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# RISK MANAGEMENT THROUGH INSURANCE AND ENVIRONMENTAL EXTERNALITIES FROM AGRICULTURAL INPUT USE: AN ITALIAN CASE STUDY

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## **Abstract**

The biological nature of agricultural production processes induce a higher degree of uncertainty surrounding the economic performance of farm enterprises. This has contributed to the development and acceptance of forms of public intervention aimed at reducing income variability that have no parallel in other sectors of the economy.

In particular, subsidized crop insurance are a widely used tool. The impact of these programs on the decisions of production generates effects on input use, land use and thus, indirectly, environmental outcomes.

The importance of this issue has grown in parallel with the growth in importance of the collective role of agriculture sector that has addressed the recent guidelines adopted by many developed countries. To examine the effects of public risk management programs on optimal nitrogen fertilizer use and land allocation to crops, this study carried out an empirical analysis by developing a mathematical programming model of a representative wheat-tomato farm in Apulia southern region of Italy.

The model endogenizes nitrogen fertilizer rates and land allocation, as well as the insurance coverage levels, participation in insurance programs and the Environmental Payment (EP). This study utilized direct expected utility maximizing non-linear programming in combination with a simulation approach.

Results show that with current crop insurance programs, the optimal nitrogen fertilizer rate slightly increases and the optimal acreage substantially increases for tomato whereas decrease for wheat. Assuming that the environmental negative effects of crop insurance are positively related to nitrogen fertilizer use, this type of public intervention implies negative environmental effects.

**Key words:** Uncertainty, Risk Management, Crop Insurance, Input Use Decisions, Environmental Externalities, Mathematical Programming.

**JEL Code:** Q10, Q14

## **Introduction**

Agriculture is arguably the sector of production where factors outside managers' control are more heavily responsible of the final result of the enterprise, something that has contributed to the development and acceptance of forms of public intervention aimed at reducing income variability that have no parallel in other sectors of the economy.

In this context, in both developed and developing countries, often the agricultural sector is characterised by fluctuating market prices, weather-induced production instabilities, insufficient provision of inputs and lack of marketing, infrastructure and facilities which generated through the years a strong presence of risk and uncertainty in the literature contributes.

Historically, risk behaviour of decision makers have been studied quite well with respect to individual agricultural producers. Most farmers adopt risk-reducing strategies involving such elements as flexibility, liquidity, diversification, and are cautious in adopting new techniques and levels of input use that yield less than maximum expected returns.

Consequently, both in the United States and in part of Europe, the attention of farmers and their representatives has focused on the potential offered by the involvement of governments in farm risk management programs. In this context, the opportunities left open by the exclusion of payments classified as part of disaster relief and income safety net programs from the aggregate support measure, on which reduction commitment have been taken after the 1994 Uruguay Round Gatt Agreement (URAA), have been considered too precious to be left unexploited.

On the other side, a strong debate in the past arose over the environmental consequences of risk management policy, e.g. crop insurance. In particular, researchers have addressed the question of whether or not the purchase of crop insurance induces farmers both to apply more or less potentially polluting chemical inputs and put in production marginal land.

These relationship between various risk management policy and farmers' agrochemical applications and land use remain unclear up till now for two reasons.

First, in terms of intensive margin, the empirical evidence remains unconvincing as to whether chemical and fertilizer applications increase, decrease, or have no effect on yield or profit variance. Leathers and Quiggin (1991) in their contribute states that chemical applications reduce risk while fertilizer applications increase risk, as measured by profit variance measure. Alternatively, Horowitz and Lichtenberg (1994) provided some reasoning and empirical evidence to suggest that pesticide applications increase risk. Babcock and Hennessy (1996) and Smith and Goodwin (1996) rebated Horowitz and Lichtenberg's argument and suggest that improper model specification biased their empirical results.

Second, in terms of extensive margin, due to the design of crop insurance subsidies and of the disaster payments programs, higher levels of transfer payments are given to comparatively higher-risk areas of production. Since many producers respond to income transfers by increasing production, high-risk areas are likely to see increases in production as well as increases in transfer payments.

In this sense, it is important to stress that since premium rates are a reflection of the amount of risk associated with a parcel of land, then subsidies provide greater transfers to farmers who are operating under risky conditions. While marginal lands are not homogeneous across space, they are often associated with a particular set of environmental characteristics, the most notable of which is soil erosion. If crop insurance is promoting production on marginal lands, and these lands are found to be highly erosive, crop insurance may be contributing to erosion of farmland, build-up of sediment in nearby waterways, and other negative environmental impacts.

### **Production's behavior, risk management tools and environmental externalities**

The history of the CAP, which established in the past decades the environment to force farmers in pushing in production of food and fibre to the detriment of the quality of rural environments, has been seen as a cause of environmental quality decline.

