Time variant risk preferences in agriculture: evidences from Italy

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Abstract

This paper investigates the stability over time of farmers' risk preferences. We rely on a panel data of over 36,000 Italian farms specialized in cereals and open field crops, during the period 1989 to 2009. We use Antle's method of moments to estimate farmers' risk preferences for different periods. We find evidences of risk preference changes over time in response to major droughts and changes in the EU Common Agricultural Policy.

Keywords: time varying risk attitude, method of moments, production uncertainty.

1. Introduction

Farmers' risk preferences are crucial for predicting farmers' production and investment decisions (Moscardi and de Janvry, 1977; Leathers and Quiggin, 1991; Hennessy, 1998; Moschini and Hennessy, 2001; Groom et al., 2008; Trujillo-Barrerra et al., 2016). Risk and risk aversion are also essential to explain differences in input use and relative adoption of modern technologies by different farmers-type (Feder, 1980). A contentious issue is the assumption made in the literature that farmers' risk preferences are stable over time (e.g. Louhichi et al., 2010; Lehmann et al., 2013). There is, in fact, a growing body of literature evidence for time-variance of risk preferences.[1] Risk aversion can be an unobservable parameter, and the question whether this and other structural parameters are stable through time become popular in macroeconomic modeling since the publication of the classic Lucas critique (Lucas, 1976).[2] Studies conducted after the onset of the financial crisis that started in 2008, address the possibility that a (negative) shock can trigger large increases in agents' risk aversion over a relatively short period of time (Guiso et al., 2013; Malmendier and Nagel, 2011). Some authors conclude that stress modulates risk taking, potentially exacerbating behavioural bias in subsequent decision-making (Porcelli and Delgado, 2009). Other papers look at temporal stability of risk preferences in relation to wealth fluctuation in developed countries setting (Brunnermeier and Nigel, 2008; Andersen et al., 2008; Sahm, 2008; Vlaev et al., 2009). In agricultural literature, little - and so far ambiguous - evidence has been provided. An early contribution to this field is the paper by Love and Robison (1984). The authors examined the intertemporal stability of risk preferences eliciting them from a small sample of 23 American farmers in 1979 and then again in 1981 and concluded that preferences were not stable over time. Nielsen and Zeller (2013) examine whether various types of shocks increase risk aversion among smallholder farmers living

1 Time-varying risk aversion is well accepted in the macroeconomics literature under the habit formation (or habit persistence) preference specification, see, for example: Sundaresan (1989), Constantinides (1990) and Campbell and Cochrane (1999).

2 Notably, Lucas (1976) argued that the parameters of traditional macro-econometric models depended implicitly on agents' expectations of the policy process and were unlikely to remain stable as policymakers changed their behaviour.

in northwestern Vietnam by using seven different elicitation methods. Their findings on how droughts affect risk preference are ambiguous as one risk preference elicitation method indicates an increase in risk aversion while the six others do not indicate an effect. Koundouri et al. (2009) find evidences of changes in Finnish farmers' degree of risk aversion over time, measuring risk attitudes before and after Finland accession to the European Union. The consequent implementation of the EU Common Agricultural Policy in Finland marked the switch from agricultural prices support to area payments, which reduced the random part of and altered the level of farm income. The authors find that agricultural policy changes reduced risk aversion of Finish farmers. And this had spill-over effects on production and land allocation decisions (Koundouri et al., 2009: 55).

Previous studies have also found that climatic extreme events can alter farmers' technology adoption decisions. For instance, the experience of droughts have been found to significantly increase the adoption of irrigation and no-till farmland (Carey and Zilberman, 2002; Ding et al., 2009; Nauges et al., 2016). Ding et al. (2009) hypothesize that farmers' experience during past droughts would change their expectations of future weather risk and water availability, and this affect their investment decision in conservative tillage. Another line of research shows that changes in behavior under risk might be caused by changes in risk perception (e.g., Menapace et al. (2013)). Using a combination of survey experiments and natural variation in rainfall shocks, Lichand and Mani (2016) document that higher worries about future rainfall by farmers that experienced a drought decrease their cognitive function and increase their susceptibility to a variety of behavioral biases.

This paper approaches the debate on risk preference stability as an empirical question, relying on a much larger dataset than those used in previous studies that estimated risk preferences. Our fundamental enquiry concerns whether the assumption of risk preferences stability over time holds in the context of major changes in the environment where farmers operate. More specifically, we focus on large changes in policy regimes, and on major production or market shocks. We expand the existing literature by investigating changes in farmers' risk attitude in response to multiple shocks coming from policy changes and extreme climate events. In order to identify farmers risk aversion and changes therein, we use the *method of moments* approach (Antle 1983, 1987).

We use of a large dataset on Italian agriculture that comprises farm level data for more than 36,000 farms specialized in cereals and other open field crops production, and refers to the period 1989 to 2009.[3] We focus on specific events that took place over this long period: the CAP policy reforms that started in 1992, which introduces main policy changes in European agriculture, and the shocks associated to two large scale drought events (i.e. in 2003 and 2007).

The paper is structured as follows: in Section 2 we describe the method of moment estimation approach. Section 3 provides background information about the events we look at and how they influence the Italian farming sector. We describe the data in Section 4. We present our results in Section 5. We conclude and suggest possible extensions to this work in Section 6.

2. Conceptual and Empirical Model

We use a flexible estimation approach where uncertainty is considered by using moments of the profit distribution as determining farmers' decisions regarding the input mix. This flexible approach has been developed by Antle (1983, 1987), Antle and Goodger (1984) and Kumbhakar (2002) and has been widely used to estimate risk preferences and changes therein (Koundouri et al., (2006); Groom et al., (2008); Di Falco et al., (2014)). This model is ideally suited to analyse responses to interventions in uncertain environments (Groom et al., 2008: 316) and is particularly appropriate to be applied when agents produce multiple crops and are exposed to various type of risks, such as production, market and policy risks (Gardebroek, 2006).

