# Adaptation to Climate Change: Farmers' Risk Preferences and The Role of Irrigation

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**ABSTRACT**. This paper investigates the effect of irrigation as a tool to adapt to climate uncertainty in agriculture. Our model relies on a moment based approach to investigate how individual producers' optimize input usage, in particular irrigation water, taking into account their risk preferences. By relying on a panel data of 122,800 Italian farm units, spread over 1981 to 2003, we capture both variation over farms and also variation over time. The latter has been weakly investigated in the literature. We derive the risk preference of the entire sample. Our preliminary findings show that risk aversion has increased over time, while down-side risk aversion has been more stable. We also find evidences that farmers specializing in different crops exhibit different risk aversion and have used irrigation water with diverse efficiency. Furthermore, higher downside risk aversion is a key determinant in the decision to adopt irrigation technology.

**Keywords**: risk attitude, method of moments, irrigation, production uncertainty.

**JEL Classification**: D81, Q12, Q54

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# 1 Introduction

With regard to water resources, climate change is expected to result in increased variability, enhanced uncertainty, and generally increased scarcity (Strzepek et al., 2011). Several studies predict that climate change will significantly impact water supply and demand throughout the world. This will have implications for localized planning and water resources management, even in those areas that have not traditionally faced fresh water shortage, such as the Alpine Region. As a result, attention is increasingly being paid to the development of adaptation strategies.

Our fundamental enquiry concerns the way in which optimal water management might facilitate adaptation to climate change in agriculture. Notably, we focus on irrigation technology and conservation policies adopted as risk management strategies. We pay particular attention in the analysis of farmers' preferences for risk, as they are a key determinant of their investment decision and response to water management policies such as water conservation ones. We discuss these issues in the context of the Italian peninsula, a very heterogeneous territory in term of topographic features and availability of water resources.

Climate-related risks expose the agricultural sector to significant uncertainties. The first and most fundamental level of adaptation to climate change in agriculture occurs at the level of the local farmer. We assume farmers are interested in water management in aid of climate adaptation, because this is consistent with the pursuit of profit maximisation in agriculture (as well as with aversion to variability). Notably, the literature on input-use adjustments, as a response to reduced water entitlement in agriculture, concludes that producers will usually adapt rationally to water scarcity signals (Groom et al., 2008). Adaptation strategies include enhanced irrigation methods and in general a more efficient use of water resources. More efficient irrigation practices are among the main *ex ante* risk management strategies implemented by farmers.[1,2]

Farmers' attitude to risk impacts their investment decision undertaken to adapt with increasing uncertainty and variability in climate. However, this is a dimension frequently overlooked in the literature. This omission may seriously limit our understanding of farmers reaction to and thus the impacts of different policy intervention, in particular of those designed to deal with the residual uncertainty remaining after local adaptation to climate change.[3] Risk considerations are necessary in the analysis of the agricultural sector as there exist a number of possible cases where intelligent policy formulation should consider not only the marginal contribution of input use to the mean of output, but also the marginal reduction in the variance of output (Groom et al., 2008). However, the variance does not distinguish between unexpected bad events and unexpected good ones. On

[1] Other adaptation strategies include crop diversification, the use of different crop varieties (e.g. changing/adopting a mix of less productive, drought-resistant varieties and high-yield water sensitive crops), change planting and harvesting dates etc.

[2] For example, in the Po river basin, in the north of Italy, farmers have traditionally relied on inefficient irrigation methods, which are still one of the main causes of waste of fresh water resource. This has been caused by the low costs and relative abundance of the water resource in this mountain-based basin. Low efficiency furrow and flood irrigation methods are still widely used, particularly in Piedmont and Lombardy. Generally, farmers in Emilia Romagna rely on more efficient irrigation methods, such as drip and sprinkler techniques. Adopting enhanced forms of irrigation is thus a particularly suitable option for famers in the Po basin.

[3] Groom et al. (2008) argue this point referring specifically to water conservation policies.

this basis, it seems important to consider also skewness in risk analysis (Di Falco and Chavas, 2009). Koundouri et al. (2006) argue that the issue of risk has rarely been addressed adequately in the relevant literature concerning farmers' decision.

This paper contributes to the existing literature by adopting a unique panel dataset to address the following questions. First, we want to investigate how farmers investment decision are influenced by their risk preferences. In particular we want to disentangle those factors such as specific topographic or soil quality characteristics, or different institutions, which may affect farmers' aversion to risk and in turn the way they react to different policies. Secondly, we want to assess what is the role of irrigation in adapting to climate change. The empirical analysis focuses on the whole Italian Peninsula.

One of the limits of the previous literature is that it mostly relies on cross-section of farmers. This hinders the comprehension of factors such as learning by doing, information gathering and accumulation of resources that may affect farmers' decision (Feder et al., 1985; Sunding and Zilberman, 2001; Koundouri et al. 2006).[4] One important contribution of this paper to the literature is the use of the rich panel data structure to capture both the within and between variation in risk preference.[5] Furthermore, the panel structure of the dataset allows for the adoption of a fix effect estimator. This provides consistent parameters even if there is correlation between the independents variables and time invariant unobserved heterogeneity, such as soil quality. We can then tackle potential endogeneity issues, caused by a possible correlation between the dependent variable (e.g. the decision to adopt irrigation technology) and time variant unobserved heterogeneity by estimating a instrumental variables model with fixed effect. We deal with these issues and enrich the existing literature in that we rely on a rich dataset from the Italian Farm Accountancy Data Network (RICA). Our dataset comprises farm level data for more than 122,800 farms and refer to the period 1981 to 2003. The panel is unbalanced with farms included into the dataset for a maximum of 22 consecutive years. A careful sample selection applied by RICA allows to consider the selected farms as representatives of the universe of Italian farms. By relying on panel data we can capture both variation over farms, similar to regression on cross-section data, but also variation over time. The latter has been weakly investigated in the literature because of the scarce availability of data. However, omitting time variations may cause a serious problem when analyzing risk attitude under climate change scenario. For example, farmers can be expected to take investment decisions and adapt their farming strategies based on their perceptions of linear changes in temperature and precipitation.

Just and Pope (JP) (1978, 1979) develop one of the most followed approaches for handling production risk econometrically. This method is based on the estimation of a stochastic production function which allows risk increasing as well as risk decreasing inputs in the production function.

