Natural Vs Financial Insurance in the Management of Weather Risk Exposure in the Italian Agriculture

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1. Introduction

It has been argued that maintaining higher level of natural capital can provide very valuable ecosystems services such as weathr risk management. A prime example is the role of crop biodiversity in agroecosystems. Existing empirical evidence stresses the rile of crop biodiversity in agricultural systems is a key strategy to hedge against weather risk in agriculture (Smale et al. 1998; Di Falco and Perrings 2005; Di Falco and Chavas, 2009). This because different crops respond differently to weather randomness and heterogeneous environmental conditions. Therefore, the risk related benefits of crop biodiversity can be particularly relevant when production is rainfed and agroecological conditions are challenging. Most of the empirical literature documenting this issue is based upon evidence from agricultural systems in developing countries. In these countries, markets for insurance are missing or do not function perfectly. Therefore, e*x ante* crop production decisions, such as crop or varietal choice, remain an essential part of risk-management strategies for farm households (Just and Candler, 1985; Fafchamps, 1992; Chavas and Holt, 1996; Dercon, 1996; Smale et al., 1998; Di Falco and Chavas 2009).[1] Farmers are thus more reliant on nature services and the adopt crop diversification as a way of exploiting them (Di Falco and Chavas, 2009). It is thus the restricted access to insurance markets that may drive large part of the observed crop diversification in the field.
A quite different situation appears when one considers agricultural systems in most of developed countries where insurance products are available. Farmers face developed markets and therefore can use financial tools to support their welfare under uncertainty. In this setting, documented by a large body of literature analyzing the factors associated with farmers' purchase of crop insurance (e.g., Gardner and Kramer, Goodwin and Smith, Knight and Coble, and Coble and Knight, Sherrick et al.) one observes a much highly specialized agriculture characterized by much less crop diversity. One of implications of both the former and the latter arguments is as follows: financial and natural insurance seem to act as substitutes. The benefits of crop biodiversity therefore are more apparent arise when markets are in fact not perfect. This paper aims to directly investigating this hypothesis by asking can natural insurance substitute for financial insurance? What are the welfare benefits of natural insurance? How large? We focus on a situation where both (interspecific) diversification and insurance products are available: the Italian agroecosytem. We investigate the link between these two potential risk management tools and their implications in term of welfare under risk. More specifically we will investigate how important if biodiversity generates a natural insurance value and if it can indeed substitute for financial one.

The importance of crop biodiversity as " natural insurance" has been theoretically addressed (i.e. Quaas and Baumgartner, 2008; Baumgartner 2007). Besides, the ecological benefits arising from a more diverse ecosystem, natural insurance is less affected from moral hazard or asymmetric information. Moreover, financial instruments can affect negatively environmental quality (Horowitz and Lichtenberg, 1993). Addressing these issues seems particularly relevant in the context of the ongoing debate on adaptation to climate change in agriculture. The development and dissemination of financial tools (of different types) can be indeed one of the most important strategy to mitigate the impact of changing climate on farmers welfare.

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[1] In this environment, management options are somewhat restricted. Insurance and risk coping mechanisms often function poorly due to credit constraints, information asymmetries and commitment failures (Deaton, 1989; Fafchamps, 1992; Kurosaki and Fafchamps, 2002). Safety nets typically provide only limited support (Dercon and Krishnan, 2000; Dercon, 2004). And off-farm, non-covariant income is limited in remote rural areas. In this context, few options exist to implement income or activity diversification.