Farmers are expected to maximize expected utility that can be depicted as a function of moments of the profit distribution by estimating the distribution of the error term. Those moments have themselves X as an argument, so that the farmer's program becomes:

$$\max_{X} E[U(\pi)] = F[\mu_1(X), \mu_2(X), \dots, \mu_m(X)] \qquad (1)$$

Where μ_j=E(Π- E(Π))^j i.e., μ_j=E(Π- μ_1)^j and j=2,...,m is the m^{th} moment of profit. These are obtained following the sequential procedure described in Kim and Chavas (2003).

[3] The relative importance of different farm's outputs is measured by FADN as a proportion of each enterprise's standard output to the farms' total standard output. For the rest of the paper, we will refer to this group of farmers as "cereals producers".

In order to obtain the m^{th} moment of profit first, we estimate the conditional expectation of profit using a quadratic functional form[4] (mean effect regression):

$$\pi_{it} = f(\boldsymbol{x}_{it}, \boldsymbol{z}_t; \beta) + \alpha_i + \gamma_{it} \quad where \quad \alpha_i + \gamma_{it} = u_{it} \tag{2}$$

We regress total observed profit from production (π_{it}) on all levels, squares and interaction of input expenditure/annual units, captured by the vector x_{it} (irrigation water, fertilizers and labour).[5] Vector x_{it} also includes the area of the utilized agricultural land. These explanatory variables are under the control of the farmer. The rest (e.g. commodity prices, weather conditions) are not directly under the farmer's control and contribute to profit variability (Zuo et al., 2014). The subscripts i=1,...,N and t=1,...,T denote respectively individual farm-units and the time periods. The vector z includes year dummies. By including them, we remove any general time trend affecting all farmers identically.

The error term associated to equation (2) is u_{it} = α_i + γ_{it}. The terms α_i are random-individual specific effects that allow us to control for unobserved farm-specific effects and γ_{it} is the idiosyncratic error term.

The panel structure of the dataset allows to estimate equation (2) using a fixed effect estimator. This provides consistent parameters even if there is correlation between the independent variables and time invariant unobserved heterogeneity.

The residuals γ_{it} of this first estimation are used to compute conditional higher moments (variance and skeweness) using the sequential estimation procedure. We assume that the farmers are concerned only with the first three moments of the distribution of profit.[6]

The second and the third moments of the distribution of profit are then regressed, using the fixed-effects estimator, on the same explanatory variables included in the estimation of the mean effect, consistently with previous empirical work (Groom et al., 2008; Koundouri et al., 2006).

$$\hat{u}_{it}^2 = w(\boldsymbol{x}_{it}, \boldsymbol{z}_t; \delta) + \check{u}_{it} \tag{3}$$

$$\hat{u}_{it}^3 = s(\boldsymbol{x}_{it}, \boldsymbol{z}_t; \phi) + \tilde{u}_{it} \tag{4}$$

[4] The choice of the linear quadratic form is following earlier studies (e.g. Kumbhakar and Tveteras, (2003); Koundouri et al., (2006); Groom et al., (2008)).

[5] All variables are scaled by their standard deviation, as in Groom et al., (2008) and Vollenweider et al., (2011).

[6] We opted against consideration of higher moments as Antle (1983) and Groom et al. (2008) found that estimation coefficients for the kurtosis were not significant. Along these lines, Koundouri et al. (2006) recognize that most distribution functions are well approximated by their first three moments.

We use the estimated coefficients from Equations (2), (3) and (4) (i.e. the vectors $\widehat{\beta}, \widehat{\delta}, \widehat{\phi}$) to compute nine analytical expression for derivatives of the each moment with respect to each input.

Finally, we estimate the System (5) of K equations (Antle 1983, 1987). Each equation is itself derived from the first order condition for the k^{th} input, thus system (5) has three equations, as the number of variable inputs included as explanatory variables, and nine unknowns, determined by the number of variable inputs and the number moments considered.

$$\frac{\partial \mu_1(\boldsymbol{x})}{\partial x_k} = \theta_{1k} + \theta_{2k}\frac{\partial \mu_2(\boldsymbol{x})}{\partial x_k} + \theta_{3k}\frac{\partial \mu_3(\boldsymbol{x})}{\partial x_k} + u_k \tag{5}$$

where θ_{jk} = -1/j!*$\partial F(\boldsymbol{x})/\partial \mu_j(\boldsymbol{x})\ /\partial F(\boldsymbol{x})/\partial \mu_1(\boldsymbol{x})$; (j=1,2,3) and u_k is the econometric error term.

This system of equations comes from the fact that the first order conditions of the farmer's program can be approximated using a Taylor expansion in matrix form. We estimate for each input k its marginal contribution to the expected profit (given by $\partial \mu_1(\boldsymbol{x})/\partial \boldsymbol{x}_k$). This is written as a linear combination of the marginal contributions of each input to the variance ($\partial \mu_2(\boldsymbol{x})/\partial \boldsymbol{x}_k$) and the skewness ($\partial \mu_3(\boldsymbol{x})/\partial \boldsymbol{x}_k$) (Antle, 1983 and 1987; Antle and Goodger, 1984).

The most important feature of this model is that the estimated parameters θ_{2k} and θ_{3k} are directly interpretable as the Arrow-Pratt (AP) and down-side (DS) risk aversion coefficients, respectively (Antle, 1987, Groom at al., 2008).