[4]Besley and Case (1993) and Koundouri et al. (2006) discuss some of the limits and opportunities in using simple cross section data. Hynes and Garvey highlight the advantages of panel data techniques over static frameworks in analyzing the determinants of Irish famers' participation to a agri-environment program (REPS). The authors claim that where no attempt is made to control for unobserved heterogeneity or path dependency, the effects of the farm-specific characteristics may be overesimated (Hynes and Garvey, 2009).

[5]The standard errors of panel-data estimators need to be adjusted because each additional time period of data is not independent of previous results (Cameron and Trivedi, 2010).

The latter consists of two separate general functions: one specifies the effect of inputs on the mean of output and another specifies the effect of input on the variance of output.[6,7]

One of the criticisms of the production function approach is that it overestimates production damages by omitting the variety of adaptations that farmers customarily make in response to changing economic and environmental conditions.[8,9] Another weakness of this approach is that although it allows to investigate how changes in factors like temperature and climate influence the mean and variance of the related items like crop yields (Chen and McCarl, 2001), it also restricts the effects of inputs across higher order moments in the way traditional econometric models do across all moments (Groom et al. 2008).

Regarding the second criticism, results of recent literature show the importance to consider higher moments, in particular skewness, in the analysis of climate related risk in agricultural production. This literature mainly builds on the moment based approach first developed by Antle (1983, 1987), Antle and Goodger's (1984) and Chavas (2004). Antle (1983, 1987) criticizes previous production function specifications as they are not adequate representations of the probability distribution of output because they impose arbitrary restrictions on the moments of output that result in arbitrary restrictions on the behavior of the firm.[10]

Our analysis relies on the "moment based approach". This approach uses a moment-based specification of the stochastic production function and allows to capture the effect of production decisions on the mean, the variance, the skewness and possibly higher moments of production and welfare. In particular, we contribute to the literature developing models that incorporate downside risk aversion.[11] This allows to investigate environmental risk exposure in terms of crop yields' failure, and more specifically farmer's risk attitude and exposure to downside risk (captured by yields' skewness). One of the main advantages of this method is that it allows to capture farmers' preference for risk. These are estimated as part of a structural econometric model in which neither the impact of inputs on risk nor the form of the utility function is restricted (Groom et al. 2008). This method is based on populations' characteristics and for this reason overcomes the problem

[6] Just and Pope, 1979 p. 278.

[7] The JP production function has mostly been estimated econometrically by a Three Step Feasible Generalized Least Square (FGLS) and a Maximum Likelihood (MLE) procedures. Saha et al. (1997) apply Monte Carlo Experiments on a JP stochastic production function showing that that for a small sample ML estimations are more efficient and unbiased than FGLS estimates. Chen and McCarl (2001) use this approach to assess the impact on climate variation on per acre pesticide costs across the US.

[8] See Mendelsohn et al., 1994 p.754.

[9] As a response to this critics Mendelshon et al. (1994) developed the *ricardian approach*, which is based on the analysis of different performances of the economic unit under consideration (e.g. the farm) across a given territory (e.g. the country, region or basin) under study. Performance is measured by land values and/or farm revenues, analyzing the impact of climate variables on these. See also Dinar et al.1998; Kurukulasuriya and Rosenthal, 2003; Mall et al. 2006; Cline, 2007; Seo and Mendelsohn, 2008a, 2008b and 2008c; Deressa and Hassan, 2010; Di Falco et al., 2011.

[10] Antle, 1983 p. 192.

[11] Anderson, Dillon, and Hardaker, 1980; Menezes, Geiss, and Tressler, 1980; Antle and Goodger, 1984; Antle, 1987, Di Falco and Chavas, 2006, 2009; Groom et al. 2008; Koundouri et al., 2003, 2006 and 2009, Chavas and Di Falco, 2012a and 2012b.

of aggregation from the individual to the population.[12] The estimated results have thus more relevance for policy analysis (Antle, 1987).[13]

Koundouri et al. (2006) model a farmers' decision to adopt new irrigation technologies, using the flexible moment-based approach. Their model is empirically estimated on a cross section of 265 farms located in Crete, Greece. Results show that risk preferences affect the probability of adoption and provide evidence that farmers invest in new technologies as a means to hedge against input related production risk (Koundouri et al., 2006). Foudi and Erldlenbruch (2011) estimate a probit model based on the decision of the farmer to irrigate or not. They show that French farmers rely on irrigation technology as a self-insurance tool against production risk, particularly the risk of droughts. In particular, they conclude that farmers adopt irrigation technology in relation to the previous year's mean and variance of climate.

The paper proceeds as follows: in section 2 we present the theoretical framework to analyze the representative agent production model under risk and possibly subject to restrictions on water resources use. In section 3 we describe a flexible estimation approach. Data are described in Section 4. We discuss the estimation procedure and our preliminary results in Section 5. Section 6 concludes by mentioning the extension to this preliminary work.

## 2 Theoretical Model of Producer Behavior under Climate Variability in Agriculture

We develop in this section the basic representative agent production model under risk. We look at the optimization problem of the farmer, who takes decisions on weather to adopt more efficient irrigation technology and may be subject to a constraint set by the authority, such as a temporary restriction upon water use (water quota). Following Groom et al. (2008) we assume that regulation for risk takes the form of temporary water quota imposed by the regulator. Furthermore, as in Koundouri et al. (2006) we assume that efficiency in water use varies across farmers: one group invests to adopt a more efficient irrigation technology and the other group doesn't. The two groups of farmers are subject to the same institutions and regulations.

We assume that climate is the primary source of production risk.[14] In the short run, farmers choose and combine variable inputs in agricultural production, such as water, fertilizers, plant protections and labour in order to hedge against production risk. Land is assumed to be a fixed factor and allocation decisions and their relationship with variable-input demand are not addressed here.[15] We assume that farmers are price-takers and they operate in perfect competition market structure. That is, their production decisions and input allocation decision will affect neither output nor input prices.

[12] Hazell, 1982; Pope, 1982; Binswanger, 1982.

[13] Antle, 1983 and 1987; Koundouri et al., 2006; Groom et al., 2008; Foudi and Erldlenbruch, 2011.

[14] We only address production risk, assuming that the farmers are price-takers and prices are perfectly predictable in the short-run. See also Koundouri et al. (2003 and 2006) and Groom et al. (2008).

[15] Groom et al., (2008) argue that this is a reasonable assumption when farmers are constrained by a *temporary* policy.

As in Groom et al. (2008) we assume that the water management policy is implemented in order to maximize a social welfare objective criterion including environmental considerations. Such welfare function would typically include the consumer surplus associated with the good produced, any environmental externalities related to natural resource depletion, and so on (Groom et al., 2008). In the specific example of the water quota, this is temporary and exogenous, so that farmers consider it as given when undertaking production and investment decisions. In order to assess the impacts of a water quota or other water management policies it is necessary to represent adequately the technology adopted by the population of farmers and also farmer preferences towards risk.

