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Abstract

Rapid environmental changes can affect agriculture by introducing additional sources of uncertainty. Conversely, policy interventions to help farmers cope with risks may have strong impacts on the environment. In this paper, we evaluate the effects of public risk management programmes, particularly subsidies on crop insurance, on fertilizer use and land allocation. We implement a mathematical programming model based on data collected from 1,092 farms in Puglia, a southern Italy region. The results show that under the current crop insurance programmes, input use is expected to increase, while the effect on production is likely to be crop-specific. The policy and environmental implications are discussed.

Keywords: uncertainty; risk management; input use; multifunctionality.

Introduction

Agricultural production is a risky activity: factors beyond the manager's control most often affect final outcomes. In particular agriculture is largely affected by weather fluctuations and climate change (Knox et al., 2010; Knox and Wade, 2012; Di Falco et al., 2014). As a result there has been increasing attention in planning public interventions aimed at reducing income variability. In the USA, Canada and vast majority of EU Member States, farmers and their representatives have paid particular attention to the potential offered by the involvement of governments in farm risk management programmes (Cafiero et al., 2007). This is to some extent, also true in less developed economies such as the Mediterranean countries (Santeramo et al., 2012; 2014).The environmental consequences of risk management policy, such as crop insurance, have been fiercely debated (Capitanio and Adinolfi, 2009; van Asseldonk et al., 2013; Dorling, 2014), but their role as determinants of insuring decisions is still unclear. Moreover, whether or not the purchase of crop insurance induces farmers to reduce the use of potentially polluting chemical inputs (intensive margin) or expanding the area of cultivated land (extensive margin)is an unresolved issue (Mishra et al., 2005; Enjolras et al., 2012). In fact, while chemical and fertilizer applications tend to influence yield and profit variance, crop insurance subsidies are usually provided to farmers located in risky areas in order to help risk-averse farmers tocope with risks and increase the cultivated area. Readers interested in this research area are referred to Babcock and Hennessy (1996), Smith and B. K. Goodwin (1996) and Moschini and Hennessy (2001).

In this framework, the FischlerCAP reform of 2003 represented a systematic attempt to reorient farm policy to place greater emphasis on environmental, landscape, food quality and animal welfare objectives. There are five key new elements in the reworked CAP framework; (i) the introduction of decoupled payments, (ii) environmental cross compliance, (iii) re-orientation of CAP support towards rural development policy by modulation, (iv) an audit system and (v) new rural development measures. In this context, direct payments are conditional upon the respect of minimum environmental, animal welfare and food safety standards, and modulation of direct payments has been made compulsory, so that each Member State is forced to divert a (small) part of its direct payment endowments to the resources available for rural and regional development policies. The latest CAP reform acknowledged that increased mobility and leisure time, added to the relocation of population towards rural areas, have all acted to increase the marginal value of environmental amenity.

A new role has been attributed to the primary sector, namely production of environmental goods and food quality and safety. This new role may be explained in terms of multifunctionality, which means that agro-environmental policies promote non-commodity outputs jointly produced with agricultural commodity outputs (Zheng and Liu, 2013).

At the same time, the new regulations arising from the CAP Health Check of 2009 confer management autonomy on Member States for the first time, authorised to use up to 10% of the national maximum ceiling, to supply specific aid in clearly defined cases. Among specific subsidies (Measure (d) insurance), there is the possibility of using the first pillar for subsidising measures to cover the risk of economic losses caused by adverse weather conditions and by animal or plant diseases or parasitic infestation (Art.70, EC Regulation 73/2009). In fact, Measure (d) allows financial contributions to be granted for payment of crop insurance premiums up to a maximum of 65% of the total premium in the form of EU co-financing (a new concept in the history of the CAP). This co-financing cannot exceed 75% of the national financial contribution.In summary, whilst both risk management and environmental policy have been specifically regulated, it remains unclear to date how such programmes might act together, without one offsetting the other.

Hence the main objective of this investigation was to clarify the relationship between risk management policy and environmental policy in the context of farmers' agrochemical applications and land use, expanding the analysis conducted by Capitanio et al. (2014). To our knowledge, these studies are unique in Europe, and the results may well bring about a review of government risk management programmes, which undoubtedly introduces potential distortion into farm-level decision-making which could be affected at both the intensive (input use) and extensive (land use) margins. There could be a knock-on effect in terms of rural and regional policy, which currently represents for southern

Europe, i.e. Italy, the driving force of development.The paper first describes the Italian crop insurance system and the debate on risk management and environmental policies; then we present the theoretical and empirical frameworks; and finally we present the empirical results and concluding comments.