Notably, the AP absolute risk aversion coefficient is approximated by:

$$AP = -\frac{E(\partial^2 U/\partial \pi)}{E(\partial U/\partial \pi)} \cong -\frac{\partial F(\boldsymbol{x})/\partial \mu_2(\boldsymbol{x})}{\partial F(\boldsymbol{x})/\partial \mu_1(\boldsymbol{x})} = \boldsymbol{2\theta_2} \tag{6}$$

while the DS risk coefficient is approximated by:

$$DS = \frac{E\,\partial^2 U/\partial \pi}{E(\partial U/\partial \pi)} \cong \frac{\partial F(\boldsymbol{x})/\partial \mu_3(\boldsymbol{x})}{\partial F(\boldsymbol{x})/\partial \mu_1(\boldsymbol{x})} = \boldsymbol{-6\theta_3} \tag{7}$$

The population average AP and DS risk aversion measures (calculated as indicated in equation (6) and equation (7) respectively) are obtained estimating system (5). The error terms across the three equations that are estimated according to equation (5), representing the inputs labour, fertilizer and water, are correlated with each other. In order to exploit these inter-equations correlation of errors and gain efficiency, we use a seemingly unrelated regression (SUR) procedure.[7] Finally, we bootstrap the standard errors, resampling them over individuals to obtain heteroscedasticity-robust standard errors for the SUR estimator (Cameron and Trivedi, 2010).

The risk parameters are constrained such that $\hat{\theta}_{2k} = \hat{\theta}_2$ *and* $\hat{\theta}_{3k} = \hat{\theta}_3$. Although each input can affect the moments of profit in different ways, the AP and DS coefficients are related to the preferences over the moment of profit and thus not assumed to be input specific.[8]

A positive and significant AP coefficient indicates that the decision maker is risk averse. This implies that an agent with a positive and significant AP coefficient has the incentive to reduce its risk exposure. Any increase in the variance of profit would in fact increase the private cost of risk bearing.

A positive and significant DS coefficient indicates that the decision maker is averse to downside risk, that is, he is averse to risk distribution towards low outcomes (such as crop failure), holding both the mean and the variance constant (Menezes et al., 1980; Antle, 1983; Di Falco and Chavas, 2009). This implies that an agent with a positive and significant DS coefficient is prone to implement management strategies that affect positively the skewness of the distribution of profits (e.g., by reducing the probability of crop failure). These considerations are related to our understanding of farmer's behaviour in a risky environment. Risk averse farmers would be more willing to adopt strategies to reduce the variance of profit and/or exposure to downside risk. The AP and DS coefficients can be used to compute the risk premium (RP), which can be used to evaluate the cost of overall risk bearing capturing both the variance and the skewness on the cost of risk. Under risk aversion the risk premium depends on all relevant moments of the profit distribution (Di Falco and Chavas, 2009).[9]

The empirical procedure outlined in this section is implemented to estimate system of equation (5) for each year and for pooled data of relevant sub-periods. Table 1 outlines the periods considered in our estimates, and summarizes the rationales for selecting each sub-periods.

[7] We computed the correlation matrix for the fitted residuals, and use it to compute the test of independence of the errors in the three equations. The Breusch-Pagan Lagrange multiplier test for error independence indicates a statistically significant correlation between the errors in the three equations. Notably, the marginal contribution of fertilizers, labor, and irrigation water to the expected profit may have similar underlying determinants.

[8] In contrast, Antle (1987) and Koundouri et al. (2006) do not impose this restriction but do not provide any reason why farmers' preferences over moments of profit should not remain the same across inputs.

[9] Thus, assuming that the farmers are concerned only by the first three moments of the distribution of profit we can write the RP as follows: $RP = \mu_2 \frac{AP}{2} - \mu_3 \frac{DS}{6}$ where μ_2 and μ_3 are respectively the second- and third- order moments of the distribution of profit.

Table 1: Selection of sub-periods for empirical analysis

Relevant Events and time period	Relevant information and hypothesis regarding risk preferences
[1] 1989-1992 Pre-cap reform period	Farmers are expected to be risk averse or risk neutral (Koundouri et al., 2009 and 2006, Groom et al., 2008).
[2] 1993-1999 Mac Sharry Reform	The process towards a (partially) decoupled support to farmers started in 1992 with the so-called Mac Sharry reform. This 7 years reform period can be broadly divided into 2 phases: a transition phase (1993-1995), and the implementation phase (1996 – 1999)
[2a] 1993-1995 • Mac Sharry - transition phase • The Uruguay Round Agreement in Agriculture entered into force • In 1993 negotiations for accession of Austria, Finland and Sweden to the EU began. They entered the EU in 1995.	Ambiguous impact on grain farmers' risk attitudes (Koundouri et al., 2009): • Risk aversion may decrease because of the reduction in the random component of farmers' income (Koundouri et al., 2009). • Farmers' risk aversion may increase due to policy uncertainties (REAS, 2010; Moschini and Hennessy, 2001).
[2b] 1996-1999 Mac Sharry - implementation phase	The uncertainty stemming from the new CAP reform and the other policy changes that happened at the beginning of the 90s decreased.
[3] 2000-2002 Agenda 2000 CAP reform, up to the 2003 climatic shock	This CAP reform did not change the basic structure of the new regime, but further reduced the intervention prices and increased the cereal area payments (Platoni et al., 2012). Hence, the two effects described in row 2a may still apply, but we expect the risk attitude enhancing drivers to be less severe. We focus on the production decisions taken up to 2002 to reduce the risk of confusing policy-driven changes in risk attitude with changes triggered by the 2003 drought (a major exogenous climatic shock).
[4] 2004-2009 Post 2003 climatic shock	A (negative) shock can trigger large increases in agents' risk aversion over a relatively short period of time (Guiso et al., 2013). In Agriculture, other authors show how experiencing extreme events may lead to sudden changes in farmers' behaviour and investment and productive decision therein (e.g. Carey and Zilberman, 2002; Ding et al., 2009; Lichand and Mani, 2015; Nauges et al., 2016). From 2005 to 2009 the CAP went through a new phase, called the Fischler reform.
[5] 2008-2009 Post 2007 climatic shock	Repeated shocks over a short period of time may exacerbate the effects described in row 4

Once we obtain the AP and DS coefficients we implement the Wald test statistic for equality of these parameters across the relevant time periods. The null hypothesis is that preferences parameters across time periods are stable. The next section provides more background information regarding the events described in Table 1.