Let U(.) be the *Von Neuman-Morgenstern* utility function representing farmers preferences under climatic risk. We assume that production risk, captured in our model by the error term $\epsilon$, is the only source of risk, as input and output prices (r and p respectively) are considered non-random by the farmer.[16] Therefore, climatic risk affects crop yield through the variable $\epsilon$, whose distribution G(.) is not affected by farmer actions. We further assume that the production function f (.) is continuous and twice differentiable. p denotes output price for a single crop, X is the K vector of inputs, and r is the corresponding vector of unit input prices. The environmental policy quota is directed towards a single input, irrigation water in our case, which is denoted $X_w$ with associated unit price $r_w$. We then have $X^{'} = (X_1,X_2,...,X_{K-1},X_w)$ and $r^{'} = (r_1,r_2,...,r_{K-1},r_w)$. The restriction imposed on $X_w$ is written as it follows:

$$X_w \leq \bar{X}_w \tag{1}$$

The agent's problem is to maximize expected profit if she is risk-neutral, or to maximize the expected utility of profit if she is risk-averse, subject to condition 1. In the latter case, the agent's problem is:[17]

$$\max_{X,x_w} E[U(\pi)] = \max_{X,x_w} \int [U(pf(\epsilon, h(\alpha)x_w, X) - r_w x_w - r^{'}X]dG(\epsilon) + \lambda(\bar{X}_w - X_w) \tag{2}$$

Where $\lambda$ is the Lagrange multiplier associated with (1).

The optimal quantity of irrigation water for a profit maximizing farmer is derived by solving the agent's problem through the following first order condition:

$$E[r_w U'] = E\left\{p\frac{\partial f(\epsilon, h(\alpha)x_w, X)}{\partial x_w}U'\right\} - \lambda \quad \Leftrightarrow \tag{3a}$$

$$\frac{r_w + \lambda/E(U')}{p} = E\left\{\frac{\partial f(\epsilon, h(\alpha)x_w, X)}{\partial x_w}\right\} + \frac{cov[U'; \partial f(\epsilon, h(\alpha)x_w, X)/\partial x_w]}{E[U']} \tag{3b}$$

Where U'= $\partial U(\pi)/\partial\pi$. We can see that the program to find the optimal quantity of input $X_k$ depends upon input and output prices, (p, r) and on the shape of functions U (.) , f (.) and G(.).

[16]See Koundouri et al., 2003 and 2006 and Groom et al., 2008.
[17]Notation follows Groom et al., 2008.

The left-hand side of equation (3b) $\{(1/p)[r_w + \lambda/E(U')]\}$ is the the price ratio under a water quota constraint.[18] For a risk-neutral farmer this term equals the expected marginal product of the irrigation water input, namely the first term in the right-hand side of relation (3b). The second-term in the right-hand side of (3b) is zero if the farmer is risk neutral and different from zero if the farmer is risk averse. Thus this term measures deviations from the risk-neutrality case. More precisely, this term is proportional and is opposite in sign to the marginal risk premium with respect to the irrigation water input (Koundouri et al., 2006 and Groom et al., 2008).

Following Koundouri et al. (2006) we incorporate into the above general model, the farmer's decision whether or not to adopt a new, more efficient irrigation technology. This decision can be modeled as a binary choice, where the farmer can choose to adopt (A = 1) or not (A = 0) an irrigation technology increasing water use efficiency (i.e. $h^1(\alpha) > h^0(\alpha)$).

The adoption of the irrigation technology will reduce production risk during years of drought and also reduce the risk associated to the imposition of a water quota or other restrictive water management policies. The new irrigation technology is in fact modeled such that the same level of output will require less water input. Thus we expect that farmers' expectations to incur into adverse climatic conditions and/or water management policies restricting the access to the water resources are an element influencing his willingness to adopt (enhanced) irrigation technology. As in Koundouri et al. (2003 and 2006) we assume conditions of certainty with regards to the use of the new equipment,[19] and that adopting the new technology implies a fixed cost ($I_1 > 0$ and $I_0 = 0$). We denote $x^1$ and $x^0$ the optimal input choices for farmers adopting and non adopting the new technology respectively.

The farmer will adopt the new and more efficient irrigation technology if the expected utility with adoption is greater than the expected utility without adoption, i.e.,

$$E[U(\pi^1)] > E[U(\pi^0)] \tag{4}$$

The maximization problem for a farmers' adopting the more efficient irrigation technology is:

$$\begin{aligned} &\max_{X^1, x_w^1} E[U(\pi^1)] \\ &= \max_{X^1, x_w^1} \int [U(pf(\epsilon, h^1(\alpha)x_w^1, X^1) - r_w^1 x_w^1 - r' X^1 - I^1]dG(\epsilon) + \lambda(\bar{X}_w - x_w^1) \end{aligned} \tag{5}$$

while the maximization problem for a farmer non adopting the more efficient irrigation technology is:

$$\begin{aligned} &\max_{X^0, x_w^0} E[U(\pi^0)] \\ &= \max_{X^0, x_w^0} \int [U(pf(\epsilon, h^0(\alpha)x_w^0, X^0) - r_w^0 x_w^0 - r' X^0 - I^0]dG(\epsilon) + \lambda(\bar{X}_w - x_w^0) \end{aligned} \tag{6}$$

[18] See Groom et al., 2008. Koundouri et al., 2006 discuss this model with no constraint: with no water quota the LHS of the equation becomes simply the input price to output price ratio $r_w$/p.

[19] i.e., future costs and benefits are perfectly known at the time of adoption (Koundouri et al., 2006). Koundouri et al., 2006 extend this model to incorporate incomplete information regarding the new irrigation technology, in a context of production uncertainty and no constraint set by the authorities on water resources use.

From equations (5) and (6) we can derive the first order conditions for the optimal irrigation water input $x_w^i$, for the farmers adopting (i=1) and non adopting (i=0) the more efficient irrigation technology. These are, respectively:

$$\frac{r_w^1 + \lambda/E(U')}{p} = E\left\{\frac{\partial f(\epsilon, h^1(\alpha)x_w^1, X^1)}{\partial x_w^1}\right\} + \frac{cov[U'; \partial f(\epsilon, h^1(\alpha)x_w^1, X^1)/\partial x_w^1]}{E[U']} \tag{7a}$$

$$\frac{r_w^0 + \lambda/E(U')}{p} = E\left\{\frac{\partial f(\epsilon, h^0(\alpha)x_w^0, X^0)}{\partial x_w^0}\right\} + \frac{cov[U'; \partial f(\epsilon, h^0(\alpha)x_w^0, X^0)/\partial x_w^0]}{E[U']} \tag{7b}$$

Equations (7a) and (7b) yields the optimal quantity of water irrigation input in term of input and output prices, the water quota and the Lagrange multiplier associated with (1).