The Fischler's reform changed the way in which support is guarantee to farmers. Moreover, the reform represented a systematic attempt to reorient the objectives of farm policy to place greater emphasis on environmental, landscape, food quality and animal welfare objectives (Grant, 2003).

There was five new key elements in the new CAP framework; the introduction of the decoupled payments, cross compliance, re-orientation of the CAP support towards to Rural Development policy by modulation, audit system, new rural development measures.

In this context, actually direct payments are conditional to the respect of minimum standards related to environment, animal welfare and food safety, and modulation of direct payments was turned compulsory, so that each Member States is forced to divert a (small) part of its direct payment endowments to the resources available for Rural Development policies.

The latest CAP reform acknowledged that the increased mobility and leisure time, added at the relocation of population towards rural areas have all acted to increase the marginal value of environmental and goods amenities.

In this context, a new role has been attributed at primary sector, so that, production of environmental goods and food quality and safety. This new role is justified in terms of multifunctionality, which means that agro-environmental policies promote non-commodities output jointly produced with agricultural commodity outputs.

Because the non-commodity outputs detain a public-goods characteristics there is not private market and therefore the State has a role in promoting agro-environmental outputs.

Agro-environmental policy may thus be seen to create a “quasi-market” for these goods in that farmers come voluntarily into environmental contracts in return for a payment.

For instance, in Europe, within the EU Rural Development Scheme framework, there are several examples of this kind of policy; Members State implemented and receive large “European” subsidy to grant these programs. Examples include English Countryside Stewardship Scheme, the German MEKA programme, and the French “La prime a l’herb”.

In short, while either of risk management and environmental policy received a specific regulation, remain unclear until now how these kinds of programmes could to act together, without offset both of them.

Until recently, few work has focused on the potential environmental impacts of government-sponsored risk management programs such as subsidized crop insurance and crop disaster payments (Horowitz and Lichtenberg 1994, Smith and Goodwin 1996, Wu 1999, Goodwin, Vandever and Deal 2004, Seo, Mitchell and Leatham, 2005).

Among others, one underlying policy question is whether the benefits provided by government-subsidized risk management programs are offset by the costs of such programs, including the costs of unintended environmental effects, and if risk management programs could offset environmental program as foreseen by Fischler’s reform.

Government risk management programs, such as subsidized crop insurance and payment in case of disaster events, undoubtedly introduce potential distortion into farm-level decision-making at both the intensive (input use) and extensive (land use) margins.

Recalling the last WTO agreement previously introduced, and the recent Fischler’s reform, that settled a new discipline for environmental payments in European agriculture, e.g. linking decoupled payments to cross compliance, we would make clear how both environmental programs and risk management in agriculture (Government financial participation in income insurance and income safety-net programs and, Payments -made either directly or by way of government financial participation in crop insurance schemes- for relief from natural disasters; art.7 and 8 annex II in Agreement on Agriculture in WTO) were expected into green box.

From this point of view, it becomes interesting to study in depth another relationship among risk management policies in agriculture and environmental policy; in particular, we refer to the content of art.8.

In this context, a point of contention underlying this classification system involves the lack of a precise definition of “minimally trade-distorting”. Clearly, absent such a definition, policies that may actually have effects on production and thus international markets may not be subject to the disciplines of the WTO; exactly as ad-hoc disaster relief payments.

At this stage, however, intuition clearly suggests that agents will alter their production behavior with the knowledge that widespread crop losses will trigger disaster payments. The argument is often made that, because disaster payments arrive after harvest and thus differ from production decisions, they cannot have an impact on production decisions and thus, will not produce undesirable market distortions.

Such an argument has some merit, but only if producers are surprised by the payments, which is not in our case. Rational expectation theory suggests that anticipation of future opportunities for updating base acreage may influence current production decisions, thus breaking the “decoupled” nature of the programs. Producers’ behavior throughout the 1980s and 1990s demonstrated that these policies were quickly incorporated into producers’ expectations; the likelihood that disaster payments would be received during periods of low yields almost certainly affected producers’ planting decisions.

## **Literature review: intensive and extensive margin**

### ***Impacts at the intensive margin***

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, Katz 1983, Briys and Eeckhoudt 1985, Hey 1985). Sandmo’s seminal paper showed that in the presence of price uncertainty the risk-averse firm will produce less than if prices were known. However, results strongly depend on the assumption made about farmer risk aversion. Connected to the results reached by Sandmo, Ishii later demonstrated that optimal output declines with increasing price uncertainty. Whereas in most economic sectors uncertainty in price may represent the dominant source of risk, in agriculture this eventuality may not be true<sup>1</sup>; in this context, the literature on the field has been focused primarily on the impact of production (yield) risk on input use.