3. Policy and historical background

3.1. The 1990s' reforms of the EU Common Agricultural Policy

The 1992 and 1999 reforms of the European Union (EU) Common Agricultural Policy (CAP) (i.e. the agricultural policy of the EU) are a major shift in the way the EU provides income support to farmers (Sckokai and Moro, 2006).

Coldiretti (2015), the largest association of Italian farmers, identifies three main CAP reforms during the period 1989-2009. The Mac Sharry Reform and the Agenda 2000 are discussed and implemented before the 2003 climatic shock, while the Fischler reform is implemented in the years 2005 to 2009. For this reason, we exclude the Fischler reform from our analysis of the impact of Policy changes on farmers' risk preferences.

The process towards a (partially) decoupled support to farmers started in 1992 with the so-called Mac Sharry reform. The 1992 reform constituted a major shift from product support (through prices) to producer support (through income support), and marked the beginning of a series of CAP reforms. These changes aimed at improving the competitiveness of EU agriculture, developing a more liberalized agricultural market and stabilizing EU budget expenditure. The Mac Sharry Reform transitional period came to an end in July 1995 and main implementation phase lasted until 1998.[10] In 1999 a new reform was introduced ("Agenda 2000"). This second CAP reform did not change the basic structure of the new regime, but further reduced the intervention prices and increased the cereal area payments (Platoni et al., 2012). Following the 1992 reform, the level of support for cereal producers reduced by about 30%, with guaranteed prices of cereals lowered by 35%. Compulsory set-aside measure and other accompanying measures were also introduced, together with two components to farm income: an *area payment* component and a

10 In November 1993 the EC presented an Agricultural Strategy Paper in which it examined three different options for reforming further the CAP. These ranged from maintaining the status quo to proposing a new radical reform, drastically reducing EU prices to world market levels and abolishing production quotas and other supply management measures. For more information, see EC (1995).

market component. The first depends on the land allocation decision while the second is the one that might generate more uncertainty, which can come from both market prices and yields. Some authors argue that the increase in the cereal area payment substantially increased the non-random income, which in turn made risky behaviour becoming preferable (Koundouri et al., 2009). Other authors, on the contrary, stress that the area payment component contributed to increase uncertainty in the sector because farmers felt uncertainty about the stability of political support for direct payments, which was a major cause of farmers' resistance to lower prices (Bernstein et al., 1999). Moreover, the introduction of the Single Payment Scheme providing farmers with a fixed amount was only done since 2007.

During the implementation period of the Mac Sharry reform, the European agricultural sector went through other major policy changes: the Uruguay Round Agreement in Agriculture (GATT) entered into force and the EU enlarged with three new members: Austria, Finland and Sweden. Subsequently, the European Commission started examining different options for the future development of the CAP.

Farms specialized in open field crops and cereals were particularly affected by the CAP reforms of the 1990s (see also Sckokai and Moro, 2006 and Platoni et al., 2012). We focus on this group of farmers for analysing the impact of the CAP changes in farmers risk attitude.

3.2. The 2003 and 2007 droughts in Italy

In the summer of 2003, Italy and many other areas of Europe faced the most severe drought event and heat wave in decades and the hottest summer in Europe since the 16th century (WMO, 2003). These severe climatic conditions began in Europe in June 2003 and continued until mid-August, with summer temperatures 20 to 30% higher than the seasonal average in Celsius degree. The agricultural sector was among the most severely hit by the persistent droughts (Fink et al., 2004; Ciais et al. 2005, García-Herrera et al., 2010).

A second severe drought hit the Italian agricultural sector in 2007. This second drought was particularly severe in the north of the Italian peninsula: it started by the end of 2006 and in January 2007 precipitations in the Po river Basin were widely under the seasonal average (20% - 40%). The poor weather conditions extended through the year, with a spring and summer drier and hotter than seasonal long term averages in many parts of Italy (ISPRA, 2008).

In both droughts instances, Italian farmers received compensation for the loss incurred, although with a time lag. In Italy, exceptional negative events officially recognised by the central government entitle farmers to receive a compensation (ex-post disaster compensation) by the National Solidarity Fund (i.e. Fondo di Solidarietà Nazionale (FSN)).[11] This is one of the two tools used by the Italian government to deal with risk and crisis in agriculture through the FSN. The second tool is subsidies on insurance policies. The two interventions are mutually exclusive in that crops and damages that are deemed insurable are not entitled to ex-post disaster compensation financed by the FSN (Santeramo et al., 2016). In Italy, the government have been rather generous in declaring the status of agricultural natural disaster (Cafiero et al., 2007). The availability of subsidized loss compensation such as ad hoc disaster aid payments or subsidized crop insurance might mitigate the impact that experiencing severe losses have on changes in risk preferences. Previous studies suggest that whether shocks are insured or not impact ex-ante risk management strategies, and in particular risk avoidance, that is, engaging activities and input uses that lower risk, even at the cost of lower expected returns (Rosenzweig and Binswanger, 1993; Carter et al., 2014).

4. Data

Our dataset comprises farm level data from the Italian Farm Accountancy Data Network (FADN) and includes more than 36,600 farms specialized in cereals and various field crops covering the 21 years period, from 1989 to 2009. Farms are located across the Italian territory. Data are unbalanced and on average each farm is included in the dataset for 3.2 years. The dataset provides detailed information about the main production orientation,[12] input expenditure by crop for key inputs such as fertilizers, labour and irrigation water, income and some other input information (such as average work units) and structural characteristics of the farms (such as altitude). Table 2 provides the definitions and the descriptive statistics for each variable.

11 The FSN was instituted in 1974. The system has been reformed over time and currently conforms to the European Community guidelines for state aid in the agricultural sector concerning compensation for damages and insurance premium subsidies (Santeramo et al., 2016). Currently, public intervention in agricultural risk management and operational aspects of the FSN are also regulated by Legislative Decree No. 102/2004.

