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**An attempt to modelling revenue insurance schemes at the
farm level by means of Positive Mathematical Programming**

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Abstract

Farmers face increasing income uncertainty and the debate is growing on the role of insurance schemes and of public support in this field.

This paper applies a PMP modelling approach that takes into explicit consideration risk aversion behaviour to test its applicability to evaluating the potential impact of insurance schemes. This is done by introducing a revenue insurance scheme into a model developed on a small group of crop farms in Italy.

The paper represents a preliminary assessment of the soundness of the proposed approach. It identifies some limitations that should be overcome to improve the proposed approach. Despite these limitations, it seems a useful tool to investigate the impact of insurance schemes and policy relevant parameters such as premium and coverage rates. Indeed, it permits the assessment of how this affects production choices, farm profitability and the impact of public support to reduce the net premium paid by farmers.

Keywords: Insurance schemes, PMP, Farmers' behaviour, Risk aversion.

JEL classification: Q12, C61, Q18.

1. INTRODUCTION

Farmers are perceived to face an increasing income uncertainty. Commodity prices have been characterised by increasing volatility in recent years. This has been experienced also in the domestic EU market given that the Common Agricultural Policy (CAP) has reduced its role in price stabilisation. The production risk is also expected to increase in the future because the current climate changes may bring about higher yield variability due to the increasing occurrence of extreme events and weather variability. For these reasons, the debate is growing on the potential role of private and of publicly funded instruments to manage farm risk. Indeed, space has been explicitly given by Reg.(EC) n.73/2009 where art. 70 allows Member States to grant financial contributions to premiums for crop, animal and plant insurance against economic losses.

Because of all these elements, it seems relevant to develop evaluation approaches able to provide insights on management strategies to cope with risk, including insurance schemes. In

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order to do so, models used in empirical analysis should explicitly take into consideration farmers' risk aversion behaviour (Moschini and Hennessy, 2001).

This paper applies a PMP modelling approach, proposed to taking into explicit consideration risk aversion behaviour (Cortignani and Severini, 2010), in order to test whether it can be used to evaluate the potential impact of insurance schemes. This is done by introducing a revenue insurance scheme into a model developed on a small group of field crop farms located in Central Italy.

The objective of the paper is to develop a preliminary attempt to assess the soundness and applicability of the proposed approach, to consider its strengths and weaknesses and to identify future developments needed to improve it. Indeed, the paper is presented with the aim of exchanging opinions with other researchers interested in the topic and to receive any critiques or suggestions with the aim of improving the approach.

Despite the limited scope of the empirical application, some very preliminary and tentatively considerations on the usefulness and drawbacks of the analysis to explore policy relevant questions are also derived.

The following two paragraphs briefly provide some background information on the insurance schemes applied in agriculture and on the developed modelling approach. Paragraph 4 presents the empirical analysis moving from the description of the farm sample to the presentation of the simulation results. The last paragraph provides the conclusions of the paper.

2. INSURANCE SCHEMES AND THE ROLE OF GOVERNMENTAL POLICIES

The most important risks affecting farmers are common to most businesses, others are unique to farming (EC, 2006). The most important risks in agriculture can be classified as (Hardaker, Huirne and Anderson, 1997): human or personal risks; asset risks; production or yield risk; price risk; institutional risk; financial risk. Despite this source of risk, all categories of risk have an effect on the income of the stakeholder. Therefore, most of the strategies implemented by risk adverse farmers are aimed at reducing the expected variability of income. Once the risk has been identified and assessed in order to develop risk management strategies (Hardaker et al., 1997), various strategies can be used to reduce income risk at the farm level. However, two main types of risk management strategies are often identified (EC, 2001): strategies concerning on-farm measures and risk sharing strategies. Participation in an insurance program belongs to this last type of strategies.

Several agricultural insurance schemes exist: from the point of view of the risks covered, these can be classified as (EC, 2006): single-risk insurance; combined (peril) insurance; yield insurance; price insurance; revenue insurance; whole-farm insurance; income insurance; index insurance.