The derivation of an analytical solution to (4) requires to define technology parameters, farmers' preferences, and the distribution of the error term $\epsilon$. In order to avoid making a serious of assumption on these elements, recent literature adopts Antle's moment based approach that allows to estimate farmers' attitude towards risk by using a flexible estimation approach.[20] This is known as the *method of moments* and it is described in the next section.

# 3 Empirical Model

Following recent literature we use a flexible estimation approach where uncertainty is considered by using moments of the profit distribution as determinant of farmers decision regarding the input mix. We focus in particular on decisions regarding adoption of more efficient technology. The key feature of this approach is that the producer problem can be written as a function of input levels alone (Groom et al. 2008) and the researcher can avoid making strong assumptions on technology parameters farmers' preferences and the distribution of the error term.

We maximize a function of moments of the profit distribution by estimating the distribution of the error term $\epsilon$, which includes climatic risks and is assumed to be the only source of production risk. Those moments have themselves X as an argument. This is equivalent to maximize expected utility of profit under restriction with respect to any input (Antle, 1983, 1987 and Groom et al. 2008). This method has the main advantage of not requiring the specification of function forms for profit $\pi(.)$, the distribution of risk G(.) and the utility function U(.).

This estimation method allows us to investigate empirically the effect of adopting irrigation water on farm productivity and risk exposure. Risk-averse farmers have an incentive to reduce their risk exposure. How the adoption of irrigation technology can influence risk exposure? The effects of irrigation technology on the mean and variance of output has been analyzed in previous literature. However it is of interest to go beyond mean and variance effects and capture how inputs contributes to the higher moments of the profit distribution. Adopting irrigation water may indeed affect the

[20] Tack et al., 2012; Antle, 2010; Di Falco and Chavas, 2006, 2009; Groom et al., 2008; Koundouri et al., 2006; Koundouri et al., 2003; Chavas and Di Falco, 2012a and 2012b.

third central moment (skewness) of the distribution of profit. Under downside risk aversion farmers are adversely affected by down side risk (e.g. risk of crop failure). A downside averse decision maker will invest in adaptation strategies to reduce such risk (Menezes et al., 1980; Antle, 1983; Di Falco and Chavas, 2009).

The farmer's program becomes:[21]

$$\max_X E[U(\pi)] = F[\mu_1(X), \mu_2(X), ...., \mu_m(X)] \quad s.t. \quad X_w \leq \bar{X}_w \tag{8}$$

where $\mu_j = E(\Pi - \mu_1)^j$ j=2,...,m is the $m^{th}$ moment of profit.

We assume that the farmers are concerned only with the first three moments of the distribution of profit.[22] The first order conditions of this program can be approximated using a Taylor expansion in matrix form. Following the procedure first developed by Antle (1983, 1987) and Antle and Goodger (1984) we estimate for each input k its marginal contribution to the expected profit (given by $\partial\mu_1(X)/\partial X_k$). This is written as a linear combination of the marginal contributions of input k to the variance ($\partial\mu_2(X)/\partial X_k$) and the skewness ($\partial\mu_3(X)/\partial X_k$). Hence the following model will be estimated for each input k:[23]

$$\frac{\partial\mu_1(X)}{\partial X_k} = \theta_{1k} + \theta_{2k}\frac{\partial\mu_2(X)}{\partial X_k} + \theta_{3k}\frac{\partial\mu_3(X)}{\partial X_k} + u_k \tag{9}$$

where $\theta_{jk}$ = -1/j! $\times$ $(\partial F(X)/\partial\mu_j(X)/\partial F(X)/\partial\mu_1(X))$ ; (j=1,2,3)

and $u_k$ is the usual econometric error term. The most important feature of this model is that the parameters $\theta_{2k}$ and $\theta_{3k}$ are directly interpretable as the Arrow-Pratt (AP) and down-side (DS) risk aversion coefficients, respectively (Groom at al., 2008).

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

$$AP = -\frac{E(\partial^2 U/\partial\pi^2)}{E(\partial U/\partial\pi)} \cong -\frac{\partial F(X)/\partial\mu_2(X)}{\partial F(X)/\partial\mu_1(X)} = \mathbf{2}\boldsymbol{\theta}_\mathbf{2} \tag{10}$$

while the DS risk coefficient is approximated by:

$$DS = -\frac{E(\partial^3 U/\partial\pi^3)}{E(\partial U/\partial\pi)} \cong -\frac{\partial F(X)/\partial\mu_3(X)}{\partial F(X)/\partial\mu_1(X)} = -\mathbf{6}\boldsymbol{\theta}_\mathbf{3} \tag{11}$$

[21] This approach follows Antle (1983, 1987) and more recent literature (Koundouri et al., 2003 and 2006, Groom et al. 2008). One of the main advantages of this approach is that the function of moments F(.) is left unspecified.

[22] We leave the inclusion of the forth moment of the distribution of profit (kurtosis) to a further extension of this paper. Groom et al. (2008) upon which we base our estimation procedure, found that estimation coefficients for the kurtosis were not significant. Koundouri et al. (2006) proceed with the estimation of the fourth moment, but recognize that most distribution functions are well approximated by their first three moments.

[23] See Antle 1983 and 1987; Groom et al., 2008; Koundouri et al., 2003 and 2006.

A positive and significant AP coefficient indicates that the decision maker is risk averse. This implies that an agent with positive and significant AP coefficient has incentive to reduce its risk exposure. Any increase in the variance of profit would in fact increase 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 crops' failure), holding both the mean and the variance constant.[24] This implies that an agent with a positive and significant DS coefficient try 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 behavior in a risky environment. Risk averse farmers would be more wiling 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 help us evaluating 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). 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:

$$RP = \mu_2 \frac{AP}{2} - \mu_3 \frac{DS}{6} \tag{12}$$

where $\mu_2$ and $\mu_3$ are respectively the second- and third- order moments of the distribution of profit.