12 We follow the FADN classification 2003/369/EC (Commission Decision establishing a Community typology for agricultural holdings): the group *Cereals Producers* includes specialist cereals, oilseed and protein crops (COP) other than rice; the group *Various Field Crops* includes specialist tobacco, specialist cotton and various field crops combined.

Table 2. Descriptive Statistics and Variables Definitions

Variables	Mean	Std. Dev.	Min	Max
Net profit / loss Farm net Income (`000 €)	22.6	91.7	-3,207	16,023
Fertilizers Total chemical fertilizer and soil improvers expenditure (€)	3,300	9,335	0	1,172,010
Water Water expenditure for all farm purposes, including irrigation (€)	370	2,155	0	138,086
Labour Total labour input expressed in annual work units (AWU) = full time person equivalents	1.61	1.91	0.02	140.16
Land Total utilized agricultural area (UAA) (hectares)	28.6	64.5	0.1	4,290

Total farms: 36,692, including: specialist cereals, general field cropping and mixed cropping.

5. Results

The AP and DS risk aversion parameters obtained estimating the System of Equations 5 for the whole period under analysis, 1989-2009, are positive, equal to 0.2538 and 0.0064 respectively, and statistically significant (Table 3). We also report in the Appendices the year-by-year risk aversion coefficients, obtained estimating System (5) through seemingly unrelated regression models for each cross-section (year).

Table 3. Estimated Risk Aversion: entire period

		years	AP		DS	
[1]	**Entire Period** farms: 116,647	1989-2009	0.2538***	[0.0265]	0.0064***	[0.0002]
[2]	**Pre-2003 shock** farms: 8,920	1989-2002	-0.0450	[0.0189]	0.0018**	[0.0001]
[3]	**Post-2003 shock** farms: 4,048	2004-2009	0.3554***	[0.0294]	0.0082***	[0.0002]

Notes: Estimation Method: SUR. Bootstrapped standard errors of the underlying estimated coefficients ($\hat{\theta}_2$ and $\hat{\theta}_3$) in brackets. Bootstrap replications: 1000. *** indicate that the Null Hypothesis of coefficients of risk aversion being zero can be rejected at the 1% level.

These results suggests that on average Italian cereals producers have been averse to risk (profit variance) and DS risk (profit skewness).[13]

We report in Table 4 the AP and DS risk aversion parameters for the periods outlined in Table 1. Our main research interest pertains to the time stability of risk preferences. Previous work indicated that the impact of the changes in agricultural support on grain farmers' risk attitudes, brought about by the application of the CAP, is ambiguous a priori (Koundouri et al., 2009: 57). For this reason, we complement the estimation showing the Wald test statistic for equality between the AP and the DS parameters across different time periods.

We analyse in more detail if and how the parameters of risk aversion have changed through time, particularly in conjunction with major policy changes (Section 5.1) and major climatic shocks (section 5.2).

13 The results are robust if we exclude from the estimation the two years hit by a major climatic shock (2003 and 2007). In this case, the estimated AP and DS coefficients are 0.2467 and 0.0063 respectively, and we still strongly reject the null hypothesis of these coefficients being zero.

Table 4. Estimated Risk Aversion and Wald test statistic for equality of coefficients across periods

Estimated Coefficients	Wald test statistic for equality across periods H0: $\hat{\theta}_2^{(t1)} = \hat{\theta}_2^{(t2)}$	 H0: $\hat{\theta}_3^{(t1)} = \hat{\theta}_3^{(t2)}$
[1] **Pre-CAP reform** (1989-1992) AP: 0.0256 [0.0138] DS: 0.0032*** [0.0001]		
	$\chi^2(1) = 11.88$ Prob > chi2 = 0.0006	$\chi^2(1) = 11.19$ Prob > chi2 = 0.0008
[2] **Mac Sharry Reform** (1993-1999) AP: -0.0590 [0.0182] DS: 0.0020*** [0.0001]		
[2a] **Transition phase** (1993-1995) AP: 0.1116** [0.0283] DS: 0.0055*** [0.0002]		
	$\chi^2(1) = 20.47$ Prob > chi2 = 0.0000	$\chi^2(1) = 26.66$ Prob > chi2 = 0.0000
[2b] **Implementation phase** (1996-1999) AP: -0.1234*** [0.0183] DS: 0.0003 [0.0001]		
	$\chi^2(1) = 0.13$ Prob > chi2 = 0.7141	$\chi^2(1) = 0.00$ Prob > chi2 = 0.9664
[3] **Agenda 2000 pre-shock** (2000-2002) AP: -0.0821 [0.0371] DS: 0.0006 [0.0003]		
[4] **post 2003 shock** (2004-2009) AP: 0.3554*** [0.0294] DS: 0.0082*** [0.0002]	$\chi^2(1) = 21.90$ Prob > chi2 = 0.0000	$\chi^2(1) = 15.85$ Prob > chi2 = 0.0000
[5] **post 2007 shock** (2008-2009) AP: 0.4768*** [0.0427] DS: 0.0102*** [0.0003]	$\chi^2(1) = 28.52$ Prob > chi2 = 0.0000	$\chi^2(1) = 17.33$ Prob > chi2 = 0.0000

Notes: Bootstrapped standard errors of the underlying estimated coefficients ($\hat{\theta}_2$ *and* $\hat{\theta}_3$) in parenthesis. Bootstrap replications: 1000. ***, ** and * denote significance at 1%, 5% and 10% respectively. The suffix t1 and t2 indicate the periods compared in the Wald Test statistics as shown in each row. Dotted brackets indicate that we reject the null hypothesis of stable risk preferences for both AP and DS coefficients at 1% level.