Crop insurance in Italy

In Italy, the government's involvement in agricultural risk management is based on the wholly state-financed National Solidarity Fund for natural disasters in agriculture (FSN), set up in 1974 with two main objectives: (i) to compensate farmers for damage due to natural disasters and (ii) to support the use of crop insurance. State contribution has constantly increased in nominal terms, although this is mostly due to the increased share of combined perils policies that benefit from higher public subsidy to premiums (80%). Tariffs show a significant reduction between 2007 and 2011 (Table 1).

However, until recently, access to disaster payments was open to all farmers, irrespective of the signing of insurance contracts. From 1981 through to 2005, appropriations by the FSN have totalled about €9.4 billion; 72% of that being spent on disaster payments, while insurance subsidies have absorbed the remaining 28%. Over the same period, disaster payments averaged €234 million per annum, reaching a maximum €522 million in 1990 (Borriello, 2003). The Italian system of compensation for natural disaster damage is mainly reactive, in the sense that the initial annual endowment of funds received by the FSN can be integrated with *ad hoc* specific legislative measures, when necessary. In 2002, total appropriations for the FSN were €481 million. The law which established the FSN also authorized operation of farmers' associations at the provincial level (*Consorzi di Difesa*) which were assigned two functions: (i) collection of farmers' insurance demands (mainly for hail) and transferring them to the insurance companies; and (ii) the coordination and enforcement of common preventive measures. Despite subsidies of about 35% to 40% of actual premiums, the spread of insurance in Italian agriculture has been rather thin: the share of insured value on total crop production — mainly fruit crops and vineyards — has never exceeded 15%, attained in 1998 but then decreasing in subsequent years. One likely reason is the possibility for Italian farmers to access compensation for natural disasters even without signing insurance policies. The Italian system has been modified in recent years by the Legislative Decree (29th March 2004)with more emphasis on crop insurance, in an attempt to reduce the cost of ex-post compensation in the event of disasters. The main changes are the possibility for farmers to underwrite newly designed contracts for innovative pluri-risk coverage directly with insurance companies, with premiums subsidised by up to 80%, and state-supported reinsurance. Eligibility for indemnity shall be determined by an income loss, taking into account only income from agriculture which exceeds 30% of average gross income or the equivalent in net income terms (excluding any payments from the same or similar schemes). Moreover, the amount of such payments shall compensate for less than 70 % of the producer's income loss in the year the producer becomes eligible to receive this assistance.

Risk management and environmental policies

There is extensive literature on the potential environmental impacts of government-sponsored risk management programmes such as subsidised crop insurance and crop disaster payments (Horowitz and Lichtenberg 1993, Smith and Goodwin 1996, Wu 1999, Seo, Mitchell and Leatham, 2005).All these studies are limited to the USA. Since North America has experienced a long history of crop insurance, large datasets allow economists to estimate crop insurance adoption patterns, chemical input use and crop acreage allocation. In contrast, in Europe such data are unavailable, explaining why farmers' behaviour under uncertainty has been under-investigated.An underlying policy question is whether the benefits provided by government-subsidised risk management programmes are offset by the costs of such programs, including the costs of unintended environmental effects, and whether or not risk management programmes could offset environmental programmes, for example, as predicted by Fischler's reform.

Concerning the use of chemical input, early studies examined the impact of price uncertainty on a competitive, one-input, one-output firm (Sandmo, 1971; Ishii, 1977; Briys and Eeckhoudt, 1985; Hey, 1985). Pope and Kramer (1979) modelled production risks by analyzing their effects on input use. They showed that, under constant relative risk aversion (CRRA) assumption, risk-averse agents tend to use more inputs in order to decrease the impact of risky activities. Ashan et al. (1982) investigated the relationship between crop insurance and input usage. They investigate the relationship between crop insurance and input usage and showed that farmers adopting full coverage crop insurance are likely to choose the risk-neutrality optimal input solution. Quiggin (1992) introduced the moral hazard problem: he found that crop insurance may lead to a reduction in input use.

One of the most cited contributions is the research by Horowitz and Lichtenberg (1993). They showed that in many instances pesticides are more accurately viewed as risk-increasing. While the conventional wisdom is that pesticides are risk-reducing inputs, they found that their use may increase rather than decrease with crop insurance. Since Horowitz and Lichtenberg's (1993) work was based on data prior to 1992, before the Reform Act came into force in the USA in 1994, some aspects of farmer behaviour may have changed.