Contrary to Antle (1987) and Koundouri et al. (2003 and 2006) we associate neither the AP and DS coefficients nor the risk premium to specific inputs (i.e. the index k is dropped in equations (10), (11) and (12)). This is because we embrace the view of Groom et al. (2008), that 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. For this reason the preferences over moments of profit should remain the same across inputs (Groom et al., 2008). We thus restrict the parameters as it follows: $\theta_{jk} = \theta_j$ and hence $AP_k$ = AP, $DS_k$ = DS and $RP_k$ = RP.

We provide an empirical assessment of these three components below, with focus on the effect of the adoption of different irrigation technologies and the territorial and institutional heterogeneity affecting irrigation decisions.

The risk premium can be further used to construct an explanatory variable that proxies risk attitudes (Koundouri et al., 2003). This variable can then be used to models explaining the determinant of irrigation as a function of risk attitude, and farm specific characteristics. Furthermore, this proxy can be used to estimate the welfare effect of policies such as water restriction, making better assumption on farmers' reaction to such policies.

[24] Menezes et al., 1980; Antle, 1983, Di Falco and Chavas, 2009.

# 4 Data

We compile a rich dataset comprising farm level data from the Italian Farm Accountancy Data Network (RICA). Farm data include more than 122,800 farms and refer to the period 1981 to 2003. Data are unbalanced with farms included into the dataset for a maximum of 22 consecutive years.[25] Sample design is adjusted every year, however, the need to develop historical series urges researchers to prefer farms surveyed in the past. Around 77% of the selected farms had taken part to the RICA in previous years (Mari et al., 2007).

By relying on panel data we can capture both variation over farms, similar to regression on cross-section data, but also variation over time. The latter has been weakly investigated in the literature because of the scarce availability of data following the same farm across time. Omitting time variations may cause a serious problem when analyzing risk attitude, especially when farmers are exposed to significant regulatory or policy changes (e.g. the case of the Common Agricultural Policy (CAP) reform in Europe) or under climate change scenario.

Data included in this panel is subject to strict regulation of data collection and harmonized in the whole European Union. Notably, RICA is a source of microeconomic data to feed in the Farm Accountancy Data Network (FADN) of the European Union. Such database is queried to get appropriate responses to EU policy decisions. Data reliability is high due to some specific features of the RICA survey: in Italy there is a legal obligation for private subjects to answer to statistical surveys.[26] Furthermore, RICA's on-field data collecting is carried out by specialized operators, often belonging to farmers' associations.[27]

A careful sample selection applied by RICA allows to consider the selected farms as representatives of the universe of Italian farms. According to the methodology established by the European Union, the sample is *stratificated* on three variables: geographical location, type of farming and economic dimension.[28] To allocate sample farms in the strata, three strategic variables are taken into consideration: Standard Gross Margin (SGM), Gross Output at Base Price and Level of Costs. Standard Gross Margin, in particular, is the concept used to determine the economic size of farm: the SGM of a crop or livestock item is the value of output from one hectare or from one animal less the specific cost of inputs required to produce that output. SGMs are expressed in European Currency (€) and are also used in the Farm Structure Survey organized by Eurostat and in the general census.

The dataset provides detailed information about production patterns, farm economic size and main production orientation, input expenditures by crop (for key inputs such as seeds, fertilizers,

[25]Notably, nine farms, all in the Tuscany region, are observed over a 22 years period.

[26]According to the legislation, no remuneration to the respondent is due.

[27]This has two positive consequences: the first one is the better understanding of technical details during data collection, which increases data reliability. The second benefit is that farmer's may have better acceptance of the survey if conducted by people belonging to category associations.

[28]Stratification is a statistical technique used to increase sampling efficiency (i.e. to minimize the number of farms required to represent the variety of farms in the field of observation).

plant protection and irrigation water), income, structural characteristics of the farms (such as altitude, soil quality and soil gradient), new investments, water sources, irrigation methods, subsidies receives, insurances by crop and calamity expenditure. Each farmer also reports the total agricultural land used, the extension of the irrigable land and the effectively irrigated area. The summary statistics for key variables included in the empirical analysis are reported in Table (1) and Table (2).

Table 1: Descriptive statistics: farm structure

| **Variable** | **Mean** | **SD** | **Min** | **Max** |
|---|---|---|---|---|
| farm id | 55,398 | 36,485 | 1 | **122,801** |
| year | 1992 | 6.4 | 1981 | 2003 |
| Economic Dimension Index | 4.4 | 1.2 | 0 | 7 |
| Altitude (MASL) | 281.6 | 286.6 | 0 | 2,000 |
| Land quality index | 2.0 | 0.3 | 1 | 3 |
| Nb of crops reported | 4.7 | 2.2 | 1 | 31 |
| Surface allocated (ha) | 20.7 | 43.2 | 0 | 4,396 |
| Surface irrigable (ha) | 7.4 | 25.1 | 0 | 3,592 |
| Surface irrigated (ha) | 5.7 | 20.1 | 0 | 3,494 |
| IRRIG (dummy) | 0.55 | 0.50 | 0 | 1 |
| CONSORTIUM (dummy) | 0.34 | 0.47 | 0 | 1 |
| AUL irrigated/AUL | 0.8 | 0.32 | 0 | 1 |

Total observations: 342,640

Table (1) shows the statistics for 122,801 farms during the period 1981-2003. The Economic Dimension Index takes values from 0 (smaller agricultural holdings, less then 1 UDE) to 7 (over 100 UDE), and is calculated according to the economic dimension units (UDE) determined by the Farm Accounting Data Network (FADN) of the European Commission. The average dimension of the agricultural holdings in the sample is slightly higher than 4 (with 4 corresponding to 8 to 6 UDE).

Table 2: Descriptive statistics: farm revenue and costs

| Variable | Mean | SD | Min | Max |
|---|---|---|---|---|
| farm id | 55,398 | 36,485 | 1 | **122,801** |
| year | 1992 | 6.4 | 1981 | 2003 |
| gross standard revenue | 19.5 | 38.7 | 0 | 833.3 |
| gross value of production | 83,723 | 205,215 | 0 | 24,800,000 |
| net profit / loss | 45,072 | 121,424 | -1,164,942 | 20,400,000 |
| total expenditure | 38,651 | 104,390 | 115 | 12,400,000 |
| variable costs | 37,861 | 101,620 | 0 | 10,000,000 |
| fix costs | 19,163 | 51,727 | 2 | 5,065,910 |
| new investments | 10,127 | 159,358 | 0 | 68,000,000 |
| Expenditure: | | | | |
| - irrigation | 326 | 1,909 | 0 | 147,847 |
| - fertilizers | 2,879 | 5,916 | 0 | 598,940 |
| - plant protection | 1,995 | 7,736 | 0 | 1,609,241 |
| - seeds and new plants | 2,018 | 12,352 | 0 | 3,200,000 |
| - insurance | 220 | 1,621 | 0 | 211,950 |
| -insurance against calamities | 140 | 2,334 | 0 | 537,005 |

Monetary values are expressed in euro (€).