Revenue insurance is the kind of insurance scheme considered in the empirical application of the model, therefore it is worth to spend some time on it. Revenue insurance combines yield and price risk coverage in a single insurance product and it can be product-specific or whole farm (EC, 2006). For example, the US Crop Revenue Coverage (CRC) is

offered for the main field crops such as maize, soybeans, wheat, rice and cotton (Edwards, 2009). This insurance could be cheaper than insuring independently price and yield, as the risk of a bad outcome is smaller: indeed, low yields may be compensated by high prices and vice-versa. An insurance company can offer a revenue insurance if it is able to determine the joint probability distribution of price and yield (EC, 2006).

A simple description of the Crop Revenue Coverage program is provided by Edwards (2009). In this program the production portion of the revenue guarantee is based on the farm Actual Production History (APH) that is an historic average of the actual yields. The yield levels used to calculate the CRC revenue guarantee range from 50% to 85% of the APH yield. Indemnity payment is the amount by which the revenue guarantee exceeds the actual revenue, if any. The revenue guarantee is the revenue calculated by multiplying the price² times the APH yield, times the chosen coverage level. The actual revenue is given by the actual harvested yield times the market price.

Governments have traditionally developed public policies aimed at dealing with risk in agriculture risk management ability of farmers and are usually justified as corrections for various forms of market failures. (Cafiero et al., 2005). One set of such measures provides incentives aimed at developing insurance markets through release of subsidies to premium payments as well as the provision of reinsurance, information and assurance of competition in the insurance industry (Cafiero et al., 2005).

Subsidising premium payments is a very common instrument world-wide. This measure is justified on the grounds that the premium must be affordable, that a sufficient volume of insurance contracts must be underwritten and that insurance companies have to find the insurance product attractive enough to remain in the business. For example, in the US Federal Crop Insurance Program, US government has encouraged farmers enrolment by heavily subsidising premiums: for example, in 2003 subsidies paid within such program have reached \$ 2041.7 million over a total amount of premium of \$ 3430.6 million or around 59% of the total amount of the premium received by the insurance companies (Glauber, 2004).

The emphasis on this instrument has increased also within the Common Agricultural Policy of the EU. Two instruments have been introduced that provided public support to cover insurance premium.

The reform of the CMO wine, by means of Reg. (EC) n. 479/2008, has introduced the possibility of providing public funds for harvest insurance in order to contribute to safeguarding producers' incomes where these are affected by natural disasters, adverse climatic events, diseases or pest infestations. This support for harvest insurance may be granted in the form of a financial Community contribution which must not exceed: 80% of the cost of the insurance premiums paid for by producers for insurance against losses as a result of adverse climatic events which can be assimilated to natural disasters; 50 % of the cost of the insurance premiums

² Different prices can be chosen for reference. See Edwards (2009) for details.

paid for by producers for insurance in other cases (Art. 14 of Reg. (EC) n. 479/2008). The support for harvest insurance may only be granted if the insurance payments concerned do not compensate producers for more than 100 % of the income loss suffered.

A broader instrument was introduced after the 2009 Health check of the CAP. Art. 68 of Reg. (EC) n. 73/2009 allows Member States to use up to 10% of their funds belonging to the first pillar to grant specific support to farmers, among others, in the form of contributions for crop, animal and plant insurance premiums (point d). According to art. 70 of the same Regulation, Member States may grant financial contributions to premiums for crop, animal and plant insurance against economic losses caused by adverse climatic events and animal or plant diseases or pest infestation. However, a financial contribution may only be granted for loss caused by an adverse climatic event or by an animal or plant disease or a pest infestation which destroys more than 30 % of the average annual production of the farmer³. The financial contribution granted per farmer shall not exceed 65 % of the insurance premium due.

However, the role of CAP in supporting the insurance scheme is expected to increase in the near future.

In its recent communication on the future of the CAP, the European Commission has proposed that “a risk management toolkit should be included to deal more effectively with income uncertainties and market volatility that hamper the agricultural sector's possibility to invest in staying competitive. The toolkit would be made available to Member States to address both production and income risks, ranging from a new WTO green box compatible income stabilization tool, to strengthened support to insurance instruments and mutual funds” (EC, 2010: page 11).

3. METHODOLOGY

Positive Mathematical Programming (PMP) models have been extensively used to evaluate farmers' adjustment to changes in market and policy conditions. However, these models generally consider risk aversion behaviour only implicitly by means of the estimated cost function included in their objective function. Few Authors have gone forward proposing ways to explicitly consider risk aversion behaviour (Heckelei, 2002; Paris and Arfini, 2000).