Smith and Goodwin (1996) criticized Horowitz and Lichtenberg's (1993) findings that multiple peril crop insurance could force farmers to increase chemical input use. They emphasized the strong linkage between increase in expected yield and increase in yield variance, if an input is considered as risk-increasing. The increase in variance positively affects the likelihood of an indemnity payment but the increase in mean yield offsets it. The net effect is ambiguous.Smith and Goodwin (1996) doubted that the expected indemnity payment increased with input use for two reasons. Firstly, chemical inputs increase production costs, and lower (increase) the expected profits (losses) when indemnity payments are made. Secondly, the critical yield that triggers an indemnity payment is determined by the farm's yield history.

Wu (1999) found that crop insurance for corn in Nebraska caused a shift in production from hay and pasture to corn. In other words, crop insurance subsidies may also promote environmental degradation due to the increase in production which may result in increases in overall chemical use for crops. Importantly, this shift involves considering environmental externalities at the extensive and intensive margin. Wu (1999) also pointed out that an increase in chemical application rates may be due to the 'moral hazard' created by crop insurance.

Choices under uncertainty: recalling the theory

For our empirical investigation we used a non-linear programming model (NLP). Following Lambert and McCarl(1985) we developed a model for farmer decision-making to capturethe strategies when deciding to enrol in the Environmental Program (EP) under uncertainty.We considered whether their participation strategies could be offset by risk management programs, such as crop insurance.In order to analyze the effects of the introduction of a subsidy on the premium of all-risk insurance on yields, we used the Italian Farm Accountancy Data Network (FADN) dataset of two samples of farms located inPuglia, a region in Southern Italy.It is representative of the Italian agricultural system, and includes a variety of different farm types. We considered wheat and tomato producers in order to differentiate the sample in terms of expected variability of yields/revenue. Our analysis concerns two case studies of the same lowland/highland system.

The choice of wheat and tomato is due to their different yield variability (tomato yields generally show higher variability than wheat) and to different production characteristics.The database is extracted from FADN-RICA and includes1,092 farms, observed over the period from 2003 to 2008. Theoretically, farmers' enrolment decisions in the EP mean dealing with various sources of uncertainty. The decision to participate in the EP must be made in the face of the well-known revenue uncertainty of agricultural production resulting from variability in output prices and crop yields. For clarity, we consider two farmers who farm in different regions. For unsubsidized insurance one farmer would pay £10 per £100 of liability; the other £20 per £100 of liability for the same insurance policy. In relative risk terms, the farmer paying £20 would have yields that are twice as risky for the same insurance policy. Given a 50% subsidy, the lower risk farmer receives a £5 per £100 of liability transfer and the higher risk farmer receives £10.Any expected utility model for risk-averse decision makers would suggest that subsidizing premiums would encourage farmers both to increase their level of production, and possibly increase it into riskier areas. The idea is that as a subsidy decreases, lower risk farmers would be less motivated to subscribe to crop insurance and riskier farmers could abandon their production (probably from marginal land). By modeling it, we could assume a multi-output firm with a fixed amount of land L^*that can be allocated between j crops. The producer's problem is to select levels of x variable inputs for each of the j crops in the production plan and to allocate L^* hectares of land among these j crops. The modeled farmer is a price taker in the output and variable input markets. The farmer decides to subscribe an *all risk* (ARI) crop insurance contract guaranteeing yield losses up to 30% of average yield, with the following payoff:$\{I_j, M_j\}$ = 1, …, I, where I_j represents the random (eventual) insurance indemnity and M_j is the non-random insurance premium for crop j. Moreover, at sowing time, the farmer could chooses to receive the environmental payments (decoupled payments), $\lambda \in \{0, 1\}$, by comply his crop practice with the CAP's rules. We are assuming that crop insurance and input decisions are made simultaneously. This requires that the planning processes underlying both decisions occur simultaneously, which would appear a logical consequence of assuming that farmer decisions are affected by the overall economic environment, i.e. government risk management programmes and environmental payments.