Pope and Kramer (1979) offer one of the first models concentrating on production risk and its effects on input use. They consider a stochastic production function, a constant relative risk aversion utility function, and allow for inputs to either increase or decrease risk. In the single input case, they show that a risk-averse agent uses more (less) of an input which marginally decrease (increase) risk.

The first authors which investigate on the relationship among crop insurance and input usage were Ashan, Ali, and Kurian (1982). They show that in the context of a one-input, one-output model, full coverage crop insurance encourages risk taking (e.g., the use of risk-increasing inputs) and causes farmers to choose inputs as if they were risk neutral. Ashan, Ali,

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<sup>1</sup> We just need to refer to the framework of the CAP before the latest reform, where price were guaranteed at fixed level.

and Kurian also argue that private crop insurance may fail because of information asymmetry creating adverse selection.

Quiggin (1992) develops a model which introduces the conditions under which, due to the moral hazard problem, crop insurance would lead to a reduction in input use. Quiggin in his model has foreseen the eventuality of only two states of nature, good and bad, and he drawn as a result that the marginal product of an input is greater in the good state than in the bad, and that the insurance contract is not contingent on input use.

One of the most cited contribute is referred to Horowitz and Lichtenberg work (1994). They pointed out that in many instances pesticide are more accurately viewed as risk-increasing, and thus their use may increase rather than decrease with crop insurance, while the conventional wisdom is that pesticides are risk-reducing inputs. In an expectation or planning context, clearly the insurance and input decisions are, to some degree, simultaneously determined. In the context of the cross-sectional analysis data, three alternative hypotheses are relevant. First, the crop insurance and input decisions may indeed be made simultaneously. Moreover, Horowitz and Lichtenberg assume that crop insurance decision has to be made before any inputs are actually applied, so that the input use does not influence the crop insurance decision. This is a strong hypothesis if we consider that crop insurance and input decisions could be made simultaneously.

Since Horowitz and Lichtenberg's contribute is dated at 1992, before, therefore, of the Reform Act brought in US in 1994, same aspect in farmers' behaviour could be altered in a while. Almost immediately, Smith and Goodwin (1996) criticized Horowitz and Lichtenberg's 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 the increase in variance of the yield, whether we consider an input as risk-increasing. The increase in variance positively affects the likelihood of an indemnity payment but the increase in mean yield offset it. The net effect is ambiguous.

Smith and Goodwin doubt that the expected indemnity payment increases with input use for two reasons. First, chemical inputs increases productions cost, 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. Later, Babcock and Hennessy (1996) argued that the effect of increased fertiliser use on the probability of low yields primarily determines whether insurance purchases will tend to cause insured farmers to increase or decrease their fertiliser expenditures. Using data from four co-operating Iowa farms growing corn continuously from 1986 to 1991 they conclude that increased fertiliser use, as measured by pounds per acre, strongly decreases the probability of low yields.

Wu (1999) found that crop insurance for corn in Nebraska caused a shift in production from hay and pasture to corn. This could imply that subsidies for crop insurance may also promote environmental degradation due to the increasing in production which may result in



increases in overall chemical usage for crops. It is important to underline that this shift involve into consideration either environmental externalities at the extensive and intensive margin. Wu also points out that an increase in chemical application rates may be due to the 'moral hazard' created by crop insurance.

More recently Nimon and Mishra (2001) followed a methodology similar to that of Smith and Goodwin. They focused their aims on the revenue insurance instruments and used survey data of wheat farmers` in seventeen states Using the aggregate measure the authors reproduce the Smith and Goodwin result for revenue insurance instead of multiple peril crop insurance. However, the authors found that the environmental impact of pesticides and fertilizers may vary across space.

### **Impacts at the extensive margin**

Literature cited focuses primarily on studies that address the issue of acreage expansion and contraction occurring as a result of crop insurance and/or disaster aid, and the environmental impacts that result from these programs. While significant literature exists on the impacts of crop insurance and disaster aid on crop choice, it will not be addressed specifically.

Environmental organizations and interest groups are suggesting that subsidized crop insurance and disaster aid is encouraging production on environmentally sensitive lands by promoting production at the extensive margin. Subsidized policies such as those that have been offered in recent decades are likely to attract riskier producers and are characterized by adverse selection and moral hazard, both forms of market distortions.

During the late 1980's, a few individuals began to realize that by providing a safety net of disaster payments and subsidized crop insurance, government programs may be directly influencing farm production levels and prices. In 1936 the editors of the Christian Science Monitor warned against the dangers of a crop insurance program encouraging production on marginal lands (Goodwin and Smith, 1996). While crop insurance, disaster relief, and the political climate that surrounds them have changed over the last half century, the warning heralded by the editors is still pertinent today.