The increased frequency of extreme events (i.e. droughts) encapsulated by climate change may stress this issue further. Projected general weather changes for Mediterranean area are clear but their magnitude however is not. Warming is expected to increase both winter and summer seasons hence affecting production. Increased CO_2-concentrations may directly enhance crop productivity while increasing water use efficiency. In severe cases, however, a substantial impact on famers 'welfare (i.e. farm income) can be expected as a result of more adverse weather conditions. The extent of this will depend on factors including crops cultivated, soil type (including texture, drainage), potentials for irrigation and risk behavior. . Given the importance of weather conditions for crop yield, selection of a proper management and coping strategy for changing climate and weather conditions is essential. Recent extremes, such as the summer of 2003 (Schär et al., 2004) with estimated losses in the agricultural sector of around 12 billion US$ in Europe (Swiss RE, 2004), stresses the importance of climatic extremes.
This paper seeks to contribute to these different strands of literature, by providing empirical evidence of the determinants of the decision to insure and its implications on farmers' welfare under uncertainty. We test for the role of crop biodiversity on the probability of adopting an insurance scheme. We then analyze the role of insurance and diversification on farmers welfare under risk. To this end we estimate a stochastic production function a' la Antle (1983) where biodiversity and insurance are regressed against the three moments of the distribution of revenues. To take into account of the potential endogeneity of the variable insurance we estimate a treatment-effects model by using a full maximum likelihood estimator. The treatment-effects model considers the effect of an endogenously chosen insurance binary treatment on another endogenous continuous variable, conditional on two sets of independent variables. Data are drawn from a very rich panel data form Italy. We have access to 8500 farmers from 2004 to 2007 (more than 25000 observations). To our knowledge this is the first empirical analysis, in this strand of literature, that make use of such large set of information.

The structure of the paper is as follows. The next section provides the background to the study. Seciotn 3 provides the information regarding the data and the variables generation. Section 5 presents the results and section 6 offers some concluding remarks.

2. **Background**

Much of the attention that risk management instruments and policy have received in recent years both in the US and in Europe is possibly due to the introduction of two articles in the WTO´s agreement for the agricultural sector. This was signed in the Uruguay Round Agreement on Agriculture (URAA), specifically at the articles 7 and 8 of Annex II, which listed government financial participation in income insurance program or income safety net and payments for relief from natural disaster among the types of support exempted from the domestic support reduction commitments, thus effectively allowing their continuation. The eligibility criteria listed in the URAA are rather ample, in that compensations of up to 70% of the losses are admitted for income losses of at least 30% of the preceding three years' average, which caused most existing disaster assistance and financial participation to crop insurance programs to be promptly marginally redefined to comply with these norms. The Italian case is particularly interesting because, as in Spain, United States and Canada, Government is heavily involved in subsidizing crop insurance and in guarantee ex-post payments in case of disaster. In Italy, Government's involvement in agricultural risk management is based on the fully publicly financed *Fondo* di *Solidarietà Nazionale* (FSN), set up in 1974 with two main objectives: to compensate farmers suffering from damages due to natural disasters and to support the use of crop insurance.

The Italian system has been modified in recent years with more emphasis on crop insurance, in an attempt to reduce the cost of ex-post compensation in case of disasters. The main changes are the possibility for farmers to underwrite newly designed contracts for innovative multiple-peril[2] coverage directly with insurance companies, with subsidy to premiums up to 80%, and publicly supported reinsurance.

In this paper, we consider the problem on a national scale in order to get a representative overview of the situation. This approach is facilitated by the data of the Farm Accountancy Data Network (FADN-RICA). We provide more details on the following paragraphs.

3. Data

As we already pointed out in the introduction, the experimental scheme of this paper allows examining major concerns about the main determinants to insurance decision that lead farms to insure against crop risk. To answer these questions, we detail in the followings subsections our variables and the main assumptions of our model.

The study uses a survey of farmers in Italy belonging to the Farm Accountancy Data Network - RICA (FADN). Data are accounted for each year from a representative sample of farms, whose size can be considered as commercial. Within the original database, we only select farms that have continuously appertained to the sample from 2004 to 2007. Finally, our sample includes roughly 8,500 farms. In the following subsections, we detail the main explanatory variables that enter in the analysis. We choose to detail a wide range of potential factors including financial and meteorological variables, often missing in the literature. For the purpose of our analysis, we selected a variable indicating the eventual subscription of a private crop insurance policy. This can be found only for the years 2004 to 2007, which delimitates our temporal analysis. For the same period, the database also gives the amount of perceived indemnities from ex-post payments.