At sowing time, total farm revenue Π is plausibly based on the expectation made on price, yield and costs experienced in the previous season, such that:

$$E(\Pi|\Omega) = p_i^e y_i^e + cov\ (p_i^e y_i^e) - c_i \qquad [1)]$$

Where,

$E(\cdot|\Omega)$ is an expectation operator conditional on the information set Ω; p_j^e is the expected price of the jth crop; y_j^e denotes the expected yield of the jth crop; $cov\ (p_j y_j)$ denotes the covariance between price and yield andi is expected to be negative (natural hedging mechanism) ; c_i is the per hectare cost of production. The per hectare revenue for crop j and farmers $i$when crop insurance is subsidised and environmental payments will therefore depend on price an yield realizations, input costs, and the environmental payments. If the income per crop is identified as $S_j\pi_j$, where S_j is acreage planted to crop j, the total crop income π is the sum of income over all crops: $\pi = \sum_j S_j \pi_j$.The representative farmer maximizes the expected utility of income, choosing the acreage allocation S_j, input use x_j, and participation in both environmental programme ϑ and insurance programme:

$$max_{A_j, x_j, \vartheta_j, i} \int u(\pi) dF\ (p_1, p_2, \ldots, p_j, y_1, y_2, \ldots, y_j) \qquad [2]$$

Where,

$F(\bullet)$represents the joint distribution function of prices and yields; the farmers' utility function $u(\bullet)$ is assumed to be a Von Neumann-Morgenstern utility function. We also assume decreasing absolute risk aversion (DARA), that is $\partial^2 U / \partial^2 \pi < 0$ (Pratt, 1964). The optimal acreage allocation and input use for each crop (S_j and x_j for all j), follows the constraints on acreage allocation$\left(S \geq \sum_j S_j \right)$.

In this way, as introduced by Seo et al. (2005), the intensive margin effect of the availability of crop insurance and disaster payments for a crop could be identified with the difference in the optimal use of input x_j when the programme is available versus when it is not. Similarly, the extensive margin effect could be viewed as a change in optimal acreage S_j when the same programmes are available.

A simple model of input and land allocation

Following Lambert and McCarl (1985), using a negative-exponential (DARA) utility function for the empirical analysis, we develop a solvable expected utility maximization model which is (a) free of restrictions on the forms of the utility function, and (b) free of assumptions regarding the distribution of the uncertain parameters. The underlying assumption in the model implies that wealth effects could affect production decisions.

With negative exponential utility ($\nu(c) = -\exp(-\theta_c)$), the objective function for problem (3) is:

$$\sum_k [1 - \exp(-R\pi_k)] \qquad [3]$$

Where,

k indexes each state (Monte Carlo random drawn), *R* is the coefficient of risk aversion, and $\pi_k = \sum_j S_j \pi_{jk}$ is profit associated to the state *k*. The coefficient of risk aversion is the ratio of the second and first derivatives of the utility function. The values for R used here are consistent with previous studies on the effects of the public subsidy at premium (Capitanio and Adinolfi, 2009; Capitanio *et al*., 2014). In particular we have set R=1 in order to assume low risk-aversion, and R=3 for high risk-aversion. Income from crop *j* in state *k* is:

$$\pi_{ijk} = p_k' y_k'(x_j) - c_j - r' x_j + \vartheta EP_{jk} + \sum_i (I_{ijk} - M_{ijk}) \qquad [4]$$

Where, the subscript k is for variables assumed to be random (e.g. prices, yields, environmental, insurance indemnities and disaster payments).

Given that we set the model at only one trigger level, the non-random insurance premium for each crop does not depend, unlike in Seo et al. (2005), on several coverage levels. This makes it easier to calculate the expected net indemnity which is equal to the expected indemnity minus the actual premium and better represents the Italian crop insurance market. Since the integration required to obtain the expected indemnity is analytically intractable for the model, we used Monte Carlo integration. In agriculture, simulation models are routinely applied to biological system analysis (e.g., crop simulation or environmental models) and there is always some uncertainty present in the system, which can be modeled by sampling from appropriate probability distributions.

Following Greene (2000), we interpret the integral as an expected value. The expected indemnity is the average indemnity for each policy over all states. Since crop yields are known to fall in a range from 0 to some maximum possible value and their distribution can be significantly skewed either to the right or to the left and the beta distribution has such flexibility, we introduced into our analysis a random crop yield which follows a beta distribution, with mean and variance that depend on the dosage of applied nitrogen fertilizer. The model was solved using the non-linear program solver in GAMS using the method suggested by Richardson and Condra (1981).

Results

The results are shown in Tables 2 and 3. With regard to the optimal fertilizer use and acreage allocation when the subsidized insurance program is available, unsurprisingly, our results show that crop insurance generally has a positive effect on the optimal nitrogen fertilizer rate for both wheat and tomato. Depending on the crop and the farmer's level of risk aversion, the optimal rate increases by about 5 q/ha. Crop insurance has a large effect on the optimal acreage allocation. When ARI is available, optimal tomato acreage almost doubles, accompanied by an appropriate decrease in wheat area. Table 2 also shows that as farmer risk aversion increases, the optimal nitrogen rate decreases for all alternatives regardless of the crop type because nitrogen is used as a risk-increasing input. In addition, optimal tomato area decreases and optimal wheat area increases, because tomato is the riskier crop. For the range of risk aversion levels explored, the optimal insurance coverage level slightly changed for tomato, but increased for wheat.

