnut GM in this application), and c denotes the measure of risk aversion. This form assumes a constant absolute risk aversion function (CARA; Hardaker et al. 2015).[7]

Love and Buccola (1991), using CARA, revealed that production decisions are affected significantly by revenue uncertainty and/or output price for risk-averse producers. As per Iyer et al. (2019), it is reasonable to assume that farmers are risk-averse, although risk aversion is necessarily a relative concept. In this analysis, three absolute risk aversion coefficients have been chosen to identify possible alternative risk aversion levels:

- risk neutral;
- 0.3 low risk aversion;
- 0.6 high risk aversion.

The choice of these values of risk aversion coefficients is arbitrary and further analyses based on experimental studies may provide context-specific insights to further refine the values. However, the chosen intervals are supported by other scholars who investigated farmers' risk attitudes in Europe (Cerroni 2018; Kumbhakar and Tveterås 2003; Groom et al. 2008; Serra et al. 2008; Piet and Bougherara 2016; Castañeda-Vera and Garrido 2017; Iyer et al. 2019).

Participation in the IST depends critically on the level of the contribution the MF requests. The willingness of farmers to participate in the IST was assessed considering the maximum contribution rate (*MaxCont*) that makes farmers indifferent about whether to participate in the scheme. In particular, the indifference level to participate in the IST is the contribution (as a percentage rate of the GM) that makes the farmers' expected utility (adhering to the IST) equal to that obtained in the baseline conditions (no IST): $E(U)_{IST} = E(U)_{BL}$.

Assessing the financial sustainability of the MF

Assessing which contribution rate will make the IST scheme sustainable from the point of view of the MF is important to manage the scheme. The basics of insurance pricing refer to a fair insurance premium (Bowers et al. 1989) defined on the following criterion: the expected losses ($E(X)$) should not exceed the collected premiums. While various premium principles can be derived, the simplest and most widely used is the expectation principle:

$$\Theta = E(X) + \delta E(X) \tag{7}$$

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[7] As it is well known, the risk aversion coefficient is constant and has the following specification: $r_a(w) = -U''(w)/U'(w)$ where $U''(w)$ and $U'(w)$ represent the second and first derivatives of the utility functions, respectively (Hardaker et al. 2015).

where Θ refers to collected premiums, and δ should be positive and large enough to have sufficiently protective solvency margins that can be derived from ruin estimates of the underlying risk process (Embrechts 1996). In the field of insurance, one often considers the *loss ratio index*; this is the ratio between losses and collected premiums. In the case of IST, this is the ratio between paid compensations and the collected contributions.

The basic consideration that drives insurance pricing is that the price (i.e. the contribution rate in the case of IST) should be both high enough to bring forth sellers and low enough to induce buyers to enroll (Finn and Lane 1997). Despite this, the literature on insurances and actuarial science generally assumes the number of insured as constant regardless of the premium charged, a limitation that is often caused by a lack of factual data on insured behaviour. This paper considers the fact that MF faces loading costs and that the RDP covers a share of the costs faced. Based on the average loss ratio the subsidized farm insurance schemes in Italy experienced in the period 2010–2015 (ISMEA 2018), a benchmark loss ratio of 0.65 is assumed. The level is assumed to be lower than one because MFs are expecting administrative and other loading costs, therefore they have a margin to constitute a fund to be used in the years in which the volume of compensation is large because of unfavourable economic farm results. Hence, a loss ratio higher than 0.65 may indicate a negative result for the MF because not all costs are covered by farmers' contributions.

Furthermore, this paper assumed that the public support is set on 70% of the costs faced as stated by the Regulation (EU) 2017/2393. Because it is still not clear which costs are the basis for establishing the extent of such support, two scenarios were considered. The first one assumes that public support is calculated overall costs; this results in charging farmers for 30% of the whole costs. The second assumes public support calculated on compensation' costs only: this results in charging farmers for 54% of the whole costs. However, moral hazard and adverse selection justify the policy intervention through public subsidies by the governments (Giampietri et al. 2020).

Under the assumption that all considered farms participate in the scheme, different configurations of the sectorial MF have been hypothesized; for example, a single national MF versus the case in which each region runs its own MF. Recognizing the potential role of risk pooling and the results of previous analysis (Trestini and Giampietri 2018), the study assesses how risky is a single national MF in comparison with that of the regional MFs.