5.1. Policy driven changes in risk attitude

First, we analyse if and how the CAP reforms triggered a change in risk attitude of cereals farmers. We focus on the Mac Sharry Reform and the Agenda 2000 Reform. We report in Table 4, rows 1-3 the AP and DS risk aversion parameters for the periods encompassing the pre-CAP reform period, as well as for the Mac Sharry Reform and Agenda 2000 implementation period up to the 2003 climatic shock, as outlined in Table 1. We also conducted sensitivity analysis by excluding from the estimation of system of equations (5) the final year preceding the implementation phase of a new reform.[14]

We find cereals producers to be risk neural in the pre-CAP period and if we look at the aggregate results for the Mac Sharry Reform (1993-1999). However, the positive and statistically significant AP coefficient associated to the Mac Sharry reform transition phase (1993-1995) indicates that farmers display a risk averse behaviour in this sub-period. As the CAP reform phases in, willingness to take risk increases, with risky behaviours becoming preferable in the second phase of the Mac Sharry reform (i.e. in 1996-1998/99).

Preferences over downside risk (profit skewness) are positive, although the estimated coefficients are very small, and statistically significant in the pre-cap period and in the first three years of the Mac Sharry Reform, and become zero afterward, which indicated a decreasing trend in DS risk aversion behaviour. Cereals producers' preferences over DS risk are thus close to risk neutrality through the whole period, which is coherent with the fact that Italian farmers participation rates to insurances programmes is exceptionally low (Mahul and Stutley, 2010; Santeramo et al., 2016). This result is easily expected in the pre MacSharry Reform' context, where the CAP achieved income stabilization indirectly, through price support mechanisms. This is also in line with the findings of studies estimating farmers' risk preferences using data from other European countries (Groom et al., 2008; Gardebroek, 2006).

The Wald test for the stability of the AP the DS parameters between the pre-CAP reform period and the Mac Sharry reform period strongly reject the hypothesis of stable risk preferences through the decade 1989-1999. We also strongly reject the Null Hypothesis of equality of estimated AP and DS risk parameters between the first triennium of the Mac Sharry period (1993-1995, which

14 The results presented in Table 4 are robust if we exclude 1992 from the pre-CAP reform estimation period and 1999 in the Mac Sharry Reform estimation period. These results for these trienniums are presented in the Appendices.

roughly corresponds to the formal *transitional phase* of the reform) compared to the *implementation phase* of this reform (1996 - 1999). We can conclude that after a temporary increase in risk aversion, possibly due to the uncertainties brought by the introduction of the CAP reform,[15] during the phase in of the Mac Sharry reform farmers gradually increase their preferences for risky behaviour, a result that points in the direction of the conclusions in Koundouri et al., 2009, who found that Finnish crop farmers were risk averse in the pre-CAP period but show risk-loving preferences in the post-CAP period.

These results seems to confirm the existence of two opposite effects, which were discussed, often to interpret opposite results in term of estimated/elicited farmers' risk preferences, in previous literature: on one side the policy reforms reduced the random component of farmers' income, which is likely one of the main causes of a decrease in farmers risk aversion, as discussed in Koundouri et al., 2009. This effect seems to dominate in the implementation phase of the Mac Sharry reform. On the other side, and despite the fact that policy interventions in the agricultural sector are often intended to reduce the level of risk faced by farmers, it is frequently difficult to foresee changes in government policies, particularly where decisions are influenced by social and political considerations (REAS, 2010) and this situation may trigger an increase of farmers' risk aversion. This result supports the analysis in Moschini and Hennessy, 2001, who stress that changes in policy interventions, such as the CAP reforms in the 1990s, can become sources of uncertainty that can create risk for agricultural investment.

The costs of risk becomes again zero after the introduction of the Agenda 2000 reform. However, in this case the results of the Wald test for similar parameters between the implementation phase of the Mac Sharry reform and the Agenda 2000 calls for caution in interpreting this change. Notably, we cannot reject at the 10% level of significance the hypothesis of similar AP and DS risk preferences for cereals producers in the final years of the Mac Sharry Reform period compared to the agenda 2000 reform period (at least until the 2003 drought shock).[16]

15 As noted in Section 3.1 farmers' policy context underwent major changes in those years, also due to GATT's entrance into force and the EU enlarged with three new members.

16 Robustness checks on alternative periods are coherent with the findings illustrated in this section. Notably, we reject the hypothesis of similar risk parameters between the agenda 2000 period and the first period of the CAP reform and between the agenda 2000 and the years preceding the CAP. These results are presented in Table A3 in the Appendix.

Aggregate results for the period 1989-2002 show that the AP coefficient is not statistically significant, indicating, on average, risk neutrality (Table 2, raw 2). However, disentangling different sub-periods reveals that there have been significant changes in risk preferences, which offset each other. The DS coefficient for the entire period is positive, small and statistically significant, coherently with the sub-periods results. A similar pattern for both the AP and DS coefficients is found if we look only at the Mac Sharry reform period (1993-1999).

In general, our analysis shows that at each introduction of a policy change, risk aversion coefficients tend to increase. The progressive uncertainty stemming from the complex system of government interventions and CAP reforms implemented since the early 1990s offset the mitigating effect on risk aversion that the passage from a price support to income support mechanism is expected to trigger. As new policies are introduced, farmers tend to become more risk averse, but this effect fades through the implementation period of the policy, and eventually the mitigating effect on risk aversion of the policy dominates.

In a way, these results support, but looking at the specific context of the agricultural sector, the famous Lucas' critique argument that changes in economic policy will affect the behaviour of the private agents (households). In our context, this means that key behavioural parameters such as risk aversion coefficients may change through time in relationship to significant changes in policies, and we shall take this into account if we are going to be concerned about the policy implications of our models or about our ability to forecast when there are changes in policy regimes, such as the CAP reforms. Since the publication of the seminal paper by Lucas (1976), several studies looking at investors' behaviours also debated whether agents react differently to policy shocks perceived as permanent or transitory. Our findings suggest the need for such better understanding also in the specific context of decision making in the agricultural sector.

5.2. Climate shocks driven changes in risk attitude

We report in Table 4 rows 4 and 5 the estimated risk parameters for the post 2003 and 2007 droughts sub-periods.