In the analysis, we take into account standard individual indicators for the farm manager such as its age, gender and education level. We can also consider whether a single farmer or a group of farmers exploits the farm. One can think that insured farmers are more educated and have a greater experience than non-insured one. Otherwise, young farmers may be more sensitive to new risk management products as they can receive more subsidies for their insurance policies.

Among the agricultural area indicators, we consider the total, cultivated and irrigated surfaces. We also take into account the farm’s cultures portfolio and its technical economic-activity specialization (vegetables, cattle, or both). In fact, the diversification of the activities is a way to stabilize the annual turnover of the farm[3]. Then, it can be assimilated to a substitute to specific insurance products. Irrigation is also perceived as a mean to hedge crop risk because it reduces soil moisture and desiccation, and increases yield return. On the contrary, biological agriculture seems to be a more risky activity.

The FADN database offers direct ways to determine the location and altitude of the farm and if it is located in a less favored area. Then, we can associate to each place different weather indicators that are considered as relevant by literature. We use the annual mean temperature and the annual cumulated precipitations. Starting from these original variables, we convert them by taking the square deviation from their average for each year. Then, we can capture the farmers' sensitivity to excessive variations of the climate. We can assume that farmers are risk-averse against excessive

[2] Until 2004, the only crop insurance contract sold in Italy has been the hail insurance.

[3] We considered as specialized farmers those which farms revenue could be attributed up to 65% from one crop.

variations and that the most exposed will subscribe crop policies. On the contrary, adverse selection effects may put them out-of-the-market as a consequence of catastrophic results for the insurance company. One can also consider that after a major event like drought or excessive rainfall, the farmers will be more willing to insure their crops. In contrast, the lack of catastrophic events may not be an incentive.

4.Empirical Strategy

The adoption of insurance can be framed within the standard theory of technology adoption. In this setting one can model a representative risk averse farm household as choosing to adopt an insurance scheme to maximize her expected utility from final wealth at the end of the production period, given the production function and her land, labor and other resource constraints. Assuming that the utility function is state independent, solving this problem would give an optimal mix of adaptation measures undertaken by the representative farm household which is given by equation 1.

$$A_{hi} = A(x^h_{hi}, x^l_{hi}, x^c_{hi}, x^B_{hi}; \beta) + \varepsilon_{hi} \qquad (1)$$

where A represents the is *h-th* insurance undertaken by the household h, and $x^h_{ht}, x^l_{ht}, x^c_{ht}$ are household characteristics, land and other farm characteristics, and climatic variables respectively. Of special interest in this paper is the role of x^B_{hi} - a count index for crop biodiversity. β, is the a vector of parameters, and ε_{hi} is household specific random error term. Households choose adaptation strategy 1 over adaptation strategy 2 if and only if expected utility from adaptation strategy 1 is greater than adaptation strategy 2, i.e. $E[U(A_1)] > E[U(A_2)]$.

A dummy variable is employed to measure if the farm households have adopted any insurance in response to exposure to bad weather. A probit regression is adopted to estimate determinants of adoption of insurance as specified by equation 1. Thus, the decision to buy insurance is measured by a dummy variable is entered into a standard household production function, y_{ht}, as specified in equation 2.One central focus of this study is to investigate if adoption of insurance have any impact on farmers welfare under risk. Let y represent output and x inputs under risk. The production technology is represented by the stochastic production function y = g(x, v), where v is a vector of random variables reflecting uncontrollable factors affecting output. To assess the probability distribution of g(x, v) we following Antle (1983) and use a moment-based approach. Consider the following econometric specification for g(**x**, v):

$$g(x^s_{hi}, x^c_{hi}, x^B_{hi}, A_{hi}, v) = f_1(x^s_{hi}, x^c_{hi}, x^B_{hi}, A_{hi}, \beta_1) + [f_2(x^s_{hi}, x^c_{hi}, x^B_{hi}, A_{hi}, \beta_2) - (f_3(x^s_{hi}, x^c_{hi}, x^B_{hi}, A_{hi}, \beta_3)/k)^{2/3}]^{1/2} e_2(v) + [f_3(x^s_{hi}, x^c_{hi}, x^B_{hi}, A_{hi}\, \beta_3)/k]^{1/3} e_3(v), \qquad (2)$$