Results

The potential impact of IST on level and riskiness of gross margin

The average GM value of the baseline is 4,800 €/ha, but values differ considerably at the regional level, varying from 2569 €/ha (Sicily) to 5876 €/ha (Campania). This reveals heterogeneity within the country. The introduction of the IST would greatly increase the average GM values in the hypothetical case that farmers did not have to pay contributions (scenario $IST_{0\%}$; Table 2).

Clearly, the GM levels fall as the contribution rate increases (Table 2). Assuming compulsory participation, the average GM of $IST_{5\%}$ is still favourable in the four regions in comparison with the baseline conditions. Lastly, the implementation of a 10% contribution rate ($IST_{10\%}$) allows farmers to reach an average GM that is like that of the baseline,

Table 2 Average GM levels by region. Baseline conditions and simulated implementation of the IST

	Baseline (€/ha)	IST (€/ha) with contribution rates set at:		
		0%	5%	10%
Campania	5876	6176	5883	5589
Lazio	5012	5435	5184	4934
Piedmont	4999	5600	5350	5100
Sicily	2569	2843	2715	2586
Weighted average	4800	5214	4974	4734

Table 3 Risk indicators by region in the baseline and with the IST

	Baseline		IST with contribution rates at:					
			0%		5%		10%	
	$GM^{5\%}$ (€/ha)	VaR (%)	$GM^{5\%}$ (€/ha)	VaR (%)	$GM^{5\%}$ (€/ha)	VaR (%)	$GM^{5\%}$ (€/ha)	VaR (%)
Campania	3279	44	4895	21	4601	22	4307	23
Lazio	2100	58	4040	26	3789	27	3538	28
Piedmont	1140	77	3840	31	3590	33	3340	35
Sicily	504	80	1950	31	1822	33	1693	35

even if it drops below this level in Lazio and Campania (Table 2). Hence, the IST could enhance the average farm GM unless contribution rates are set at approximately 10% or more. However, when participation is not compulsory, increasing the contribution rate is expected to make some farmers not joining the scheme. If participating and non-participating farms differ, this can also indirectly affect the average GM of participating farmers. In particular, adverse selection may play a role in this phenomenon if the less risky farmers (who, *ceteris paribus*, avoid participation) have a GM lower or higher than the overall average GM.

To assess the impact of the IST on the riskiness of farm income, results of the $VaR_\%$ and the $GM^{5\%}$ were observed. $GM^{5\%}$ is the GM level that marks the 95th percentile: at this point, there is a 5% probability of obtaining a value below this GM level. As expected, the riskiness of the activity drops strongly when the IST is implemented; indeed, $VaR_\%$ decreases radically moving from the baseline to the implementation of the IST regardless of the contribution rate level because of the positive role that the indemnifications provides to farmers experiencing relevant drops in their GM (Table 3).

Risk increases as the contribution payment increases (from $IST_{0\%}$ to $IST_{10\%}$). In both of the last options (with and without IST), two regions over four (Lazio and Campania) may lose less than the other regions do in relative terms.

The impact of IST can be appreciated also graphically: the IST shifts the left tail of the CDFs of GM in each region on the right (Fig. 1).

The results suggest that the IST could greatly reduce the risk faced by farmers except in the case of very high contribution rates; it also supports the average income levels of the farmers.
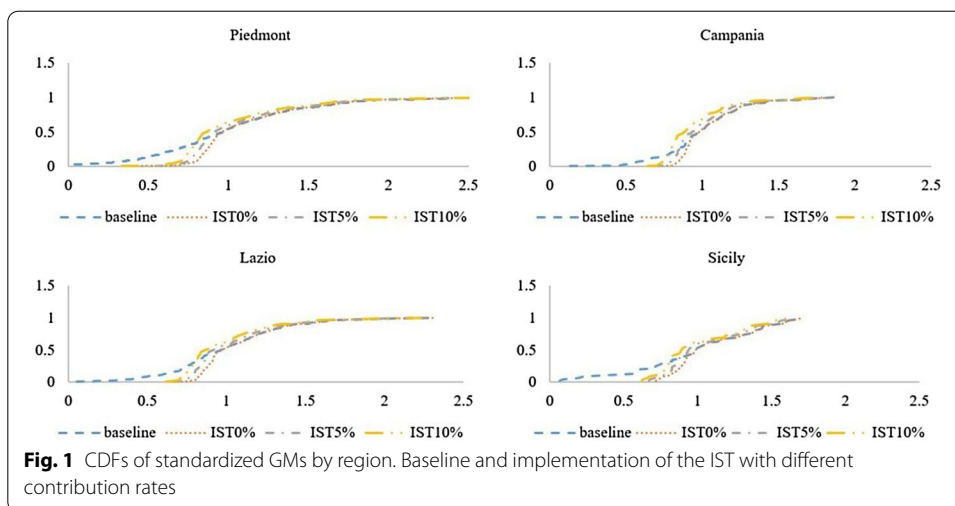
Fig. 1 CDFs of standardized GMs by region. Baseline and implementation of the IST with different contribution rates