The following Tables (3) and (4) provide information on the main irrigation methods adopted as well as on the water sources across the whole italian territory. We analyzed the same tables for specific regions[29] observing significant differences both in term of irrigation methods and main source of irrigation water. This depends on the crops cultivated but it is also due to the heterogeneous topographical and soil quality feature of the Italian peninsula. For example the Po river basin area in the north of the country has not traditionally faced hydrological constraints, while areas in the south of the peninsula face systematical periods of drought during the summer period.

Table 3: Irrigation sources

| | Freq. | Percent | Cum. |
|---|---|---|---|
| Farm well | 61,193 | 30.8 | 30.8 |
| River or lake | 58,933 | 29.7 | 60.5 |
| Collective irrigation | 66,859 | 33.7 | 94.1 |
| Other | 11,660 | 5.9 | 100 |
| Total | 198,645 | 100 | |

We further integrated the farm level dataset with climatic variables. These are monthly average temperature, monthly average maximum and minimum temperatures and monthly cumulated

[29]Tables by region are non reported, available upon request.

Table 4: Irrigation methods

| | Freq. | Percent | Cum. |
|---|---|---|---|
| Furrow | 8,139 | 4.1 | 4.1 |
| Scroll | 62,696 | 31.6 | 35.7 |
| Sprinkle | 99,033 | 49.9 | 85.5 |
| Dripping | 18,317 | 9.2 | 94.7 |
| Other | 10,460 | 5.3 | 100 |
| Total | 198,645 | 100 | |

precipitation, averaged at municipality administrative level from numerous meteorological stations located across the italian territory. Meteorological time series come from the main networks operating in the Italian territory, as collected and elaborated by the Italian Environmental Agency (APAT). These data are available for the whole period under analysis (1981-2003). We associated the climate data to each farm, accordingly to the municipality it belongs to.[30]

## 5 Estimation Procedure and Preliminary Results

The first aim of our estimation procedure is to obtain the sample-average risk parameters. We report the results for there main inputs: fertilizers, plant protection and irrigation water.

In the first step of the estimation procedure we estimate the conditional expectation of profit using a quadratic functional form. We regress total observed profit from crops production on all levels, squares and interaction of input expenditures.[31,32] The choice of the linear quadratic form is coherent with the recent literature (e.g. Kumbhakar and Tveteras, 2003; Koundouri et al., 2003; Koundouri et al., 2006; Groom et al., 2008). We compute a within estimator by using the fix effect model with standard errors clustered at the province's administrative level.[33] The residuals of this first estimation are used to compute conditional higher moments (variance and skeweness) using a sequential estimation procedure (Kim and Chavas 2003). That is, the square of the estimated error from the mean effect regression is used as a consistent estimate of the second central moment of the profit distribution (i.e. the variance), while the cube of the estimated error from the mean effect regression is used as a consistent estimate of the third central moment of the profit distribution (i.e. the skewness). The two moments so obtained are regressed (i.e. used as dependent variables) on the same explanatory variables included in the estimation of the mean effect.[34]

We use the coefficients of these estimations to compute analytical expression for derivatives of the expected profit on derivatives for higher moments, for each input. The nine expressions so

[30]When the match at municipality level was not possible, we did it at province's administrative level.

[31]Groom et al., 2008, Koundouri et al., 2006.

[32]All variables are scaled by their standard deviation.

[33]The Hausman test leads us to the rejection of the null hypothesis that the random effects method provides efficient estimates. In performing the test, we specified that the covariance matrices of both the FE and RE estimations are based on the (same) estimates disturbance variance from the efficient estimator (see Cameron Trivedi, 2010 p. 267).

[34]That is: input expenditures, their squares and interactions.

obtained are used to estimate the system of Equation (9).[35]

Table (5) reports the estimation results of the farmers' risk attitude. These have been estimated using a three stage least square (3SLS) model.[36] We used as exogenous instruments the maximum and minimum average temperature and the cumulated precipitation during the "growing season" ($1^{st}$ of March to $31^{st}$ of September). These exogenous variables are appropriate instruments as they are assumed to be exogenous to risk attitude, but correlated with irrigation, plant protection and fertilizers choices.[37] Through the 3SLS procedure we exploit inter-equations correlation of errors, as we believe that errors across the three equations of the system are correlated.[38] Notably, the three input analyzed (fertilizers plant protection and water) are used jointly and their use is determined for a given location by the farmer.

The risk parameters are constrained such that $\widehat{\theta}_{2k}=\widehat{\theta}_2$ and $\widehat{\theta}_{3k}=\widehat{\theta}_3$, for the reasons discussed in section (3).[39] The estimated parameters for the second and the third moments are used to compute the population average AP and DS risk aversion measures (calculated as indicated in Equation (10) and Equation (11)) .

In a second step, the estimated risk parameters will be incorporated into a discrete model of technology adoption, along with climate variables and farmer's characteristics.

Table 5: Estimation Results

| | **Cereals** | **Arable Land** | **Field Vegetables** |
|---|---|---|---|
| AP | 2.064*** | 0.687*** | 0.341*** |
| DS | 2.541*** | 0.183*** | 0.062*** |
| **Intercepts:** | | | |
| Fertilizer | 0.088*** | 0.028*** | 0.198*** |
| Plant protection | 0.069*** | 0.100*** | -0.000 |
| Irrigation water | 0.018*** | 0.006*** | -0.000*** |

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

[35] We have at this stage nine new data series as we are considering three moments and three key production inputs.

[36] Results were also obtained using a seemingly unrelated regression model (SUR). The coefficients obtained were in line with those obtained using the 3SLS estimation procedure.

[37] To be noted that we refer here to *current year's* temperature and precipitation, while we do believe that long term trends in climate may affect farmer's risk attitude.

[38] 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 statistically significant correlation between the errors in the three equations. This should be expected as the marginal contribution of fertilizers, plant protection, and irrigation water to the expected profit may have similar underlying determinants.

[39] k indexes the three inputs: fertilizers, plans protection and water.