Recently, a way to explicitly incorporate such behaviour into PMP models has been proposed and empirically tested (Cortignani and Severini, 2010). This approach, formally described in the appendix, is based on a simple expected utility framework under the uncertainty of activity gross margins and assuming constant absolute risk aversion coefficients (McCarl and Spreen, 1997). It has allowed the development of PMP models that consider farmers' risk preferences in an explicit way.

³ This is calculated on the basis of the preceding three-year period or a three-year average based on the preceding five-year period, excluding the highest and lowest entry.

The proposed paper proceeds further by testing the use of this kind of models in evaluating the potential role of revenue insurance schemes. This is done by using a three-year constant sample of filed crop FADN farms located in central Italy, where durum wheat is the most important crop.

The model has the following general structure:

$$\begin{aligned} \max_{x_{n,t}} Z &= E(\overline{gm}_{n,t})' x_{n,t} - d_{n,t}' x_{n,t} - \frac{1}{2} x_{n,t}' Q_n x_{n,t} - \frac{1}{2} \phi_n' x_{n,t}' \Sigma_{gm} x_{n,t} \\ \text{s. to} \\ A' x_{n,t} &\leq b_{n,t} \quad [\lambda_{n,t}] \end{aligned}$$

where $E(\overline{gm}_{n,t})$ are the expected unitary gross margin values; $x_{n,t}$ are the model variables that refer to the land allocated to each activities in the n -th farms and t -th year; $d_{n,t}$ and Q_n are the parameters of the quadratic cost function; ϕ_n are the coefficients of absolute risk aversion and Σ_{gm} the covariance matrix of the unitary gross margins.

The parameters $d_{n,t}$, Q_n , the $\lambda_{n,t}$ dual values and ϕ_n are estimated by imposing the first-order conditions of the considered farm model taking into account exogenous information (i.e. supply elasticities) (Heckelei, 2002). The Σ_{gm} has been calculated by taking into consideration the variability of gross activity margins observed during a three-year period in the farm sample.

The model with the insurance scheme, used to conduct simulations, considers an insurance scheme for a single crop: in the empirical application this is durum wheat. The farmer pays an insurance premium and, if the unitary revenue of that crop falls below a contractual level, he/she receives an indemnity calculated on the basis of the difference between the contractual and the actual revenue level. In this case, the expected gross margin vector and covariance matrix of gross margins are recalculated and differ from the case without the insurance scheme.

In this first analysis, it is assumed that all farmers participate in the insurance scheme whenever they grow durum wheat in a sort of "compulsory participation". It is important to stress that this very restrictive hypothesis is motivated by the objective to approach the modelling process by gradually adding complexity. It is in our intention to try to extend the approach to explicitly model the participation choice as well. Despite this limitation, it is worth noting that the model allows the level of the farmers' participation and the amount of premiums paid to vary by adjusting the area devoted to this crop. In this way, farmers can even avoid enrolling in the program by opting not to grow the insured crop.

In the model with insurance, the expected values and the covariance matrix of the gross margins takes into account the role of the insurance scheme, considering both the indemnities obtained and the insurance premiums paid.

4. EMPIRICAL ANALYSIS

4.1. Available dataset

The study area is an agricultural area of central Italy in the province of Ancona (Marche). A sample of 27 FADN farms (constant in the period 2005-2007) specialized in cereals, oilseed and protein crops has been taken into consideration⁴.

Table 1: Share of each crop in terms of the total cropped area per year and average of three years (%)

	2005	2006	2007	Average
Oats	0.0	0.7	0.3	0.3
Durum Wheat	63.3	49.9	64.1	59.1
Common Wheat	0.7	0.2	0.0	0.3
Maize	3.8	3.8	6.4	4.7
Barley	4.1	2.6	0.7	2.5
Sorghum	0.0	0.2	4.1	1.4
Beans	1.8	2.0	4.4	2.7
Peas	2.6	5.4	2.5	3.5
Sugar beet	7.8	3.6	1.7	4.4
Sunflower	14.4	18.9	13.8	15.7
Other crops	1.4	12.8	2.1	5.4

Source: Own calculation on FADN data

Most of the area is cultivated to durum wheat which, on average, uses around 60% of the cropped area (Table 1). Other important crops are sunflower and maize.