Table 4 Maximum contribution rate making farmers indifferent to participate in the IST—three risk aversion' hypotheses

	Risk neutral (%)	Low risk-averse (%)	High risk-averse (%)
Campania	5.5	7.5	9.5
Lazio	8.5	12.5	17.5
Piedmont	10.5	19.5	25.5
Sicily	9.5	13.5	18.5
Weighted average	8.3	13.0	17.4

Farmers' indifference to participate in the IST

The scenario $IST_{0\%}$ dominates the baseline conditions in all four regions (Fig. 1). The CDFs referring to the scenario $IST_{0\%}$ never lie above that of the baseline; this shows that participating in the IST could be preferred over the baseline (without IST). This suggests that farmers would be indifferent to participate under this favourable but implausible condition: farmers must contribute the MF to enroll. The analysis assumes farmers are all indifferent to participate for each level of contribution. In the event of information asymmetry, this can lead to problems of adverse selection.

The *E(U)* approach allows identifying the maximum contribution rate (*MaxCont)* at which farmers are indifferent to participate in the IST (i.e. $E(U)_{BL} = E(U)_{IST}$; Table 4).

As foreseen, the *MaxCont* increases as risk aversion increases. The average rate moves from 8.3%, when farmers are assumed to be risk-neutral, but it increases up to 17.4% assuming a high level of risk aversion. These results suggest that, under the considered conditions, there is a relatively high indifference level to participate in the IST, even for moderate levels of risk aversion.

However, the level of indifference to participate in the IST, expressed in terms of *Max-Cont*, differs among regions: farmers are indifferent to participate with higher and lower rates in two regions (respectively, Piedmont and Campania) than farmers in the other two regions. This suggests that the contribution rate could be differentiated by region.

Table 5 Minimum contribution rate to make the MF economically sustainable—without and with public support

	No public support (%)	With public support (%)	
		On compensation costs only (54%)	On all costs (30%)
Campania	7.5	4.1	2.3
Lazio	12.5	6.8	3.8
Piedmont	16.5	8.9	5.0
Sicily	14.5	7.8	4.4
Weighted average	12.4	6.7	3.7

Table 6 Number of cases of indemnification by region and year

	Absolute values (n. obs.)					Relative values (%)				
Year	Campania	Lazio	Piedmont	Sicily	Total	Campania	Lazio	Piedmont	Sicily	Total
2008	1	3	25	2	31	8	30	40	50	34
2009	1	3	31	2	37	7	27	38	50	33
2010	8	5	54	1	68	40	28	66	25	55
2011	6	6	33	2	47	32	20	40	40	35
2012	3	14	35	1	53	23	48	42	25	41
2013	7	13	23	0	43	50	42	28	0	33
2014	3	4	7	2	16	18	17	8	40	12
2015	1	3	12	0	16	5	13	14	0	12
2016	1	3	28	1	33	6	14	34	20	26
2017	1	12	18	3	34	7	55	33	60	36
Total	32	66	266	14	378	20	30	34	30	31

Financial sustainability of the MF

From the MF point of view, the minimum contribution rates required to make the management of the IST financially sustainable are shown in Table 5.

Without public support, the average contribution rate that allows the MF to obtain a loss ratio of 0.65 is 12.4%. If the public support covers 70% of the compensations' costs (i.e. not including management costs), reaches 6.7% on average. Clearly, the minimum contribution rate decreases if the public support covers all costs reaching 3.7% (Table 5). Note that, the analysis assumes no information asymmetry that rules out adverse selection and moral hazard. Conversely, the minimum contribution rate required by the MF should increase. For example, in presence of adverse selection, charging a contribution make the less risky farmers exit the scheme and the MF is left with the more risky farmers.