The reported results exhibit some interesting features. Table (5) shows the AP and DS parameters for different categories of farms, grouped accordingly to their main farming activity.[40] Notably, previous literature suggests that conclusions on risk attitude of a given group of farmers can't be extended to producers predominately growing other crops (e.g. vegetables).[41] Italian farmers specialized in the mentioned cultivations seem to be risk averse, and thus their preferences shall be represented through a concave utility function. Farmers specializing in vegetables exhibit lower risk aversion than those specializing in cereals and arable land crops.[42] This indicates that farmers are willing to sacrifice a portion of their expected profit in order to avoid the risk associated with fertilizers, plant protection and irrigation water used as input in the production function. However, producers of different crops are willing to do so to different extents. The significant and positive DS measure indicates that farmers exhibit down-side risk aversion, thus being averse to a profit distributions skewed towards negative values. Farmers are willing to edge against disastrous events, especially those specializing in cereals. Farmers specialized in field vegetables production exhibit less risk aversion also with respect to extreme events.

By analyzing the constant terms we can infer that over the whole period, farmers seems to have used inputs efficiently. Estimates of the intercepts that are different from zero can be interpreted as deviations from profit maximizing choice of the particular input (Groom et all., 2008). Cereals producers have been generally less efficient than farmers specialized in arable land crops and field vegetables, especially in the use of irrigation water. The constant term associated to irrigation water input for cereals (excluding rice) is positive, significant, and higher than the constant associated to irrigation water for the farmers specialized in vegetables and arable land. This may imply that irrigation water has been overused by cereals producers.[43] One of the explanation may be that in many areas in Italy poorer soil types of marginal quality are often cultivated with remaining or lower quality cereals seeds. In this areas, farmers most likely do not adopt efficient farming practices adopted elsewhere in their land.

By making use of our unique 23 years panel, we also investigate how the risk behavior of the sample evolved over time. Table (6) reports the AP and DS parameter for cereals producers, dividing the sample into two separated decades: the period 1981 to 1991 and 1993 to 2003. The choice of the cutoff year is not arbitrary: in 1992 the Common Agricultural Policy (i.e. the the agricultural policy of the European Union) was reformed to shift from product support (through prices) to producer support (through income support).[44] These changes aimed at improving competitiveness of EU agriculture, developing a more free agricultural market and stabilizing the EU budget expenditure. Following the reform the level of support to cereals producers reduced of

[40] Conoff and O'Neill (2012) survey a range of studies that calculates the Arrow Pratt measure of relative risk aversion and finds that the estimated values ranges from -142 to +11.

[41] Groom et al., 2008.

[42] This is coherent with the tendency of the Italian Insurances Companies to consider cereals producers more risk averse than vegetable producers.

[43] A constant term close to zero indicates that, given the marginal cost, the input is efficiently used. This is because the estimated system of equations (9) is derived from the first order condition for expected profit maximization. If there are no systematic deviations from expected utility maximization and no specification errors the intercepts for each input shall be equal to zero (Antle, 1987).

[44] The reform is known as the "MacSharry reform", after the former EU Commissioner for agriculture Ray MacSharry.

Table 6: Risk Aversion Evolution over Time (Cereals Excluding Rice)

| | **Whole Sample** | **1981-1991** | **1993 - 2003** |
|---|---|---|---|
| AP | 2.064*** | -0.175 | 1.992*** |
| DS | 2.541*** | 2.948*** | 2.416*** |
| **Intercepts:** | | | |
| Fertilizer | 0.088*** | 0.059*** | 0.098*** |
| Plant protection | 0.069*** | 0.105*** | 0.039*** |
| Irrigation water | 0.018*** | 0.038*** | 0.019*** |

p < 0.10, ** p < 0.05, *** p < 0.01.

about 30%, with cereals granted prices lowered by 35%, to levels closer to the equilibrium market price. Compulsory set-aside measure and other accompanying measures were also introduced, such as agri-environment programs,[45,46] early retirement and diversification.[47] Given the nature of the mentioned changes, we can speculate that the reform may have affected the risk attitude of our farmer's sample. In particular we expect that before the MacSharry reform farmers may have more incentive to undertake riskier production decision. Our results confirm this hypothesis: it is very interesting to notice that the risk preferences over the second moment of the distribution of profits (variance) has changed over time. Results reported in Table (6) shows that cereals producers have become more risk averse after 1992, thus increasing their willingness to give up a higher fraction of their expected profit in order to receive a given level of profit in the future with certainty. However, preferences over down side risk (profit skewness) have remained rather stable over time.[48]

Let us turn to the analysis of the determinants of irrigation adoption. Do do that, we implement a population-averaged probit regression with semi-robust standard errors.[49] The estimation results are provided in Table (7). We incorporate the estimated risk parameters, as well as long term climate realizations and other control variables, in a discrete choice model (e.g. probit), in order to analyze how production risk and farmer's risk attitude affect the decision to adopt irrigation technology. As discussed, the literature shows that risk preferences affect the probability of adoption of irrigation technologies and provide evidence that farmers invest in new technologies as a means to hedge against input related production risk (Koundouri et al., 2006).

[45]Agri-environment measures are designed to encourage farmers o protect and enhance the environment of their farmland. These programs include water use reduction measures, designed to preserve water resources by reducing irrigation and/or reducing water loss from the soil (European Commission, 2005).

[46]Hynes and Garvey (2009) use panel data techniques to model the participation of Irish farmers to agri-environmental schemes.

[47]See www.ec.europa.eu/agriculture/cap-history/1992-reform

[48]This conclusion has interesting implication and opens the venue to further research, as agent's risk attitude is often assumed time-invariant.

[49]We avoid potential efficiency loss, which could be an issue in performing a pooled model, by taking into account the dependence over time. This is made possible by the panel structure of our dataset. The population average model has different conditional mean than that for random effects model, unless the random effects are multiplicative or additive (Cameron Trivedi, 2010). We assume that the random effect model would not be appropriate, and thus the population average estimator gives consistent estimates.

We find that cereals and vegetables producers located at higher altitudes are less likely to adopt irrigation schemes. This probably reflects higher irrigation costs. Notably, a study of the European Union includes Northern Italy (where most of the farm at higher altitudes are located) among those European regions is which irrigation is carried out mail as a complement to rainfall. In these countries or regions, however, the areas of irrigated agriculture tend to be increasing, as farmers invest in irrigation equipment, primarily in order to reduce risk and increase yields of certain drought-prone crops.[50] A higher land quality index is positively correlated with the probability of adopting irrigation.This could be explained because of a possible higher marginal return of irrigation in areas with higher soil quality. Interesting, crops diversification (i.e. number of crops cultivated) has a positive significant impact on the probability of adopting irrigation for cereals producers but is not significant for open field vegetables producers. In general, higher expenditure in other key inputs of the production function, such as fertilizers, have a positive significant impact on the probability to adopt irrigation.