where $f_2(x^s_{hi}, x^c_{hi}, x^B_{hi}, A_{hi}, \beta_2) > 0$, $(f_2)^3 \geq (f_3/k)^2$, and the random variables $e_2(v)$ and $e_3(v)$ are independently distributed and satisfy $E[e_2(v)] = E[e_3(v)] = 0$, $E[e_2(v)^2] = E[e_3(v)^2] = 1$, $E[e_2(v)^3] = 0$, and $E[e_3(v)^3] = k > 0$. This means that the random variables $e_2(v)$ and $e_3(v)$ are normalized with mean zero and variance 1. In addition, $e_2(v)$ has zero skewness ($E[e_2(v)^3] = 0$), but the random variable $e_3(v)$ is asymmetrically distributed and has positive skewness ($E[e_3(v)^3] = k > 0$). It follows from (4) that

$$E[g(x^s_{hi}, x^c_{hi}, x^B_{hi}, A_{hi}, v)] = f_1(x^s_{hi}, x^c_{hi}, x^B_{hi}, A_{hi}, \beta_1), \qquad (2a)$$

$$E[(g(x^s_{hi}, x^c_{hi}, x^B_{hi}, A_{hi}, v) - f_1(x^s_{hi}, x^c_{hi}, x^B_{hi}, A_{hi}, \gamma, \beta_1))^2] = f_2(x^s_{hi}, x^c_{hi}, x^B_{hi}, A_{hi}, \gamma, \beta_2), \qquad (2b)$$

$$E[(g(x^s_{hi}, x^c_{hi}, x^B_{hi}, A_{hi}, v) - f_1(x^s_{hi}, x^c_{hi}, x^B_{hi}, A_{hi}, \beta_1))^3] = f_3(x^s_{hi}, x^c_{hi}, x^B_{hi}, A_{hi}, \beta_3). \qquad (2c)$$

The specification (1) therefore provides a convenient representation of the first three central moments of the distribution of g($x_{hi}^{s}, x_{hi}^{c}, x_{hi}^{B}, A_{hi}$, v).[4] Lets collapse the terms $x_{hi}^{s}, x_{hi}^{c}, x_{hi}^{B}, A_{hi}$ in **x** Indeed, from (2a) the first moment (the mean) is given by $f_1(\mathbf{x}, \beta_1)$. From (2b) the second central moment (the variance) is given by $f_2(\mathbf{x}, \beta_2) > 0$ and from (2c) the third moment (measuring skewness) is given by $f_3(\mathbf{x}, \beta_3)$. In addition, if we treat the distribution of $e_2(v)$ and $e_3(v)$ as given, the three moments $f_1(\mathbf{x}, \beta_1)$, $f_2(\mathbf{x}, \beta_2)$ and $f_3(\mathbf{x}, \beta_3)$ are sufficient statistics for the distribution of $g(\mathbf{x}, v)$ in Equations 2a, 2b and 2c. In general, one expects mean output $f_1(\mathbf{x}, \beta_1)$ to exhibit positive and decreasing marginal productivity with respect to x: $\partial f_1/\partial x > 0$ and $\partial^2 f_1/\partial x^2$ being a negative definite matrix. However, the effects of inputs x (or insurance) on the variance and skewness of output are empirical issues. For example, from (2b) an input can be variance increasing, neutral or decreasing. Similarly, from (2c) the same input can increase or decrease downside risk exposure when $\partial f_3/\partial x > 0$ (< 0). Of special interest here are the effects of insurance and diversity on the variance and skewness of production.

Equation (2) can be interpreted as a standard regression model where the dependent variable is production $y = g(\mathbf{x}, v)$, $f_1(\mathbf{x}, \beta_1)$ is the regression line representing mean effects, and $\{[f_2(\mathbf{x}, \beta_2) - (f_3(\mathbf{x}, \beta_3)/k)^{2/3}]^{1/2} e_2(v) + [f_3(\mathbf{x}, \beta_3)/k]^{1/3} e_3(v)\}$ is an error term with mean zero, variance $f_2(\mathbf{x}, \beta_2)$ and skewness $f_3(\mathbf{x}, \beta_3)$. The error term exhibits possible heteroscedasticity (given by $f_2(\mathbf{x}, \beta_2)$) and skewness (given by $f_3(\mathbf{x}, \beta_3)$). Let (i, j) denote the i^{th} farm household in the j^{th} location.

