INDEX BASED COMPENSATION FOR WEATHER RISK IN THE ITALIAN AGRICULTURE. A FEASIBILITY STUDY BASED ON ACTUAL HISTORIC DATA.

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DRAFT – NOT TO BE CITED

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Abstract

The paper explores the feasibility of the use of weather index based derivatives for farms' risk management in an Italian province. Based on a combination of detailed local weather data and of data on farms' yields, various possible weather indexes are found that are highly correlated with yields of the major crops in the area. Simulations show that hedging through such index based derivatives can be effective in protecting the stability of farms' incomes, at a cost that is likely to be much lower than that of the current system of subsidized crop insurance and ex-post compensation.

Keywords

Agricultural risk management, weather derivatives, index based yield insurance.

Introduction.

Since 1974, when the Italian *Fondo di Solidarietà Nazionale in Agricoltura* (FSN) was created, risk management in the Italian agriculture has been strongly influenced by the intrusive presence of the public sector. The rhetoric has been that farmers alone either would not correctly perceive the risk they faced, or could not adequately manage their risk, given the limited development of the markets for risk management tools, and therefore the intervention of a "benevolent State" was needed.

The intervention evolved in the forms of a subsidy to crop insurance premiums paid by farmers, and of ex-post compensation for damages that were not covered by insurance. The budget allocated to the FSN over the years has been non negligible. In the period 1981-2002, the average yearly public expense for this kind of assistance has been of 225 Million €.

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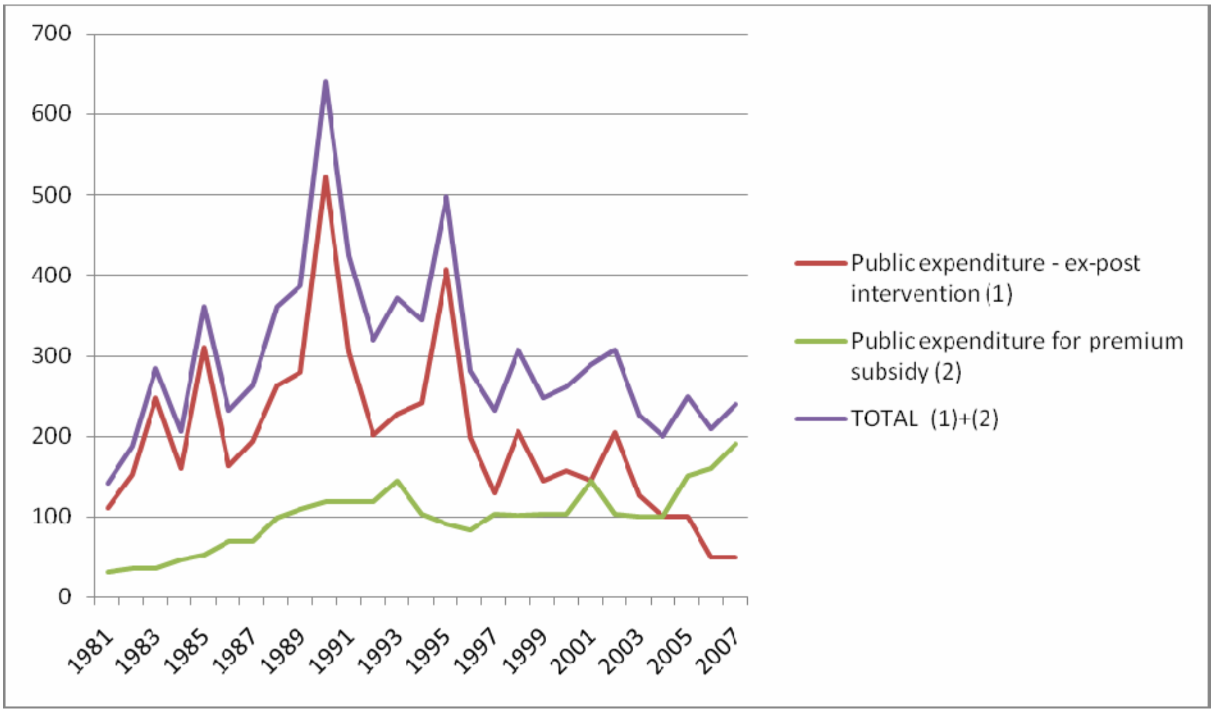
Figure 1: Italy FSN expenditure for compensation payments and insurance premium subsidies 1981 – 2007 (Mln €)



Source: Italian Ministry of Agriculture

However, the results of the strong Government's involvement are rather disappointing if we consider that, after more than 30 years of assistance through release of premium subsidies, the market for crop insurance has not been able to develop beyond that for a few risks (typically hail and fire) that existed and were widely used even before the strong public involvement. On the other hand, ex-post compensation has absorbed the larger share of the available funds, until recently, when it has been limited by the availability of public funds rather than by the competing role played by market-based preventative actions, suggesting that the demand for it has been strong and not related to the competing role of insurance.