Plantinga (1996) illustrates that some government policies aimed to manage both price and yield risk, including price controls, crop insurance and others, could cause forced distortions in markets as well as farm-level decision making.

He emphasized this point carrying out a study on the environmental effects of milk price supports, using county level data for Wisconsin.

Plantinga illustrated that reducing the price support for milk in Wisconsin would reduce incentives for profit maximizing producers to operate on marginal lands and would

subsequently enhance environmental quality by reducing soil erosion and improving wildlife habitat through forestation.

Yet in 1996 Griffin addressed the production impacts of crop insurance and disaster payments on planted acres in the Great Plains using two single equation empirical models with time-series, cross-sectional, county level data. Focusing on six major crops (corn, soybeans, grain sorghum, barley, cotton, and wheat) for the dependent variable, Griffin's study measured the impact that crop insurance participation, risk subsidies, deficiency payments, and disaster payments had on total planted acres for the six crops for the periods 1974-1977 and 1989-1992. Results suggested that roughly 16 million acres were in production that otherwise would not have been without disaster payments, crop insurance, and risk subsidies. To address the environmental impacts of this additional acreage, Griffin estimated the amount of soil erosion that could be attributed to the 16 million acres. In a crude estimate, the study suggested the amount of soil loss that could be attributed to crop insurance and disaster payments to be 61.4 million tons.

Keeton et al. (1999) estimated the effects of disaster assistance and crop insurance on land-use patterns for the same crops in the plains and Midwestern states. More specifically, Keeton et al. tried to investigate on the possibility that government programs could push farmers in production to risky regions of the U.S.

Cropping data was taken from 285 Crop Reporting Districts (CRD) for the years 1978-1982 and 1988-1992, together with data on disaster assistance and crop insurance premiums. Changes in land-use patterns were measured by the dependent variable by capturing the change in total cropland for the six crops in each CRD between the two time periods. Keeton estimated that for every 1-percentage point increase in crop insurance participation, an additional 1.5 million acres are planted to the top six crops in the U.S. As pointed out in the study, such an increase implies that around 45 million additional acres may be in production as a result of crop insurance when including 30 million CRP acres.

Lastly, Goodwin and Smith (2003) found that almost half of the reductions in soil erosion due to the Conservation Reserve Program (CRP) were offset by participation to income support programs which positively affected the raises in erosion from farmer responses.

### **Non-linear Programming programming model**

The desire to reflect uncertainty of future events within decision-making problems has led to a number of risk models. Many of these risk models attempt to reflect the decision maker's expectations of possible outcomes and their probabilities, along with the decision maker's attitude toward assuming risk.

Linear programming is understandably often the mathematical programming model of choice when first addressing a complex real-world problem. But only a small portion of all measurable real-world problems can be treated as linear to a sufficient degree of accuracy; hence, nonlinear programming (NLP) must be used to improve the model accuracy, realism and validity.

Several reasons have made linear programming models widely used: the model is uniform and easy to set up; the theory is well-developed, easily understood, "nice and clean"; the algorithms are easy to understand and to trust; data input and post-optimality analysis are automated and standardized; large models can be solved efficiently. On the contrary, nonlinear programming models do not have a universal form and take a lot experience and expertise to set up properly. The solution concepts, e.g., KKT-points and local solutions, are elusive and most algorithms are sophisticated and take time to understand. Furthermore, they are not as robust for large scale problems as linear programming and there is no guarantee of global solutions.

Briefly, from Lambert and McCarl (1985) "by definition the expected utility of any distribution of wealth equals the mathematical expectation of the utility of wealth evaluated at each of the possible states of nature. If all increments of wealth are caused by the decision being considered, then wealth arising from a decision  $X$  would equal initial wealth plus net income due to  $X$ . Assuming that total wealth is a simple linear function of  $X$  and that  $C_k$  is the vector of net wealth contributions per unit of  $X$  under the  $k$ th state of nature, then  $C_k X$  is the increment to wealth under the  $k$ th event. Total wealth under  $k$ th state of nature thus can be written:  $W_k(CX) = W_o + C_k X$ . Using this relationship, the expected utility from a decision  $X$  over  $N$ -possible discrete states of nature would be  $EU[W(CX)] = \sum_{k=1}^N Pr_k U(W_o + C_k X)$  where  $Pr_k$  is the probability of the  $k$ th state of nature occurring and  $U(W_o + C_k X)$  is the utility obtained from the wealth level achieved under state  $k$  with decision  $X$ ."