The role of A_{hi} is inserted via the predictions from the system of equations (1). It is important to stress that crop diversification – captured by x_{hi}^{B} - can affect equation (2) both directly and indirectly. Directly via its contribution to productivity and risk exposure, indirectly via its potential role (as substitute or complement) on adopting insurance. To estimate the value of production model in equation (2), we employed a pseudo-fixed effect model. Use of a standard fixed effect model has an obvious advantage over random effect and other linear models (such as Tobit or truncated regressions). It produces consistent parameter estimates by controlling unobserved heterogeneity that might be correlated with observed explanatory variables. However, standard fixed effect models rely on data transformation that removes the individual effect. It can be important, instead to model the individual effect. This is particularly true in our case that the variable of interest (adaptation) is measured at household level. One way to address this issue is to run a random effect model but at the same time control for unobserved heterogeneity using Mundlak'a approach (Wooldridge 2002). This approach is some times referred in the literature as Pseudo-fixed effect model. The right hand-side of our pseudo-fixed effect regression equation includes the mean value of the time (plot)-varying explanatory variables following Mundlak's (1978) approach. This approach relies on the assumption that unobserved effects are linearly correlated with explanatory variables as specified by:

$$\psi_h = \bar{x}\alpha + \eta_h,\ \eta_h \sim \text{iid}(0, \sigma_\eta^2)$$

where $\bar{x}$ is the mean of the time varying explanatory variables within each household (cluster mean), α is the corresponding vector coefficient, and η is a random error unrelated to $\bar{x}'s$. The vector α will be equal to zero if the observed explanatory variables are uncorrelated with the random effects. The use of fixed effects techniques and Mundlak's approach also helped address the problem of selection and endogeneity bias, if the selection and endogeneity bias are due to time invariant unobserved factors, such as household heterogeneity (Wooldridge, 2002). If we failed to control for these factors, we would not obtain the true effect of adaptation. Thus, the use of the

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[4] Recently, the stochastic production function approach has been criticized by Chambers and Quiggin (2000) who suggested the adoption of the "state- contingent" approach to model production uncertainty.

pseudo-fixed effect model in this paper helps to address the potential endogeneity bias due to the inclusion of the adaptation variable in the right hand side of the food production model. Moreover the estimation of the parameters α allows us to test for the relevance of the fixed effects via an F test. The test is implemented on the estimated coefficient in the vector α are jointly equal to zero. We rejected the null hypothesis. It is, therefore, important to adopt a fixed effects specification. To further probe our results we consider the situation in which the variable insurance is endogenous by fitting a treatment-effects model. Thus we consider the effect of an endogenously chosen binary treatment conditional on two sets of independent variables (Wooldridge, 2001).

[TABLE 1 ABOUT HERE]