Therefore, without public support, farmers are indifferent to join in the scheme and MF is economically sustainable only if farmers have a high risk aversion. Under these circumstances, the minimum contribution rate that an MF could receive is less than the farmers' indifference level to participate in the IST at 0.6 risk aversion coefficient (compare Tables 4 and 5). In contrast, the presence of public support allows MF to charge a lower contribution rate. This also makes risk-neutral farmers indifferent to

**Table 7** Loss ratio (compensations/contributions) by region and year

	Campania	Lazio	Piedmont	Sicily	Total
2008	0.14	0.69	0.96	1.67	0.89
2009	0.08	0.37	0.72	1.42	0.66
2010	1.50	0.47	1.35	0.56	1.24
2011	1.07	0.35	0.74	0.78	0.68
2012	1.19	0.95	0.69	0.55	0.77
2013	1.85	1.15	0.45	0.00	0.67
2014	0.31	0.36	0.13	0.43	0.19
2015	0.07	0.24	0.27	0.00	0.24
2016	0.08	0.41	0.65	0.38	0.56
2017	0.16	1.21	0.63	0.98	0.69
Weighted average	0.65	0.65	0.65	0.65	0.65
Max	1.85	1.21	1.35	1.67	1.24
Standard deviation (SD)	0.69	0.36	0.34	0.55	0.30
Mean	0.64	0.62	0.66	0.68	0.66
Min	0.07	0.24	0.13	0.00	0.19
Semi SD (right side)	0.81	0.40	0.32	0.67	0.25

participate if the MF charges the minimum contribution rate that allows it to reach the 0.65 loss ratio. However, the minimum contribution rate varies across regions: higher values are found, respectively, in the north (Piedmont) and the south (Sicily) of the country (Table 5). These results suggest that careful consideration should be given to differentiating the contribution levels among regions. Indeed, differences among regions exist in terms of the relative number of indemnified observations (Table 6).

On average, 31% of the farms are indemnified in the whole sample and the whole period considered; the range of indemnified farms varies from 20% (Campania) to 34% (Piedmont) (Table 6).

An additional aspect affecting the economic sustainability of the scheme lies in the fact that MF may face high volumes of compensations paid to farmers in specific years, thereby pushing the level of the loss ratios above what can be managed by the MF (Embrechts 1996). When a large number of farms are indeed indemnified, the available protective solvency margins of the MF may be not adequate to manage the fund. While the MF can pursue adequate risk management strategies (e.g. securing additional solvency margins or underwriting re-insurance contracts), they come at a cost that ultimately results in higher contribution rates being charged to associated farmers.

Findings show the percentage of indemnified farms at the national level varies over time, from 12% in 2014 and 2015 to 55% in 2010. The variability is even more significant within regions, with values between 0% (Sicily) and 66% (Piedmont). This clearly shows that the variability of the amount of compensations the MF paid to farmers over the years is higher in the case of regional MF making its financial management riskier than a single national MF. If MF were established for individual regions, the percentage of indemnifications could be higher than the national average. Hence, linking the four regions in a national MF allows risk pooling; the risk to be borne at the level of each region can be distributed at the national level. Indeed, in a specific