If we wish to find the decision  $X^*$  that maximizes expected utility over all feasible decisions, we should solve the following programming problem:  $Max_X \sum_{k=1}^N P_k U(W_o + C_k X)$  with  $\sum_j a_{ij} X_j \leq b_i$  and  $X > 0$ . This formulation is inherently a nonlinear programming problem (also called "direct expected utility maximizing nonlinear program", that is, DEMP) Because NLP is a difficult field, researchers have identified special cases for study. A particularly well studied case is the one where all the constraints  $g$  and  $h$  are linear. The name for such a problem, unsurprisingly, is "linearly constrained optimization".

Actually, because the availability of new algorithms and software, the number of application based on NLP is raised, opening in this way a new scenarios in the risk analysis in agriculture.

### **A possible effort of an empirical investigation by non-linear programming model**

Theoretically, farmers' enrolment decisions in the Environmental Program (EP) involve 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. As emphasized above, the purpose of this study is to develop a model of farmer decision-making to understand how farmers formulate their participation strategies when deciding to enroll in the EP under uncertainty; moreover, if their participation strategies could be offset by risk management programs, such as crop insurance.

To be clear, for example, 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 percent 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 this design encourages both farmers to not only increase their level of production, but to possibly increase it onto riskier, marginal lands as well. Marginal lands make up what is referred to as the extensive margin or areas of farmland that are of a lower quality in terms of crop yield and productivity. Marginal lands are often located on the edge of production and are likely to be used given an increase in commodity prices or a decrease in production costs.

The idea is that as a subsidy decreases, lower risk farmers would be less motivated to subscribe crop insurance and riskier farmers could leave their production (probably from marginal land). How to model it?

We could assume that the modeled farmer earns income by cultivating crops on total acreage  $S$  and purchasing inputs  $x = \{x_1, x_2, \dots, x_N\}$  to crops  $j = 1, \dots, J$ .

Farmer has also the possibility to subscribe a crop insurance contracts, characterized by the following payoff:  $\{I_j, M_j\} = 1, \dots, I$ , 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, farmer choose to entry in the environmental payments (decoupled payments),  $\lambda \in \{0, 1\}$ . If farmer facing revenue reductions of more than 30% of the preceding three years average, then disaster payment are guaranteed from public solidarity.

Running the model, we assume that crop insurance and input decisions has been made simultaneously. This does not require that timing of the decisions be contemporaneous, but only that, the planning processes underlying both decisions occur simultaneously. It appear a logical consequences of assuming that farmer decisions are affected from the overall economic environment, i.e. government risk management programs, payment in case of disaster events, environmental payments, which undoubtedly introduces a potential distortion into farm-level decision-making at both the intensive and extensive margins.

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

$$E(p_i y_i) = p_i^e y_i^e + cov(p_i^e y_i^e) - c_i$$

where E is an expectation operator;  $p_i^e$  is the expected per quintal price of the  $i$ th crop;  $y_i^e$  denotes the expected yield per hectare of the  $i$ th crop;  $cov(p_i^e y_i^e)$  denotes the covariance between price and yield and underline the natural hedging mechanism among price and yield;  $c_i$  is the per hectare cost of production.

Per hectare revenue for crop  $j$  when crop insurance is subsidized, payments in case of disaster events are guaranteed and environmental payments occur is:

$$\pi_{ijf} = \mathbf{p}'\mathbf{y}'(\mathbf{x}_j) - c_{jf} - \mathbf{r}'\mathbf{x}_j + \lambda EP_j + \sum_i (I_{ifj} - M_{ijf})$$

where  $\mathbf{p}'$  is the vector of the the random price,  $\mathbf{y}'$  is the vector of the random crop yield per acre as a function of the input levels  $\mathbf{x}_j$ , is the non-random variable cost, and  $\mathbf{r}$  is the price vector of inputs  $\mathbf{x}$ .  $I_{ifj}$  represents the environmental payments and  $\lambda$  is an indicator variable for participation in the environmental program ( $\lambda = 1$  if the farmer choose to participate, 0 otherwise).

In this scenario, income per crop could be represented as  $S_j \pi_j$ , where  $S_j$  is acreage planted to crop  $j$ , and total crop income  $\pi$  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  $\mathbf{x}_j$ , and participation in the environmental program  $\lambda$ , and insurance program  $i$ :

$$\max_{A_j, \mathbf{x}_j, i, \lambda_j} \int u(\pi) dF(p_1, p_2, \dots, p_j, y_1, y_2, \dots, y_j) \quad , \quad (2)$$

The farmer's utility function  $u(\bullet)$  is the Von Neumann-Morgenstern ( $u' > 0, u'' < 0$ ), whereas  $F(\bullet)$  is the joint distribution function of prices and yields.