5. Results

Table 2 reports the econometric results. We provide alternative specifications. As point of reference we presents a probit model and a standard pseudo fixed effects model in column (1) and (2). Thus we are ignoring the endogenous nature of the variable insurance. Columns (3) and (4) are presenting the treatment model (using MLE) where the variable insurance is considered as endogenous. The robustness of the endogenous treatment model relies on the existence of instruments (or excluding conditions). Otherwise the parameters identification will happen only via the non linearity of the treatment equation. While this is theoretically possible is not advisable (Wooldridge, 2001). As "instruments" we used lagged value of the weather variables: minimum and maximum high temperature. These are variables that can affect the propensity to insure but do not affect this year revenues. We extend the number of variables in the treatment equation by including age of the farmer and if she or he belongs to an association of producers. Columns (4) and (5) report the results from the risk estimation. To capture the full extend of risk exposure we have both the variance and the skewness of yields. We begin commenting the results of the treatment equation. We find that farms with large inputs use are more likely to adopt the insurance scheme. Larger land endowment seems negatively correlated with the probability of insuring. This perhaps indicate that investing in land is also a strategy to hedge against bad environmental conditions. Lagged minimum and maximum temperature are both statistically significant. The estimated coefficient are both positive therefore experiencing increase in extreme temperatures increase the probability of adoption of the insurance. Lagged rainfall instead has a opposite effect. Of special interest is the coefficient estimated for the variable diversity. It is negative and significant. Farmers that rely more on the natural insurance tend to buy less financial insurance. To identify the implications of both natural and financial insurance we now turn to estimation of farmers welfare under uncertainty. This entails to estimate the contribution of both biodiversity and financial insurance on the three moments of the distribution of revenues. The estimated coefficients behave very similarly in all the three equations. Both diversity and financial insurance are positively correlated with the expected revenues. They are also positively correlated with the variance of the revenues. This means that both diversity and insurance can increase the variability of revenues. This does not imply that they are risk increasing strategies. The second moment of the distribution, infact, does not distinguish between an unexpected bad event and an unexpected good event (Di Falco and Chavas, 2009). To fully capture the extent of risk we analyze the role of the two variables on the skewness of the distribution. They are both statistically significant and positive. Therefore they both prevent that the revenues will fall below a given threshold level. All the factors of productions are positively correlated with farm revenues. Thus land, seeds and fertilizers seem to play a very important role in determining revenues. The variable "chemical" displays many zero values. Basically almost 30 per cent of the sample are using no chemical fertilizers. This large presence of zeros may bias the estimation. To include this important variable in the log –log , we follow Battese (1997), using [β0D + β 1ln(Chemical + D)], where D = 1 if Chemical = 0, and D = 0 if Chemical t > 0, and β 0 and β1 are the parameters.

[Table 2 – About here]

The impact of weather variables is very important. We have a consistent result on the variable insurance. We find that is positively correlated with the expected revenues. Therefore, the adoption of the insurance scheme increase farmers' welfare. It is interesting to note that crop diversification ha a positive impact on farmers' welfare as well. This is consistent with existing findings in the literature that highlight higher productivity and revenues of more diversified farms. The effect of lagged weather variables on the take up of insurance is also as expected.

6. **Concluding remarks:**

Improving farmers's ability to withstand extreme weather events, particularly those predicted as a result of climate change, is of paramount importance in modern agriculture. Farmers may manage the welfare implications of challenging weather conditions via both conservation strategies (i.e. maintaining crop biodiversity) aor financial insurance. In this paper we empirically address this potential trade off. We model the decision to adopt financial insurance as function of the existing crop diversification and a set of other drivers. This will inform our understanding of the viability of the insurance schemes via the investigation of the underlying factors that determine farmers decision to adopt an insurance scheme against extreme events. We then assess the implications in terms of welfare under uncertainty. We have used a very rich farm level panel data for Italians' farmers having the availability of information regarding more than 8000 farms followed for 4 years. In our analysis we mainly focused on the possible effects of weather variables on yields; aimed to this result, we specified an equation where farm revenues are regressed against weather variables. We included, in the estimation procedure, farm fixed effect and controlled for the potential endogeneity of the decision to adopt insurance to manage extreme events. The first result which from our empirical analysis is that the adoption of insurance is positively correlated with welfare (captured by farm revenues and reduces the implications of risk exposure. We find that maintaing crop biodiversity obtain the very same results. In this context, both natural and financial insurance seems to be a very important tool for risk management at the farm level.

The analysis of the determinants of the decision to insure revenue unearthed some interesting information. Farmers that have larger land endowments are less likely to adopt an insurance scheme, while, surprisingly, farms that have more crop diversification are more likely to adopt the insurance scheme. This may indicate that crop diversification may act as complement for financial insurance and not as substitute. The effect of climatic variables on the take up of insurance is as expected. There is evidence of a statistically significant quadratic terms for the extreme temperatures. This may stress the importance of reaching some threshold level in order to adopt the insurance scheme. Further research should be allocated to investigate the role of farmers risk aversion in determining these results.