4.2. Simulation scenarios

While the calibrated model relies on the assumption that the analysed insurance scheme is not available to the farms taken into consideration (BASELINE), all simulations refer to the case in which all farms producing durum wheat participate in the program. Here the definition of the baseline insurance simulation case (BLINS) is described first. Then, two other sets of simulations are described: those referring to the level of unitary premium (PREM) and those referring to the level of coverage level (COVE).

⁴ We would like to thank the Italian Institute of Agricultural Economics (INEA) of Rome that has supplied the FADN farm data.

Table 2: Synthesis of the simulation scenarios.

Simulation code	Short description of the simulations.
BLINS	Baseline insurance simulation case. It considers full coverage (100% indemnity) and premium set at 198 €/ha.
PREM	Simulations considering different level of the premium paid by farmers: increases and decreases of: 20%, 40%, 60%, 80% and 100% from the BLINS case.
COVE	Simulations considering different levels of insurance coverage: full coverage (100%), 80%, 60% and 40% coverage levels have been considered.

All simulations assume that an indemnity (*ind*) is paid to farmers whenever the level of unitary revenues from durum wheat is below its expected revenue level ($E(\text{rev})$). This latter level is calculated on the basis of the weighed average of unitary revenues from all observations (i.e. three years and all farms considered) in the following way:

$$E(\text{rev}) = \frac{\sum_{n,t} \text{rev}_{n,t} * x_{n,t}^0}{\sum_{n,t} x_{n,t}^0}$$

where $x^{\circ}(n,t)$ are the amount of land devoted to durum wheat in the considered three-year period.

The unitary premium paid (*pre*) is identified on the basis of the arbitrary hypothesis that is needed to ensure a loss ratio of 80%: the expected total amount of indemnities ($E(TIND)$) should be equal to 80% of the expected total amount of premiums ($E(TPRE)$)⁵. These are calculated on the basis of the available three year data set in the following way:

$$E(TIND) = \sum_{n,t} (E(\text{rev}) - \text{rev}_{n,t}) * x_{n,t}^0$$

$$E(TPRE) = \sum_{n,t} \text{pre} * x_{n,t}^0$$

Note that a uniform unitary premium per hectare of durum wheat (*pre*) is assumed to be applied in all farms.

⁵ Formally, the level of the premium (*pre*) is the one that satisfies the following rule: $E(TIND) = 0.8 * E(TPRE)$. Note that this ex-ante evaluation may not be satisfied ex-post given that farmers also adjust their production decisions on the basis of the level of the premium.

The unitary revenues for durum wheat in all observations (i.e. for all n and t) are then recalculated introducing the insurance scheme previously described. This generates a new set of unitary gross margins that differs from the original one only by the gross margins of durum wheat. This set is then used to recalculate the variance-covariance matrix for unitary gross margin. Given that the insurance scheme applies only to durum wheat, the matrix differ from the one used in the calibration only in the elements referring to this crop.

This procedure identifies the parameters to perform the baseline insurance simulation (BLINS).

Another set of simulations analyses the impact of changing the level of the unitary premium (pre). Moving from the baseline insurance simulation, simulations are run taking several levels of the premiums into consideration. In particular, the following 10 levels have been considered: + and – 20%, 40%, 60%, 80% and 100% of the baseline level.

The last set of simulations refers to different levels of coverage level ($COVE$). The basic hypothesis retained in all previously described simulations is that the indemnities are paid applying a 100% coverage level. Therefore:

$$ind_{n,t} = E(rev) - rev_{n,t} \quad \text{if } E(rev) > rev_{n,t} \text{ and } 0 \text{ otherwise}$$

This additional set of simulations considers lower levels of coverage levels: 100%, 80%, 60%, 40% coverage levels. In other words, the farmers receive only a share of the full indemnity. Note that, to keep the discussion simple and to allow for the comparability of simulation results, the unitary premium is kept at the level that makes the total gross margin with insurance equal to the one of the observed case (without insurance)⁶.