Constraints include an acreage allocation constraint  $\left( S \geq \sum_j S_j \right)$ , which imply an optimal acreage allocation and input use for each crop ( $S_j$  and  $x_j$  for all  $j$ ), after solving optimization.

In this way, as introduced by Seo et al, 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 program are available versus when it is not. Similarly, we could look at the extensive margin effect as a changing in optimal acreage  $S_j$  when the same programs are available.

### **Empirical model: utility and profit**

Lambert and McCarl pointed out that “the literature indicates that E-V analysis assumes the decision process is characterized by (a) a quadratic utility function, (b) an underlying normal distribution of wealth, (c) a situation in which risk is small relative to decision maker wealth, and/or (d) a situation wherein the E-V solutions are a reasonable approximation to the expected utility solutions (Levy and Markowitz; Tsiang 1972, 1974). These assumptions have been repeatedly debated: (a) the quadratic utility assumption has been criticized because of its risk aversion assumptions (Arrow); (b) the symmetry implied by the normality assumption has been criticized (Hanoch and Levy); (c) the small risk assumption has been criticized because some situations do not involve risks which are small; and (d) the close approximation assumption (Levy and Markowitz) can be criticized because the approximation may not be close enough (see Hanoch and Levy, p. 344).”<sup>2</sup>

Due these introductory considerations, the authors wrote “However, it would seem desirable to develop a solvable expected utility maximization model which is (a) free of restrictions on the forms of the utility function (particularly regarding the sign of the risk aversion parameter and its derivative with respect to wealth), and (b) free of assumptions regarding the distribution of the uncertain parameters.”<sup>3</sup>

In the past, due to the lack of adequate algorithms, large nonlinear programs have been difficult to solve. Fortunately, actually modern software permit to implement analysis otherwise unobtainable.

In the following section we conduct the analysis using direct expected utility maximizing non-linear programming (DEMP), combined with simulation approach (Lambert and McCarl). DEMP uses mathematical programming to find the crop acreage, input use, and

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<sup>2</sup> In, Lambert, D.K. and McCarl B., 1985. “Risk Modeling Using Direct Solution of Nonlinear pproximations of the Utility Function”. *American Journal of Agricultural Economics* 67 (4), p.847.

<sup>3</sup> Page 847.

risk management program parameters that maximize expected utility as a function of randomly drawn prices and yields.

Generally, as previously explained, it is too easy to get by with linear programming on a wide range of problems.

Therefore, we utilized DEMP to maximize expected utility directly, by virtue of using quadratic programming, recurring at Monte Carlo integration by simulate data mining from a sample of yield and price, under the hypothesis oh the distribution of these parameters (Turvey, Lambert, and McCarl).

We recurred for the empirical analysis to a negative-exponential (constant absolute risk aversion) utility function. The beneath assumption imply in the model that the wealth effects does not affect production decisions.

With negative-exponential utility ( $v(c) = -\exp(-\theta_c)$ ), the DEMP objective function for problem (2) is:

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

where  $k$  indexes each state (Monte Carlo random drawn),  $R$  is the coefficient of absolute risk aversion, and  $\pi_k = \sum_j S_j \pi_{jk}$  is profit associated to the state  $k$ . Income from crop  $j$  in state  $k$  is:

$$\pi_{ijk} = \mathbf{p}_k' \mathbf{y}_k'(\mathbf{x}_j) - c_{jf} - \mathbf{r}' \mathbf{x}_j - \text{EP}_{jk} + \pi_i (I_{ijk} - M_{ijk})$$

which differ from the previous equation (1) only for the fact that each random variable has indexed by  $k$ . Values for  $R$  were chosen in accordance with the previous investigation carried out on the effects of the public subsidy at premium.

In this context, the ARI insurance indemnities for any state  $k$  and crop  $j$  could be represented as:

$$I_{ARI,jk} = PEF_{ARI,j} \max \left\{ CVG_{ARI,j} y_j - y_{jk}^*, 0 \right\}, \quad (5a)$$

where  $y_j^*$  is the average yield used by ARI.

Differently from Seo et all, the non-random insurance premium for each crop does not depends on the chosen coverage level, esteemed that we settled the model only on one trigger level. This eventuality facilitates the computation of the expected net indemnity which is equal to the expected indemnity minus the actual premium.

Recurs at Monte Carlo integration<sup>4</sup> is used to estimate numerically the expected indemnity, since the integration required to calculate the expected indemnity is analytically intractable for the model.