References:

Baumgärtner, S. (2007). The insurance value of biodiversity in the provision of ecosystem services. *Natural Resource Modeling* 20(1), 87-127

Blank S.C. and McDonald J. (1996). Preferences for Crop Insurance When Farmers Are Diversified. *Agribusiness* 12(6): 583-592.

Battese, G.E. 1997. "A Note on the Estimation of Cobb–Douglas Production Functions

When Some Explanatory Variables Have Zero Values." *Journal of Agricultural Economics*

48:250–52

Cafiero C., Capitanio F., Cioffi A., Coppola A. (2007). Risk and Crises Management in the reformed European Agricultural Crises Policy, *Canadian Journal of Agricultural Economics* 55, 419-441.

Choi B.P. and Weiss M.A. (2005). An Empirical Investigation of Market Structure, Efficiency, and Performance in Property-Liability Insurance. *Journal of Risk and Insurance* 72 (4): 635-673.

Di Falco S., and C. Perrings (2005). Crop Biodiversity, Risk Management and the Implications of Agricultural Assistance. *Ecological Economics*, 55(4).

Di Falco S. and J.P. Chavas, On Crop Biodiversity, Risk Exposure and Food Security in the Highlands of Ethiopia. *American Journal of Agricultural Economics* 91(3)

Froot, K. A., 2001, The Market for Catastrophe Risk: A Clinical Examination, *Journal of Financial Economics*, 60: 529-571.

Garrido A. and Zilberman D. (2007). Revisiting the Demand of Agricultural Insurance: The Case of Spain. Contributed paper presented at the 101st Seminar of the European Association of Agricultural Economists. Berlin, Germany.

Glauber J.W. (2004). Crop Insurance Reconsidered. *American Journal of Agricultural Economics* 86 (5): 1179-1195.

Goodwin B.K. (1993). An Empirical Analysis of the Demand for Multiple Peril Crop Insurance. *American Journal of Agricultural Economics* 75: 425-34.

Grace M.F., Klein R.W. and Kleindorfer P.R. (2004). Homeowners Insurance With Bundled Catastrophe Coverage. *Journal of Risk and Insurance* 71 (3): 351-379.

Harrington S.E. and Niehaus G.R. (eds) (1999). Risk Management and Insurance, Irwin/McGraw-Hill, 674p.

Kelly M. and Kleffner A.E. (2003). Optimal Loss Mitigation and Contract Design. *Journal of Risk and Insurance* 70 (1): 53-72.

Knight, T.O. and Coble, K.H. (1997), ''Survey of US multiple crop insurance literature since 1980'', *Review of Agricultural Economics*, Vol. 19, pp. 128-56.

Lustig H.N. and Van Nieuwerburgh S.G. (2005). Housing Collateral, Consumption Insurance and Risk Premia: An Empirical Perspective. *Journal of Finance* LX (3): 1167-1219.

Mishra A.K. and Goodwin B.K. (2003). Adoption of Crop versus Revenue Insurance: A Farm-Level Analysis. *Agricultural Finance Review* Fall 2003, 143-155.

Niehaus G. (2002). The Allocation of Catastrophe Risk. *Journal of Banking and Finance* 26: 585-596.

Puelz R. (1999). Reviewed work: Risk Management and Insurance. *Journal of Finance* 54 (3): 1187-1189.

Quaas, M. F. and S. Baumgärtner (2008). Natural vs. Financial Insurance in the

Management of Public-good Ecosystems. *Ecological Economics* 65: 397–406

Schär C., Vidale P.L., Lüthi D., Frei C., Häberli C., Liniger M.A. and Appenzeller C. (2004), " The role of increasing temperature variability in European summer heatwaves", *Nature*, 427, 332-336.

Serra T., Goodwin B.G. and Featherstone A.M. (2003). Modeling Changes in the U.S. Demand for Crop Insurance During the 1990s. *Agricultural Finance Review* Fall 2003, 109-125.

Swiss Re (2004), "Climate change futures: Executive roundtable" (Swiss Re, Centre for Global Dialogue, Ruchlekon, *Switzerland*, 2004).