5. ANALYSIS OF THE SIMULATION RESULTS

As already mentioned, the empirical test has been developed mainly for testing the model and to demonstrate that it responds to change in some policy relevant variables. In particular, the empirical test considers three main aspects: a) the introduction of the considered insurance scheme; b) changes in the levels of the premium paid by farmers; c) decreases in the insurance coverage levels.

In each simulation, as well as in the calibrated case, data on areas planted with durum wheat, cropping pattern, expected farm gross margins, expected indemnities and total premiums paid are presented. All data refer to the total of the results obtained by running the model in the income conditions prevailing in the three years taken into consideration (2005-2007).

⁶ The more realistic case could have been taken into consideration in which reducing the coverage level should also allow to reduce the level of the premium. Indeed, because decreasing the coverage level reduces the total amount of indemnities paid, the insurance companies are able to reduce the level of the premium in order to sell a larger amount of insurance contracts.

The introduction of the revenue insurance scheme under the conditions defined by the simulation scenario BLINS (taking a 100% coverage and a premium of 198 €/ha of durum wheat into consideration) has a negative impact on the expected unitary gross margin of these crops (Table 3). This is due to the fact that the expected indemnities do not fully cover the premium paid. However, the insurance scheme reduces the expected variability of economic results (Table 3).

Table 3: Durum wheat. Basic economic parameters.

		BASELINE	BLINS
Expected gross margin	(€/ha)	646	605
Total variance of durum wheat gross margins	(€ ²)	130,160	99,629
Premium	(€/ha)	0	198
Expected indemnity	(€/ha)	0	158

Note: Data are calculated as weighted average on the whole farm sample and the three years.

Despite this latter effect, it is not able to compensate for the reduction of expected gross margin: therefore the introduction of the insurance (that is required for every unit of land devoted to durum wheat) has the effect of reducing the convenience of planting durum wheat. Indeed, the area devoted to this crop declines from the observed condition of around 14% and it is replaced by other crops such as maize and other cereals (Table 4). Note that some of the considered farms stop producing wheat: this is the case particularly in those farms where the expected indemnities are relatively lower if compared with the premium. Indeed, while in the calibrated case 67 farms cultivated durum wheat, when the insurance was in place, only 59 farms actually plant durum wheat.

The introduction of the insurance scheme also has negative consequences on farm gross margin, at least under the considered compulsory nature of the participation in the insurance scheme (Table 4). On the contrary, insurance companies could have an expected amount of premiums higher than the expected amount of indemnities paid, obtaining a loss ratio of around 84% (Table 4). Note that this value is higher than the one calculated ex-ante on the basis of the data observed in the three considered years (i.e. 80%) and on which the base line premium level (i.e. 198 €/ha) has been calculated. This is the result of the fact that the farmers for whom participation in the program is less convenient – who are also the farmers where the insurance companies gain the better margins, do actually reduce or even stop producing durum wheat.

Finally, it is worth noting that the reduction of the farm gross margins due to the introduction of the insurance scheme is higher than the margin obtained by the insurance companies (i.e. the difference between the expected total amount of the premiums perceived by and of indemnities paid by the insurance companies). This means that, even taking into consideration that the insurance companies should have to remunerate the resources (e.g. labour and capital) used for managing the activity, the margin remaining at the insurance companies is

not large enough to compensate for the welfare losses experienced by farmers under the specific conditions considered here. This suggests that the model could, at least potentially, also be used to verify the overall impact of the introduction of insurance schemes.

In any case, the simulation results suggest that, under the specific simulated conditions, the insurance scheme is not convenient for the considered farmers and, for this reason, it there will be a lack of demand for insurance contracts.

This condition can change if the level of the net premium paid by farmers is changed. In particular, its reduction can be achieved if the government intervenes by covering part of the premium subsidizing it. The results of the simulations show the level of the premium influences cropping patterns and farm economic results. An increase in the net premium reduces the amount of land dedicated to durum wheat that is also, in this case, completely replaced by other crops, because no land is left idle in the considered range of increases (Table 4). For example, an increase of 20% in the level of the premium generates a decrease of durum wheat by another 7% (From -13.9 to 20.3 %) (Table 4).

Table 4: Cropping patterns and main economic results under the calibrated (no insurance) and different levels of the insurance premium. Whole sample three-year average.