In our study, crop insurance positively affected both crops at the intensive margin. It would be inappropriate to compare our results with others in the past due to the different areas investigated. Regardless of yield distribution, when crop insurance is available, farmers find it optimal to bear more risk and so choose fertilizer rates accordingly. Given our conditional yield distributions, this means an increase in the fertilizer rate. Since our analysis was conducted for a unique scenario, it would be prudent to avoid direct comparisons to other studies carried out previously.

Concluding remarks

The environmental impact of farming continues to play a significant role in policy debates regarding the role of government in the agricultural sector of the economy. It has been argued that government policies that reduce the production risk facing a producer may incentivize activities harmful for the environment. For example, the provision of state-subsidised crop insurance may encourage producers to bring economically marginal land into production. If that land is also more environmentally fragile than land already farmed, this reduction in risk provided by state-subsidised crop insurance could lead to a reduction in environmental quality. In addition to crop insurance, the government has set up a myriad of other programmes designed, among other things, to provide income support and reduce income variability in the agricultural sector. Some of these programme payments are linked to the current production of a particular crop, while other programme payments are decoupled from current production.

While such programmes provide incentives to expand production on the extensive margin, they may also lead to reductions in environmental amenity and prejudice multifunctionality objectives. In addition to encouraging production on environmentally fragile land, farm subsidies and risk management policies provide incentives for producers to alter their crop mix, cropping practices (including input use) and conservation practices.

Although cautiously waiting for further empirical or theoretical evidence may be probably wiser, it seems clear so far that insurance subsidies have the potential to alter land use, cropping practices and conservation practices, and may contribute to increased soil erosion. Moreover, it would seem that subsidising premiums could offset the benefits of environmental programmes, as foreseen by the Fischler CAP reform of the European agricultural support system. Government risk management programmes undoubtedly introduce potential distortion into farm-level decision-making which affect either input and land use. Southern European regions, which are greatly affected by regional development policy, maybe affected by these negative externalities.

A few caveats limit the present analysis. Firstly, the theoretical model we have implemented assumes that crop acreage is fixed, and that allocation is feasible only for two different crop types. The model predictions are also limited to a partial equilibrium framework. Modelling environmental externalities of crop insurance subsidies is challenging and beyond the scope of this paper. Secondly, having assumed that the region is homogeneous we are only partially able to disentangle changes due to extensive or intensive margins. This issue is also a topic for future research.

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Table 1 Crop insurance market in Italy (2005-2012)

Descriptor	Unit	2005	2006	2007	2008	2009	2010	2011	2012
Certificates	n° (000)	212	211	236	264	226	208	207	214
Insured quantities	Mln t	14.8	14.8	16.3	20.4	18.2	20.1	19.8	*na*
Insured hectares	000 ha	1074	1125	1051	1450	1355	1153	1164	*na*
Insured Value	Mln €	3,810	3,789	4,379	5,436	5,131	5,312	6,145	6,826
Total Premiums collected (TP)	Mln €	269	265	292	338	317	285	287	321
Indemnities (VR)	Mln €	159	149	184	272	234	169	171	231
Public Contribution *	%	65.90	66.62	66.78	66.34	67	66.41	66.12	*na*
Average tariffs	%	7.4	7.5	7.22	6.75	6.70	5.78	5.74	*na*
VR/TP	%	59.6	55.4	64	81	75	60	58	*71.9*

(*)premiums/insured value
Source: Ismea (2011, 2013)

Table 2 Intensive margin – Estimated change (%) in nitrogen fertilizer use.

	Risk-neutral farmers		Risk-averse farmers	
	Tomato	Wheat	Tomato	Wheat
Scenario				
EP only	*Baseline*	-42.1%	-43.1%	-2.9%
ARI and EP	+4.2%	+6.7%	+6.7%	+4.3%

ARI and EP indicate, respectively, all risk insurance and environmental programs.

Table 3 Extensive margin changes – Estimated change (%) in cropped area allocation.

	Risk-neutral farmers		Risk-averse farmers	
	Tomato	Wheat	Tomato	Wheat
Scenario				
EP only	*Baseline*	147.4%	218.1%	-21.2%
ARI and EP	+50.5%	-13.8%	-8.8%	+62.8%