Simulation and simulation modelling are frequently used terms to define various types of models and modelling techniques. In the light of this inconsistency it may be necessary to narrow down the meaning of simulation to the purpose of this study. Pegden et al. (1995) define simulation “as the process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behaviour of the system and/or evaluating various strategies for the operation of the system”. This is a general definition and one that is well suited to the use of simulation in economic-type applications.

In agriculture, simulation models are routinely applied to biological system analysis (e.g., crop simulation or environmental models) and every time there is some uncertainty present in the system, which can be modelled by sampling from appropriate probability distributions.

Following Greene, “In certain cases, an integral can be approximated by computing the sample average of a set of function values. The approach taken here was to interpret the integral as an expected value. We then had to establish that the mean we were computing was finite. Our basic statistical result for the behavior of sample means implies that with a large enough sample, we can approximate the integral as closely as we like.

The general approach is widely applicable in Bayesian econometrics and has begun to appear in classical statistics and econometrics as well.”Green consider the general computation,

$$F(x) = \int_L^U f(x)g(x)dx,$$

where  $g(x)$  is a continuous function in the range  $[L, U]$ , and further, he suppose that  $g(x)$  is nonnegative in the entire range. “To normalize the weighting function, we suppose, as well,

that  $K = \int_L^U g(x)dx$ , is a know constant. Then  $h(x)=g(x)/K$  is a probability function in the range because it satisfies the axioms of probability.

$$\text{Let } H(x) = \int_L^x h(t)dt.$$

Then  $H(L)=0$ ,  $H(U)=1$ ,  $H'(x)=h(x)>0$ , and so on.

$$\text{Then } \int_U^L f(x)g(x)dx = K \int_L^U f(x) \frac{g(x)}{K} dx = KE_{h(x)}[f(x)],$$

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<sup>4</sup> Greene pp. 181-183



where we use the notation  $KE_{h(x)}[f(x)]$  to denote the expected value of the function  $f(x)$  when  $x$  is drawn from the population with probability density function  $h(x)$ . We assume that this expected value is a finite constant”

Thus the expected indemnity is the average indemnity for each policy over all states

$$k : \sum_k I_{ijk} (PEF_{ij}, CVG_{ij}).$$

### ***Crop Production Function***

Random crop yield follows a beta distribution with mean and variance that depend on the dosage of applied nitrogen fertilizer. The beta distribution detects the property previously introduced<sup>5</sup>.

Using a conditional beta density for crop yield requires specifying or estimating the mean  $\mu_y$  and the variance  $\sigma_y^2$  as functions of the nitrogen fertilizer rate, and then substituting these functions into equations

$$v = \frac{(\mu_y - A)^2 (B - \mu_y) - \sigma_y^2 (\mu_y - A)}{\sigma_y^2 (B - A)} \quad \text{and}$$

$$\gamma = \frac{(\mu_y - A) (B - \mu_y)^2 - \sigma_y^2 (B - \mu_y)}{\sigma_y^2 (B - A)}$$

by obtain equations for  $v$  and  $\gamma$ .

With this conditional distribution for yield, implicitly the farmer directly chooses the mean and the variance of the yield distribution when apply the nitrogen fertilizer rate. Following the Nelson and Preckel conditional yield distribution, the farmer’s choice of the nitrogen fertilizer rate even affect indirectly the mean and variance of the yield distribution, through the approximating functions used for the parameters  $v$  and  $\gamma$ .

For this analysis, the functions for the dependence of the mean and variance of wheat and tomato yield on the nitrogen application rate were estimated using data from experiments conducted between 2003 and 2005 in Apulia region, Foggia province. Nitrogen fertilizer rates were experimentally varied from 0 to 300 q/ha and correspondently wheat and tomato yields has been measured for each plot for a total of 53 observations.

A quadratic equation identifies the final result for mean and variance with all estimated coefficients significant at the 5% level.

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<sup>5</sup> See page 113.

The final equations for the mean ( $\mu$ ) and variance ( $\sigma$ ) of durum wheat and tomato yield, respectively, as a function of the nitrogen rate ( $x$ ) are:

$$\mu_w = 112.4 + 23.87x_w - 0.108x_w^2$$

$$\sigma_w^2 = 16455 + 367.3x_w + 3100x_w^2 \text{ and,}$$

$$\mu_t = 189,89 + 34,56x_t - 0.342x_t^2$$

$$\sigma_t^2 = 23456 + 546,78x_t + 4560x_t^2$$

The model was solved using the nonlinear program (NLP) solver included in GAMS (General Algebraic Modeling System). Simulation for draw yields from the assumed distribution, and prices were carried out by Excel. The optimal fertilizer rate was determined as an integer variable by specifying fertilizer rates in 0.1 q/ha increments centered at the province mean for each crop; the fertilizer rate implied also the level of the mean and variance of the yields.