	BASELINE	BLINS	PREM									
			20%	40%	60%	80%	100%	-20%	-40%	-60%	-80%	-100%
Cropping patterns:	(ha)	Percentage change from the observed values (%)										
Durum wheat	1380	-13.9	-20.3	-26.5	-32.7	-38.7	-44.6	0.6	8.1	10.7	13.1	15.2
Maize	112	10.1	14.9	19.4	23.8	28.3	32.8	-4.4	-11.8	-9.1	-11.0	-16.6
Other cereals	105	152.6	210.5	265.5	318.9	370.7	420.6	0.3	28.2	31.4	27.2	22.8
Sunflower	365	0.3	1.5	2.6	4.5	7.4	10.6	-0.8	-18.5	-24.1	-27.2	-28.7
Other industrial crops	245	8.8	15.0	21.0	26.8	32.2	37.3	-0.1	-16.6	-25.4	-31.4	-36.9
Forage crops	30	-7.3	4.6	17.9	26.0	27.5	28.9	-0.9	-68.6	-69.3	-69.3	-69.3
Economic results:	(€)	Percentage change from the observed values (%)										
Gross Margins	1992	-2.4	-4.7	-6.8	-8.7	-10.5	-12.1	0.0	2.9	5.9	9.0	12.1
Premiums	0.0	235.0	260.9	280.7	294.0	301.2	302.2	219.6	177.1	120.9	61.7	0.0
Indemnities	0.0	197.8	181.8	166.8	151.8	137.0	122.8	218.5	226.9	231.6	235.9	240.1
Loss ratio [^]	0.0	84%	70%	59%	52%	46%	41%	99%	128%	192%	382%	0%
Government grant ^{^^}	0.0	0.0	43.5	80.2	110.3	133.8	151.1	-	-	-	-	-

[^]: Total expected amount of premium divided by total expected value of indemnities. Based on observed three-year data.

The opposite situation occurs when the net premium is decreased, as could be the case when a public subsidy is granted to applicants. However, the impact of reductions is not symmetric in comparison with equivalent relative increases: for example, reducing the premium by 20% reduces the area devoted to durum wheat by around an additional 14% (Table 4). In other words, the model is more sensitive to decreases than to increases in the premium. However, the marginal impact of decreasing the premium on the durum wheat area is declining (Table 4).

The increase of the premium has a clear negative affect on the farmers' economic results and vice-versa (Table 4). In particular, decreasing the premium to around 20% allows the

maintaining of the gross margin at the level observed in the calibrated case (without insurance). However, note that this condition occurs by means of different cropping patterns characterised by an area planted with durum wheat which is slightly larger than in the observed case (Table 4). This is consistent with the idea that, for the same level of gross margin, the reduction of the risk related to durum wheat and generated by the insurance makes it more convenient to plant this crop. The premium level has been considered as baseline for the simulations referring to changes in the coverage level.

Increasing the premium paid clearly increases the revenues of the insurance companies (total amount of premium) while reducing the total amount of indemnities paid. Therefore, these changes cause a considerable decrease in the loss ratio, making the activity more profitable for insurance companies (Table 4). The opposite happens when the premium is reduced, unless a public subsidy is going to cover the gap between the base line premium (198 €/ha) and the net premium paid by farmers. A hypothesis on the amount of subsidies to be granted in order to cover this gap and which considers the amount of land devoted to durum wheat is provided in Table 2.

The last set of simulations refers to the decreases in the indemnity coverage. Starting from the case in which the farmers receive a full compensation (100% coverage), reductions in coverage of 20, 40 and 60% have been considered, in all cases maintaining the premium at the level so that the total expected gross margin with insurance is the same as in the calibrated one.

Decreasing the coverage clearly reduces the convenience of growing durum wheat. For example, a coverage level of 80% (20% less than the full coverage) causes the area planted with durum wheat to decrease by 12.6% (Table 5).

Table 5: Cropping patterns and main economic results under different levels of coverage. Whole sample three-year average.