Fig. 2 Loss Ratio levels by region and for a national MF (total) from 2008 to 2017
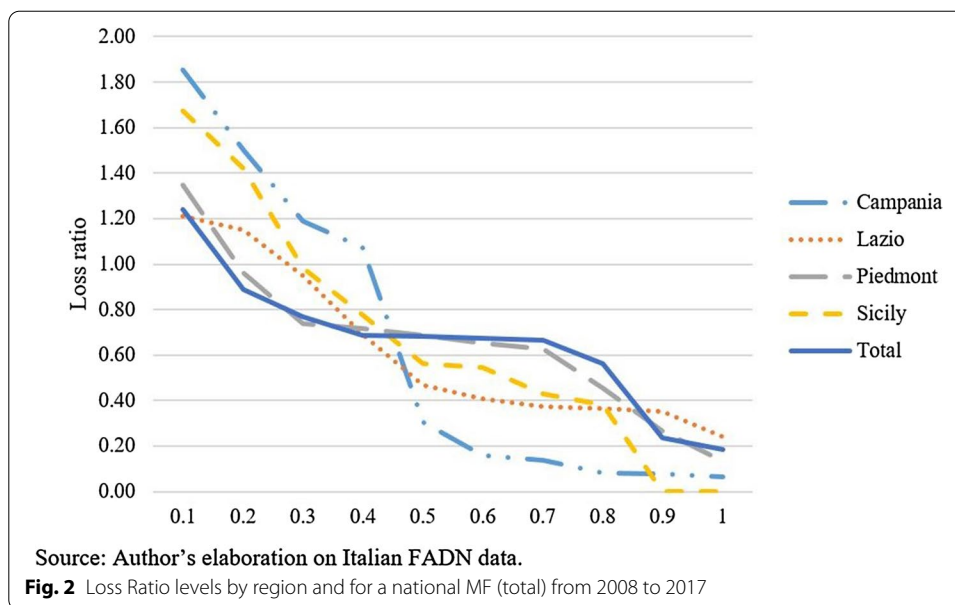
year, the low GM levels experienced by a specific region may be compensated by a high GM level in another region.

The evolution of the loss ratios over time provides a way to assess the riskiness faced by the MF. In the case of the national MF, it varies strongly among years: in many cases, it exceeds 0.65 (that has been set as the break-even reference level) reaching a maximum of 1.24 in the case of the total sample (Table 7).

Here, the variability of the loss ratio, assessed as a standard deviation, is 0.30. However, variability is higher in the case of all four regional MFs; in particular, the standard deviation of the loss ratio is very high in Campania and Lazio (Table 7).

The differences existing among regions are also confirmed by the values of the semi-standard deviation that accounts only for the loss ratios that are higher than the average (i.e. right side semi-standard deviation). This indicator shows clearly that Campania is the riskiest region, having the highest value of this index. It is followed by Sicily and Lazio, while the northernmost region (Piedmont) has the lowest level of risk: this latter is very similar to that potentially faced by a national MF (Fig. 2).[8]

These results suggest that managing a national MF is less risky than managing regional MFs separately. In the latter, the loss ratios can become very high, putting the financial sustainability of the regional MFs under pressure. In contrast, the national MF can more effectively use the risk-pooling principle, a result that confirms what has been already established by Trestini and Giampietri (2018).

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[8] This graph derived directly from data in Table 7 by ordering the data for each region from the highest to the lowest loss ratios.

Discussion

The analysis shows that the proposed approach provides useful results in regards to the extent of the reduction of farm income risk and the level of farmer's contributions that makes an income-based risk management scheme feasible while also accounting for the role of public support. Results of the empirical application have shown that the IST could reduce substantially the risk hazelnut farmers face throughout Italy. This confirms that the IST could potentially be effective in stabilizing farmers' incomes as already shown in other contexts (Liesivaara et al. 2012; Mary et al. 2013; Castañeda-Vera and Garrido 2017; Severini et al. 2019a; Trestini and Giampietri 2018). Furthermore, public support results in the enhancement of the average level of income of the farm population as shown in other analyses (Severini et al. 2019b). However, this analysis contributes to the literature in showing that the latter occurs up to a given level of the contribution rate the MF is going to charge associated farmers. Hence, it is possible to assess under which conditions this seldom-investigated indirect effect of the policy arises.

The analysis provides a way to assess farmers' indifference level to enroll in income risk management schemes, a topic addressed in very few studies (Castañeda-Vera and Garrido 2017). This is important because the overall impact of the introduction of an income-based risk management scheme depends critically on the level of farmers' participation (Coble and Barnett 2013). The results empirically demonstrate how important the level of farmers' risk aversion is in this regard (Meraner and Finger 2019). Similarly, the level of contribution asked to farmers influences their willingness to join the scheme, as well as the financial sustainability of the insurance.