The results show a clear increase in cereal producers' risk aversion after the 2003 drought.[17]

[17] This finding confirms the year-by-year estimations presented in the Appendices.

Starting in 2003, risk preference coefficients are positive and the Null Hypothesis of coefficients of risk aversion being zero can be strongly rejected for all alternative time periods.[18] We can thus conclude that cereals producer are risk averse in the period 2003-2009.

We further perform the Wald test for equality of risk parameters before and after these droughts.

The Null Hypothesis of equality of AP and DS risk parameters before and after the 2003 and 2007 climatic shocks is strongly rejected.

The increase in risk aversion over the second moment of profit distribution supports recent studies showing the possibility that a negative shock (such as a financial crisis or a severe drought) can trigger large increases in agents' risk aversion over a relatively short period of time (Guiso et al., 2013; Malmendier and Nagel, 2011), and that stress modulates risk taking, potentially exacerbating behavioural bias in subsequent decision making (Porcelli and Delgado, 2009; Lichand and Mani, 2016). Cereals farmers also appear to be more willing to give up part of their expected profits in order to receive a given level of future profit with certainty, compared to the Agenda 2000 implementation period that preceded the droughts. However, the DS risk aversion parameters remain very small, which is consistent with the very low uptake of crop insurance by Italian farmers. This result is interesting and deserves further investigation, because of its implication on farmers' vulnerability and reliance on public support to cope with climatic shocks, which can become more frequent under climate-change scenario.

Finally, it is interesting to notice that if we compare the results exposed in this section with those presented in Section 5.1, we find evidences that the effect of climatic shocks on farmers risk preferences is stronger and less ambiguous than policies-induced changes in risk attitude.

6. Concluding Remarks

We find evidence for changes of risk preferences over time using the example of Italian agriculture over the period 1989 to 2009. Studies conducted after the onset of the financial crisis that started in 2008, address the possibility that a (negative) shock can trigger large increases in agents' risk aversion over a relatively short period of time. In agricultural applications, however, little - and so far ambiguous - evidence has been provided. This paper uses an empirical framework to assess

18 Results are stable if we include 2003 in the post-2003 estimation (row 4) and 2007 in the post-2007 estimation (row 5). We present these results in Table A4 in the Appendix.

whether the assumption of risk preferences stability holds in the context of major changes in the environment where farmers operate, for example due to policy change, or after a major production shock, which can be of climatic or other nature.

Using a rich panel data structure, we are able to capture the time dimension in risk preference’s evolution. Our results found variation across time in the key parameters attached to risk preference, more evident for aversion to the second moment of the distribution of profit, while aversion to extreme (downside) events exhibits more time invariant characteristics.

We found that the climatic shocks of 2003 and 2007 triggered an unambiguous increase in cereals producers’ risk aversion, and that in general exogenous climatic shocks have a stronger and less ambiguous effect on risk preferences than changes triggered by policies reforms.

Other authors provided general insights that the changes in policy interventions, such as the CAP reforms in the 1990s, can become sources of uncertainty that can create considerable risk for agricultural investment (Moschini and Hennessy, 2001). We suggest that the build-up of progressive uncertainty through the complex system of government interventions that characterizes the European policy framework of the late 1990s and early 2000 led an increase of risk aversion. Instead, policies that aim to stabilize farmers’ income and that are implemented for long enough without undergo a continued reform process tend to trigger more risk loving behaviours, a result also found in other studies (Koundouri et al., 2009).

These findings open up future avenues of research, as it is mostly assumed that individual risk aversion is time invariant. As European agriculture is increasingly exposed to climate change and possibly significant policy changes and the support of risk management is of increasing relevance in recent CAP reforms (e.g. El Benni et al., 2016), researchers and policymakers alike need to enhance their understanding of the implication of risk preferences that are unstable over time.

These conclusions provide ground to extend to the agricultural sector the discussion triggered, mostly among macroeconomists, by the famous Lucas Critique to econometric policy evaluation (Lucas, 1976).

The instability of risk preferences is potentially a serious barrier to our understanding of farmers’ decision-making under uncertainty, particularly relevant also in the context of risk exposure in agriculture.

In this paper, we use the method of moments on a much larger panel dataset of those used in previous similar studies in Europe. This method allows retrieving agents' preference for risk even when survey data with risk preferences elicitation nor the results of *ad hoc* field and lab experiments are available. Our approach does not replace these methods. On the contrary, such methods shall provide further tests for the robustness of our findings and enhance understanding of time invariant risk preferences in agriculture. Such methodological comparison is beyond the scope of this paper and left for future research.

7. Appendix

Table A1. Year-by year Estimated Risk Aversion

		Year	Farms	AP	st err	DS	st err
Pre-CAP reform		1989	6828	0.0572	0.0283	0.0033***	0.00019
		1990	6540	-0.0147	0.0269	0.0028***	0.00017
		1991	6676	0.0386	0.0233	0.0034***	0.00015
		1992	6727	0.0181	0.0333	0.0036***	0.00020
Mac Sharry Reform		1993	6616	0.0493	0.0357	0.0046***	0.00020
		1994	5939	0.1909*	0.0505	0.0071***	0.00031
		1995	5444	0.0842	0.0489	0.0047***	0.00030
		1996	6135	-0.0229	0.0346	0.0024*	0.00023
		1997	6182	-0.0875	0.0432	0.0010	0.00028
		1998	6053	-0.1289*	0.0391	-0.0003	0.00027
		1999	5850	-0.2096***	0.0293	-0.0014	0.00021
Agenda 2000		2000	5667	-0.1438	0.0727	0.0003	0.00047
		2001	6195	0.0119	0.0448	0.0027	0.00033
		2002	5844	-0.0960	0.0598	-0.0002	0.00042
	Drought shock	2003	4636	0.2834***	0.0368	0.0073***	0.00025
		2004	4524	0.2076**	0.0446	0.0059***	0.00032
		2005	4638	0.2495***	0.0285	0.0063***	0.00021
		2006	4539	0.2880***	0.0443	0.0074***	0.00036
	Drought shock	2007	4637	0.2906**	0.0613	0.0066***	0.00039
		2008	3464	0.2983**	0.0602	0.0063**	0.00050
		2009	3512	0.5098***	0.0263	0.0120***	0.00021

Notes: Bootstrapped standard errors of the underlying estimated coefficients ($\hat{\theta}_2$ *and* $\hat{\theta}_3$) in brackets. Bootstrap replications: 1000. ***, ** and * denote significance at 1%, 5% and 10% respectively.