We analyze long term averages of climate variables as a proxy of farmers attitude to climate change. Long term average maximum temperature are significant determinant of the probability to adopt irrigation for cereals producers, while the coefficients are not statistically significant for vegetable producers. However, higher minimum temperature are negatively correlated with the probability to adopt irrigation. This could be explained by the heterogeneity of the territory under analysis: farmers in regions with the higher long term minimum temperature are mostly located in southern areas, where irrigation is more expensive. These farmers may rely on other adaptation strategies then adopting irrigation, such as growing crops more heat-tolerant. Higher long term average rainfall makes farmers more likely to adopt irrigation in the case of cereals producers but less likely in the case of vegetable producers. This result shall be further investigated, for example using location dummy variables, as it may relate to the geographic concentration of the producers. In one case the driving effect may be the fact that irrigation is adopted as a complement to rainfall (in this case we would expect a negative significant coefficient, as we obtained for vegetables producers). In other regions the price effect may prevail as in areas traditionally more water-abundant irrigation may be cheaper.

We now comment the results for columns (2) and (4) (Table (7)), providing insides on the coefficients associated to the variance and skewness of the revenue distribution. These captures how farmers adapt to weather effects, as we assumed that climate is the primary source of production risk (see Section (2)), modeled through the econometric error term. The most interesting results come from the analysis of the skewness parameters, interpreted in light of the results presented in Table (5). Cereals producers display the higher downside risk aversion (Table (5)). This is coherent with a positive and significant skewness coefficient for cereals producers: agents with the higher DS risk aversion are more likely to adopt adaptation strategies that reduce the probability of crop failure (e.g. to adopt irrigation technology). The skewness coefficient of vegetable producers is also positive but not statistically significant, which may be related to the lower DS risk parameter displayed by this producers' group (Table (5)). The coefficients parameters associated to the variance of revenue distribution are statistically significant but negative for both producers groups. This may indicate that farmers are investing in adaptation strategies other than irrigation to reduce risk exposure.

[50] Source: "The Environmental Impacts of Irrigation in the European Union" (2000).

Columns (1) and (3) of Table (7) show the results of estimations including risk premiums as explanatory variables, instead of the variance and skewness of the revenue distribution. The coefficient is significant in the case of cereals producers but not for vegetable producers. We obtained a negative coefficient for cereals producer, which may be counterintuitive. This may be due to the fact that the more risk averse cereals producers are located in areas with more arid climate and thus a more expensive and/or regulated access to irrigation water.[51]

These results evidence the importance of understanding the group-specific characteristic of the impacted farmers (which are in turn determined by local climate, territorial characteristics and main farming activity) when designing effective adaptation policies involving irrigation technology and more in general the access to water resources.

[51] A deeper analysis of this claim is left to a further extension of this paper, as we plan to include location dummies in the empirical investigation.

Table 7: Estimation Results Irrigation Probit

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Cereals | Cereals | Vegetables | Vegetables |
| Dep. Variable: Irrigation Dummy | IRRIG | IRRIG | IRRIG | IRRIG |
| Altitude (MASL) | -0.0027*** | -0.0027*** | -0.0013*** | -0.0013*** |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Land Quality[a] | 0.2069*** | 0.2095*** | 0.1162*** | 0.1039** |
| | (0.045) | (0.045) | (0.044) | (0.043) |
| Nb of Crops | 0.0254*** | 0.0214*** | 0.0132 | 0.0100 |
| | (0.006) | (0.006) | (0.012) | (0.012) |
| Fertilizers (€) | 0.000014*** | 0.000022*** | 0.000027* | 0.000019 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Plant Protection (€) | 0.000004 | 0.000014*** | -0.000011 | 0.000026** |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| Max Temperature: LT average | 0.0509*** | 0.0537*** | 0.0614 | 0.0456 |
| | (0.014) | (0.014) | (0.037) | (0.038) |
| Min Temperature: LT average | -0.2092*** | -0.2114*** | -0.1950*** | -0.1821*** |
| | (0.021) | (0.021) | (0.029) | (0.029) |
| Precipitation: LT Average | 0.0092*** | 0.0090*** | -0.0120*** | -0.0118*** |
| | (0.001) | (0.001) | (0.002) | (0.002) |
| Risk Premium (cerals) | -0.0099** | | | |
| | (0.005) | | | |
| Risk Premium (vegetables) | | | 0.0001 | |
| | | | (0.000) | |
| Variance (cereals) | | -1.0544*** | | |
| | | (0.203) | | |
| Skewness (cereals) | | 0.2157*** | | |
| | | (0.069) | | |
| Variance (vegetable) | | | | -0.1055** |
| | | | | (0.046) |
| Skewness (vegetable) | | | | 0.0054 |
| | | | | (0.003) |
| Constant | 0.5446* | 0.5075* | 3.2454*** | 3.4267*** |
| | (0.294) | (0.294) | (0.750) | (0.762) |
| Observations | 22,259 | 22,259 | 9,655 | 9,655 |

Monetary values are expressed in euro (€).
Semi-robust standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
[a]Land quality is an index taking values: 1(low), 2 (average) and 3 (high).

# 6 Preliminary Conclusion and Extensions

As discussed in the earlier sections, there are significant variation in irrigation practices and efficiency levels of the same across regions in Italy. Given the scale of data we have, it will be possible to conduct sub-sample analysis of contrasting regions and derive heterogeneous parameters associated with risk preferences and farm input adaptive mechanism to climate change. This will also allow us to better study how farmers use irrigation as a coping mechanism to climate change.

One important contribution of this paper to the existing literature is the use of the rich panel data structure to capture both the within and between variation in risk preference. Our preliminary 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 events exhibits more time-invariant characteristics.

Our data permits to conduct similar analysis for different farmers' group. Following Groom et al. (2008), we compared the risk preferences derived for vegetables and arable land with that of cereals, confirming the existence of heterogeneous risk attitudes between different producers' categories. The differences in policy measures such as the agriculture support prices in Europe across vegetables and cereals categories can also be used to further study policy lessons on farm level input choice responses.

We found consistent results between farmers' risk parameters and the drivers for adopting irrigation technology. In particular, higher downside risk aversion is a key determinant in the decision to adopt irrigation technology. Our results stress the importance of understanding the group-specific characteristic of the impacted farmers (which are in turn determined by local climate, characteristics of the territory and the main farming activity, among others) when designing effective adaptation policies in the agricultural sectors.

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