This paper suggests a way to assess and compare both the maximum contribution rate which would make the farmers indifferent to participate and the MF financially sustainable with and without public support and under different degrees of farmers risk aversion. The study has relevant policy implications: it allows identifying the conditions to ensure the successful development of the considered income risk management scheme. The results of the analysis suggest that the sector-specific IST considered in this empirical application could be feasible in principle, as supply can interact easily with farmers' demand, at least in the considered case study. Indeed, in three out of four cases, the maximum extent to which even limitedly risk-averse farmers are indifferent to participate in the IST exceeds the minimum contribution that makes the MF managing the IST financially viable. Hence, under the assumption of no information asymmetry on which the analysis rests, there are opportunities for interactions between the supply and the demand for the IST with a level of policy support lower than the current one. The presence of public support strongly increases the opportunities for developing this new risk management tool. However, it is important to note that in presence of adverse selection, results can change because increasing the contribution level makes the less risky farmers exit the scheme and, as a result, the MF is left with the riskier farmers.

Contracting protection tools is a good compromise for both improving farm resilience to yield and price variability and restraining public expenditure. Likewise, sharing risk management responsibility with farmers is essential to develop the responsibility and involvement of farmers and other stakeholders (Cordier 2014; Castañeda-Vera and Garrido 2017). Finally, findings provide insights into the geographical dimension of the MF of the tool that has been proved to be an important issue in the policy design

(Giampietri et al. 2020; Severini et al. 2019a). Results suggest that the establishment of a single national mutual fund allows risk diversification reducing the risk of insolvency for the mutual fund. However, it seems useful to set different contribution rates for farmers belonging to different regions to reflect area-specific levels of risk.

Conclusion

The results of the analysis suggest that the proposed approach could be used to assess the implication and feasibility of income-based risk management schemes such as the IST in other EU countries and sectors. Extending the analysis in this direction is advisable to yield wider results. While our results are supportive of implementing the IST in the considered case study, this may not necessarily be the case in other regions and sectors. Indeed, the results derived by this kind of approach seem useful for stakeholders or scholars interested in the efficient design and implementation of income-based risk management schemes. Furthermore, this kind of analysis can feed the debate at the EU and world-wide levels on income-based risk management tools.

The proposed approach allows investigating the potential implication and potential degree of success of introducing the IST providing two pieces of information that are potentially useful for the design of income-based risk management schemes—such as the IST—also in other contexts. On the one hand, it seems important to consider the level of heterogeneity existing within each country. If this is not negligible, farmers' contributions should be differentiated among regions because they face different levels of income risk. On the other hand, it seems important to have a limited fluctuation of compensations over the years to ensure the financial viability of the institution managing the scheme, i.e. the MF. If this goal is perceived as important, it is advisable to take advantage of the risk-pooling principle and opt for a scheme managed at a nation-wide level, rather than within individual regions. Indeed, a regional scheme could more likely face years in which the amount of compensations paid strongly exceeds the amount of the contributions received. If a regional scheme should be developed, it should manage such adverse conditions by collecting larger funds, negotiating the opening of credit lines, or underwriting reinsurance contracts (Pigeon et al. 2014). However, these strategies may be costly and cause an increase in the level of farmers' contributions. This, in turn, is expected to reduce the level of farmers' participation.

In the end, it is important to mention one general shortcoming of the proposed approach and two limitations that affect the specific empirical application. The analysis assumes rational behaviour and no information asymmetry. Furthermore, it is based on specific assumptions regarding the functional form of the utility function and risk aversion levels. This leads to a possible future extension of the analysis toward the use of experimental data to better specify the nature of farmers behaviour. The first limitation of the empirical application refers to the fact that because of the limited number of sampled farms and the willingness to compare regions where income levels and risk differ, the analysis refers to the average farm-specific income calculated over the whole considered period. This is not fully in line with the EU Regulation that calculates compensations based on data from the three previous years or the Olympic average of the

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preceding five years. However, future studies may assess the opportunities offered by the Omnibus regulation regarding the use of indices for the determination of income losses, solving part of the problem concerning the calculation of farm incomes for those companies that are not obliged to draw up annual financial statements.

The second limitation regards the assumption that all farms in a region face the same relative risk by referring to standardized GMs. If additional data become available, it could be possible to develop an analysis that will overcome these two limitations that could have not negligible implications on the results of the analysis.

Abbreviations
CAP: Common agricultural policy; CDF: Cumulative distribution function; CARA: Constant absolute risk aversion function; EU: European Union; ETL: Expected tail loss; FADN: Farm accountancy data network; GM: Gross margin; IST: Income stabilization tool; MaxCont: Maximum contribution rate; MF: Mutual FUND; RDP: Rural development programmes; VaR: Value at risk.

Availability of data and materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests
The authors declare that they have no competing interests.

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