Table A2. Estimated Risk Aversion: 3-years periods

	years	AP	DS
Pre-CAP reform farms: 10,518	1989-1991	0.0281 [0.0152]	0.0031*** [0.0001]
Mac Sharry Reform phase 2 farms: 9,641	1996-1998	-0.0841* [0.0231]	0.0010 [0.0002]

Notes: Bootstrapped standard errors of the underlying estimated coefficients ($\hat{\theta}_2$ *and* $\hat{\theta}_3$) in brackets. Bootstrap replications: 1000. ***, ** and * denote significance at 1%, 5% and 10% respectively.

Table A3. Wald Test Statistic for equality between AP and DS: sensitivity analysis

	AP	DS
	Pre-Reform period (1989-1991) vs Mac Sharry Reform (1993-1998)	
[1]	H_0: $\hat{\theta}_2^{(1989-1991)} = \hat{\theta}_2^{(1993-1998)}$ $\chi^2(1) = 6.34$ Prob > chi2 = 0.0118	H_0: $\hat{\theta}_3^{(1989-1991)} = \hat{\theta}_3^{(1993-1998)}$ $\chi^2(1) = 4.46$ Prob > chi2 = 0.0348
	Mac Sharry Reform: transition phase (1993-1995) vs implementation phase (1996-1998)	
[2]	H_0: $\hat{\theta}_2^{(1993-1995)} = \hat{\theta}_2^{(1996-1998)}$ $\chi^2(1) = 11.53$ Prob > chi2 = 0.0007	H_0: $\hat{\theta}_3^{(1993-1995)} = \hat{\theta}_3^{(1996-1998)}$ $\chi^2(1) = 15.35$ Prob > chi2 = 0.0001
	Mac Sharry reform implementation phase (1996-1998) vs Agenda 2000 (2000-2002)	
[3]	H_0: $\hat{\theta}_2^{(1996-1998)} = \hat{\theta}_2^{(2000-2002)}$ $\chi^2(1) = 0.01$ Prob > chi2 = 0.9304	H_0: $\hat{\theta}_3^{(1996-1998)} = \hat{\theta}_3^{(2000-2002)}$ $\chi^2(1) = 0.19$ Prob > chi2 = 0.6666
	Pre-Reform Period (1989-1991) vs Agenda 2000 (2000-2002)	
[4]	H_0: $\hat{\theta}_2^{(1989-1991)} = \hat{\theta}_2^{(2000-2002)}$ $\chi^2(1) = 6.08$ Prob > chi2 = 0.0137	H_0: $\hat{\theta}_3^{(1989-1991)} = \hat{\theta}_3^{(2000-2002)}$ $\chi^2(1) = 7.71$ Prob > chi2 = 0.0055
	Pre-reform (1989-1992) vs Agenda 2000 implementation (2000-2002)	
[5]	H_0: $\hat{\theta}_2^{(1989-1992)} = \hat{\theta}_2^{(2000-2002)}$ $\chi^2(1) = 5.34$ Prob > chi2 = 0.0209	H_0: $\hat{\theta}_3^{(1989-1992)} = \hat{\theta}_3^{(2000-2002)}$ $\chi^2(1) = 7.40$ Prob > chi2 = 0.0065
	Agenda 2000: pre 2003 Drought (2000-2002) vs post 2003 Drought (2004-2009)	
[6]	H_0: $\hat{\theta}_2^{(2000-2002)} = \hat{\theta}_2^{(2004-2009)}$ $\chi^2(1) = 21.90$ Prob > chi2 = 0.0000	H_0: $\hat{\theta}_3^{(2000-2002)} = \hat{\theta}_3^{(2004-2009)}$ $\chi^2(1) = 15.85$ Prob > chi2 = 0.0001
	Agenda 2000: pre 2007 Drought (2000-2006) vs post 2007 Drought (2007-2009)	
[7]	H_0: $\hat{\theta}_2^{(2000-2006)} = \hat{\theta}_2^{(2007-2009)}$ $\chi^2(1) = 9.95$ Prob > chi2 = 0.0016	H_0: $\hat{\theta}_3^{(2000-2006)} = \hat{\theta}_3^{(2007-2009)}$ $\chi^2(1) = 5.03$ Prob > chi2 = 0.0249
	pre 2003 Drought (1989-2002) vs post 2003 Drought (2004-2009)	
[8]	H_0: $\hat{\theta}_2^{(1989-2002)} = \hat{\theta}_2^{(2004-2009)}$ $\chi^2(1) = 32.06$ Prob > chi2 = 0.0000	H_0: $\hat{\theta}_3^{(1989-2002)} = \hat{\theta}_3^{(2000-2002)}$ $\chi^2(1) = 20.09$ Prob > chi2 = 0.0000

Table A4. Estimated Risk Aversion – post droughts sensitivity analysis

		years	AP		DS	
[1]	**Post-2003 shock** farms: 10,081	2003-2009	0.3453***	[0.0257]	0.0081***	[0.0002]
[2]	**Post-2007 shock** farms: 5,938	2007-2009	0.4190***	[0.0364]	0.0092***	[0.0003]
[3]	**Inter-droughts period** farms: 6,774	2004-2006	0.2491***	[0.0427]	0.0102***	[0.0003]

Notes: Bootstrapped standard errors. Bootstrap replications: 1000.

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