	BASELINE	COVE			
		100%	80%	60%	40%
Cropping patterns:	(ha)	Percentage change from the observed values (%)			
Durum wheat	1380	0.6	-12.6	-17.8	-22.8
Maize	112	-4.4	9.0	12.7	16.3
Other cereals	105	0.3	141.0	187.6	232.6
Sunflower	365	-0.8	0.1	1.1	2.0
Other industrial crops	245	-0.1	7.1	12.7	17.5
Forage crops	30	-0.9	-5.7	-0.6	10.1
Economic results:	(€)	Percentage change from the observed values (%)			
Gross Margins	1992	0.0	-2.0	-3.8	-5.6
Premiums	0.0	219.6	190.8	179.5	168.5
Indemnities	0.0	218.5	160.9	112.8	70.3
Loss ratio [^]	0.0	1.0	0.8	0.6	0.4
Government grant ^{^^}	0.0	58.1	50.5	47.5	44.6

[^]: Total expected amount of premium divided by total expected value of indemnities. Based on observed three-year data.

Because the premium is kept constant, the decrease of the coverage level has a negative impact on farm economic results. For example, moving to a coverage level of 80% reduces the total expected gross margin by 2% (Table 5). Because reducing the coverage level reduces the total indemnities paid by the insurance companies, there are very positive consequences for them because the loss rate declines (Table 5).

6. CONCLUSIONS

This paper has used a PMP modelling approach that takes risk aversion behaviour into explicit consideration. This has been applied to evaluating the potential impact of introducing a revenue insurance scheme into a small group of field crop farms located in Central Italy.

The analysis has several limitations which are important to mention before summarising its main results.

The choice of the farmers to participate in the insurance scheme has not been modelled yet. However, we hope to proceed further with the modelling exercise in the near future in order to investigate such a policy relevant aspect.

The modelling approach that takes risk aversion behaviour into consideration relies on a simplified and restrictive expected utility framework that assumes constant absolute risk aversion coefficients. As it is known, other approaches have been developed in order to take into account less restricting forms of risk aversion behaviour. Therefore, it will be interesting to investigate whether these more complex approaches could be integrated or not into the proposed modelling approach.

The empirical test considers only one specific type of insurance scheme and a very limited and specific sample of farms. Therefore, we hope to apply the model to other insurance schemes and to a larger database in order to achieve a more substantial empirical test.

Despite these limitations, the analysis has arrived at some interesting results. The model has been able to investigate the impact of introducing an insurance scheme and of changing some policy relevant parameters such as premium and coverage rates. It can be used to assess how this affects production choices and the relative profitability of both farmers and insurance companies. Furthermore, it allows the assessment of whether a public support aimed at reducing the net premium paid by farmers is needed to make it convenient and to increase the level of enrolment into the insurance scheme.

The results of the empirical test seem to suggest that the proposed model responds in a coherent way to the considered simulations. Decreasing (increasing) the level of the premium increases (decreases) the acreage of durum wheat and positively (negatively) affects farm economic results. The opposite happens when the level of coverage of the insurance scheme decreases. Finally, in the considered empirical conditions, the analysis suggests that the insurance scheme could not be established without public intervention aimed at covering part of the premium paid by farmers.

It is possible to conclude that the proposed approach seems potentially interesting even if it should be better analysed and subject to further empirical tests. In particular, it is currently

affected by some limitations that should be overcome in order to improve the approach. Regarding this last point, we would be pleased to receive any critical comments and suggestions from the participants in the seminar and readers. In this way, we hope to set the agenda for future research that we have to follow in the coming months.

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APPENDIX. DESCRIPTION OF THE ESTIMATION MODEL.

In our analysis we use the Heckelei and Wolff method (2003) extending it to explicitly considering risk aversion. The method uses the Generalized Maximum Entropy (GME) approach (Golan, Judge and Miller, 1996) covered by the restrictions needed to determine the appropriate curvature of the cost function. The GME is used frequently when the number of observations is lower than the number of parameters to be estimated (ill-posed problems).

However, the GME can also be used in well-posed problems because it allows a flexible incorporation of out of sample information such as supply elasticities (Heckelei, 2002).