Van Asseldonk, M., Meuwissen M. and Huirne R. (2002). Belief in Disaster Relief and the Demand for a Public-Private Insurance Program. *Review of Agricultural Economics* 24(1): 196-207.

Wang H.H. and Zang H. (2003). On the Possibility of a Private Crop Insurance Market: A Spatial Statistics Approach. Journal of Risk and Insurance 70 (1): 111-124.

Wright, B. D. and Hewitt J. A. (1994), "All-Risk Crop Insurance: Lessons From Theory and Experience. In D. L. Hueth e W. H. Furtan (A cura di,), Economics of Agricultural Crop Insurance: Theory and Evidence, Chapter 4, pp. 73-112. Boston/Dordrecht/London: Kluwer Academic Publishers.

Zanjani, G. (2002). Pricing and Capital Allocation in Catastrophe Insurance, *Journal of Financial Economics*, 65, 283–305.

Table 1. Variables Descriptive Statistics

Variables	Mean			St.dev.		
	North	Middle	South	North	Middle	South
Chemical Fertilizers (Euro) in logs	3403,92	2316,49	1979,22	11333,77	6701,16	10423,08
Seeds (Euro) in logs	5364,76	4787,02	3786,52	42299,93	38880,40	25998,88
Land (hectares) in logs	35,25	37,95	32,34	95,69	73,08	56,73
Minimum Temperature (°C)	5,12	9,58	12,14	31,34	42,45	31,85
Maximum Temperature (°C)	17,54	19,35	21,40	63,54	73,15	62,13
Rain (mm/year)	784,32	721,89	705,23	234,56	341,68	367,15
Fertility (higher fertility degree)	*	*	*	*	*	*
Div (crop diversification degree)	*	*	*	*	*	*
Insurance (crop insurance premium paid Euro)	297,81	107,08	81,73	4400,17	1079,87	1214,37
Producers organization	*	*	*	*	*	*

Table 2. Estimation results

	lnplv	Variance	Skewness
	(1)	(2)	(3)
Biodiversity	0.234***	0.268***	0.192**
	(0.0199)	(0.0302)	(0.0902)
Insurance	1.520***	2.097***	5.512***
	(0.0357)	(0.0462)	(0.156)
Fertilizer	0.176***	-0.104***	-0.194***
	(0.00814)	(0.0123)	(0.0369)
Dummy for fertilizer	1.398***	-0.474***	-1.034***
	(0.0517)	(0.0782)	(0.234)
Land	0.462***	-0.0186	0.222***
	(0.00851)	(0.0129)	(0.0385)
Seeds	0.0120***	0.00326	-0.0408**
	(0.00377)	(0.00573)	(0.0171)
Min Temperature	0.0490***	0.0265***	0.0211
	(0.00615)	(0.00928)	(0.0280)
Max Temperature	-0.0950***	-0.0422***	-0.0232
	(0.00633)	(0.00955)	(0.0288)
Rainfall	0.0000118	0.000168*	-0.000486*
	(0.0000637)	(0.0000958)	(0.000295)
Treatement equation- dependent variable Insurance			
Biodiversity	-0.103**	0.0187	0.0988*
	(0.0516)	(0.0459)	(0.0537)
Fertilizer	0.417***	0.300***	0.352***
	(0.0278)	(0.0225)	(0.0280)
Dummy for fertilizer	2.333***	1.607***	1.038***
	(0.232)	(0.178)	(0.284)
Land	-0.275***	-0.146***	-0.130***
	(0.0199)	(0.0175)	(0.0196)

Seeds	0.297***	0.0948***	0.215***
	(0.0189)	(0.0133)	(0.0189)
Age	-0.0750	0.0997**	0.0211
	(0.0522)	(0.0500)	(0.0560)
Producers association	-0.152***	0.00571	0.00677
	(0.0330)	(0.0305)	(0.0353)
Lag min temperature	-0.0555***	-0.0335**	-0.0544***
	(0.0158)	(0.0152)	(0.0172)
Lag max temperature	0.101***	0.0552***	0.0878***
	(0.0164)	(0.0159)	(0.0179)
N	17005	17005	17005