GAMS interfaced with Excel by the GDXXRW program distributed with GAMS. GAMS sends the required means and variances to Excel, then Excel generates appropriately correlated yields and prices using the method of Richardson and Condra, as suggested from McCarl to Seo et al.

## **Empirical Results and main conclusions**

Table 1 report the optimal fertilizer use and acreage allocation when the subsidized insurance program is available. Unsurprisingly, our results shows that crop insurance both generally have 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 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 hectares.

The results in table 1 also show that as farmer risk aversion increases, the optimal nitrogen rate decreases for all alternatives regardless of the crop because nitrogen is used as a risk increasing input. In addition, optimal tomato acreage decreases and optimal wheat acreage increases, because tomato is the riskier crop. For the range of risk aversion levels explored, the optimal insurance coverage level slightly changed both for tomato, but increased for wheat.

In our study, crop insurance positively affected both crops at intensive margin. It is incorrect for us to compare our result with others reached in the past; because the different methodology utilized and different area investigated, it is not possible to compare our conclusions.

Regardless of the yield distribution, when crop insurance is available, farmers find it optimal to bear more risk and so choose fertilizer rates accordingly. Considering our conditional yield distributions, this implies an increase in the fertilizer rate. However, settled that the farmer simultaneously chooses the crop acreage allocation and insurance coverage, focusing only on the variance effect of fertilizer on crop yields is a misplaced simplification of our analysis.

Once again, because conducted in a different scenario, would be prudent to avoid assimilating our analysis to other carried out in the past.

**Table 1 - Optimal farmer choice at intensive and extensive margin**

	Moderately risk averse <sup>a</sup>		Highly risk averse <sup>a</sup>	
	Tomato	Wheat	Tomato	Wheat
	Optimal Nitrogen Fertilizers Rate (q/ha)			
Government program				
EP only <sup>b</sup>	23,56	1,54	19,97	0,23
ARI and <u>EP</u> <sup>c</sup>	28,87	6,28	25,13	4,98
	Optimal Acreage Allocation (ha)			
Government program				
EP only <sup>b</sup>	,93	4,56	,87	1,52
ARI and <u>EP</u> <sup>c</sup>	4,89	1,13	2,75	8,72

a Coefficients of absolute risk aversion are  $4.0 \times 10^{-6}$  and  $7.0 \times 10^{-6}$  for moderately and highly risk averse, respectively.

b MLP means the Marketing Loan Program.

c APH means the Actual Production History yield insurance.

d CRC means the Crop Revenue Coverage revenue insurance.

e Optimal choice when both insurance programs are available is APH for cotton and CRC for sorghum.

The environmental impacts of agricultural production activities continue to play a significant role in policy debates concerning the role of the government in the agricultural sector of the economy. It has been argued that government policies that reduce the production risk facing a producer create potential incentives for the producer to undertake activities harmful to the environment. For example, the provision of public-subsidized crop insurance may encourage producers to bring economically marginal land into production. If that land is also more environmentally fragile than land already in production, this reduction in risk provided by public-subsidized crop insurance could lead to a reduction in environmental quality. In addition to crop insurance, the government has provided a myriad of other programs designed, among other things, to provide income support and reduce income variability in the agricultural sector.

Some of these program payments are linked yet to the current production of a particular crop, while other program payments are decoupled from current production.

If these programs provide incentives to expand production on the extensive margin, they may also lead to reductions in environmental amenities.

In addition to encouraging production on environmentally fragile land, agricultural subsidy and risk management policies provide incentives for producers to alter crop mix, cropping practices (including input use), and conservation practices. If a crop receives higher deficiency payments or insurance premium subsidies, farmers have an incentive to alter production in favour of that crop. If that crop also requires more extensive cultivation and input use, this shift will lead to a reduction in environmental amenities.

Government payments that increase the current return to crop production may discourage the implementation of conservation practices that may increase or maintain long-term crop yields at the expense of short-term yield. Government payments that increase the return to crop production may also decrease the incentive to shift land into less environmentally damaging uses, such as pasture or range.

While much attention has been focused on the impact of government policies on water quality, soil erosion is a key indicator of changes in environmental quality. The extent of soil erosion on agricultural land is dependent on the specific use of the land (e.g., cultivated vs. noncultivated cropland), the level of cover vegetation, the physical and chemical characteristics of the soil, and the agricultural practices (including cropping and conservation) employed on the land. If agricultural subsidy and risk management policies have the potential to alter land use, cropping practices, and conservation practices, they may contribute to increases in soil erosion. In addition to reducing future crop yields, soil erosion increases leaching and surface runoff which contributes to water quality degradation, habitat destruction, and flooding associated with increases in sedimentation.

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