Considering that the data refer to several years ($t = 1, \dots, T$), the GME problem is specified as follows:

$\mathbb{E} \left[\max_{\mathbf{w}_t} \lambda_t (w_t, \mathbf{d}, \phi, Q, L, \lambda_t) H(w_t) \right] = - \left[\sum_{t=1}^T \lambda_t \ln \left[\sum_{i=1}^S w_{i,t} \right] \right] - \mathbf{w}' \boldsymbol{\varepsilon} \ln \mathbf{w}' \boldsymbol{\varepsilon}$
 s. to

$$E(gm_t) - \lambda_t A - d_t - Q(x_t^0 - Vw_t) - \phi \Sigma_{gm}(x_t^0 - Vw_t) = 0$$

$$E(gm_t) - \lambda_t A - d_t - Q(x_t^0 - Vw_t) - \phi \Sigma_{gm}(x_t^0 - Vw_t) < 0$$

$$A'(x_t^0 - Vw_t) = b_t \quad \square$$

$$Q = LL' \quad \text{con } L_{j,i'} = 0 \quad \forall i' > j$$

$$V^\varepsilon w^\varepsilon = \left[\left(Q^{-1} - Q^{-1} A [(A)' Q^{-1} A]^{-1} A' Q^{-1} \right) \odot \left[\frac{gm^o}{x^0} \right]' \right]$$

$$\sum_{s=1}^S w_{j,t,s} = 1$$

$$\sum_{s=1}^S w_{j,i,s}^\varepsilon = 1$$

where $H(w_t)$ is the level of entropy, the errors vector (Vw_t) is re-parameterized as the expected value of a discrete probability distribution by defining the V support matrix and the w_t probabilities vector; elasticities ($V^\varepsilon w^\varepsilon$) can be re-parameterised in the same way as the error terms by defining the V^ε support matrix and the w^ε probabilities vector⁷; gm_t are the gross margins of each activity; λ_t is the shadow price of land over several years; A is the technical coefficients matrix; d_t and Q are respectively the parameters associated with the linear term and the quadratic term of the cost function; x_t^0 are the observed levels of activity in different years; ϕ are the coefficients of absolute risk aversion for each farms n and Σ_{gm} the covariance matrix of the gross margins⁸; L is the lower triangular matrix of the Cholesky decomposition.

⁷ The intuition behind the objective function is that the entropy criterion pulls towards the centre of the elasticity support range, in opposition to the error terms of the data constraints. The smaller the elasticity support range, the higher the penalty for deviating from the support centre. Consequently, the width of the support range reflects the precision of the *a priori* information (Heckelei and Wolff, 2003).

⁸ Upper and lower bounds on the level of the coefficient of absolute risk aversion have been imposed. The E-V risk aversion coefficient equal the E-standard error risk aversion coefficient divided by twice the standard error. Because the E-standard error risk aversion coefficient usually ranges from 0 – 3 (MacCarl and Spreen, 1997), these values have been chosen as lower and upper bounds. The Σ_{gm} has been calculated taking into consideration the variability of gross activity margins observed during the three-year period.

Notice that λ_t , α_t , Q and also ϕ are all estimated simultaneously by means of the considered approach. It is clear that the number of parameters to be estimated is large and, thus, that some a-priori exogenous information could be very useful to improve the quality of the estimates of so many parameters. Unfortunately, the only exogenous (i.e. not available from the FADN database) information available to develop the empirical analysis is that of the land allocation elasticities with respect to own gross margins.

Equation (7) imposes the first order conditions of the observed activities (*Marginal Revenue = Marginal Cost*) and (8) for those not observed (*Marginal Revenue < Marginal Cost*). The equation (9) ensures that the land allocated to different crops in each year is equal to the total available land. Equation (10) ensures the proper curvature of the cost function and (11) is the combination between the elasticity re-parameterization ($V^s w^s$) with the Jacobian matrix that contains the partial derivatives of the land demand functions $\left(\frac{\partial x_t}{\partial gm_t}\right)$ and the matrix $\begin{bmatrix} gm^o \\ x^o \end{bmatrix}$ is defined as the sample mean of activity gross margin ($[gm]^T \phi$) divided by the sample mean of observed land allocation ($x^T \theta$). Equations (12) and (13) relate to the probability law (where s is the number of support values).

Notice that all available information covers several years and that only one cost function with parameters Q for all periods is estimated. The error vector (Vw_t) can be interpreted in different ways: an error in the measurement of the variable, an error of the optimization process, a limit to achieving optimal allocation determined by specific economic circumstances or a combination of these factors (Heckeley and Wolff, 2003).