A fair interpretation of such state of affairs would highlight at least two important points that this paper tries to assess, and that relate to forms of both market and state failures. First, agricultural risk has characters that make traditional market based instruments (such as traditional insurance) less effective than internal solutions and strategies (such as those based on income source diversification, storage and marketing management, technological innovation adoption, and so forth). Second, once a public institution that generates rents at various levels has been created, it is very difficult to reform or to abolish it. What should appear clear by now, based on the long Italian experience, is that the combination of a failing market with a failing State is hardly capable of assisting farmers in dealing with their risk.

The research we are conducting and whose preliminary results we present in this paper tries to provide indications for a possible solution to the highlighted inefficiencies, by reconsidering what the fundamental origin of production risk in agriculture is, why traditional market instruments fail, and why the presence of the State – at least the way in which it has been common in Italy – has been more detrimental than beneficial to farmers and to the general public.

We advance the possibility that the most relevant component of production risk, i.e., the one that can be either directly or indirectly traced back to the variability weather conditions, could be dealt with use of appropriately designed derivatives whose underlying asset is a combination of objectively measurable local weather indexes. The mechanism could either be exploited by a Government that wants to provide assistance to farmers in managing their production risk, or used by insurance companies to design effective crop yield coverage.

The advantages of such an option over the current system of subsidized crop insurance and ex-post compensation would be manifold. First, the problems related to asymmetric information on the actual extent of damages would disappear. If the contract is appropriately designed, that is, if compensation is based on the index value rather than on the actually measured farm's loss, neither adverse selection nor moral hazard would plague this type of insurance. No single farmer would be able to strategically affect the value of the composite weather index, and no costly damage adjustment is needed.

Second, the public nature of the weather information, as opposed to the private information that insurance companies have on the past performance of their insurance funds, might stimulate competition among supplier of risk management tools, therefore by reducing the problem of rent capturing that so often plagues the insurance industry.

Third, yield risk management through weather index based derivatives could complement the management of other relevant risks, such as for example price risk, that for some commodities can also be managed through financial instruments.

Fourth, the development of such a system would require no major reform in the existing legislative framework, to the extent that index based coverage could be included among the possible contracts offered by insurance companies to farmers (and, at the beginning, also entitled to public support, in accordance with the EU guidelines on state aids) or among the publicly provided risk management tools (for example, by linking ex-post compensation in an area to specific values of the composite index rather than to a complex and politically vulnerable mechanism of disaster declaration).

The main practical problem that need to be resolved is the discovery of the most appropriate weather index to be used, and this is the research direction that we take here. Such an index needs to be highly correlated to the production that one aims at protecting, and it may well be highly specific to the specific homogeneous area that one intends to cover. Fortunately, the existence of a diffused network of weather stations makes the problem less relevant for the conditions of the current Italian agriculture, of what it might be, for example, for the conditions of less developed Countries.

In this paper, we present the preliminary results obtained by comparing the time series of weather data collected for an Italian province with the series of yields of the major crops for the same province, and show how the index could be formed and utilized to define an insurance contract. The results are to be considered still preliminary, given that delay in obtaining longer series of the weather indexes and more detailed local yield data has, up to now, prevented us to explore some of the implications of the proposed scheme. Nevertheless, we feel that the material presented is sufficient to feed a fruitful discussion on the topic.

The paper is organized as follows. First, in section 2, a brief overview of the past history and current status of agricultural risk management in Italy is presented, to the aim of highlighting the major problems that afflict it. Then, in section 3, a simple method for finding a suitable weather index is described and applied to the case study of three crops in the Italian province of Grosseto. Section 4 will discuss the results obtained and the limit of the analysis performed so far, suggesting the directions for further research in which we are currently involved, and the final section 5 concludes by summarizing the main results and by providing the initial possible practical implementation guidelines.

2 The current system of agricultural risk management in Italy

Public intervention in agricultural risk management in Italy has a long tradition. The *Fondo di Solidarietà Nazionale in Agricoltura (FSN)* was instituted in 1974 with the aim of providing farmers with the means to effectively manage their production risk. The system has evolved over the years with numerous reforms until recently, when Italy has adopted the Community guidelines for state aid in the agricultural sector concerning compensation for damages and insurance premium subsidy, with the issue in 2004 of the Legislative Decree n° 102 on the 29th of March. The Decree defines new operational rules for the FSN and disciplines on financial tools for risk management and capitalisation incentives in favour of agricultural firms. The Italian FSN is composed of two different supply services: financing of insurance policy and ex-post payments, although this general principle is subject to many exceptions that will be described in the following paragraphs.

2.1 Ex-post compensation

The Law instituting the FSN states that, in case an exceptional events occur, farmers are entitled to a compensation for the damages suffered.

The discipline of the compensation aid has not changed very much over time.[1] In order to activate the compensation, the status of exceptional event needs to be official recognized by the Central Government. To this aim, when an adverse event occurs (most commonly drought, flood and late frost) the involved regional Governments present a request to the Ministry of agriculture that, after verifying the actual extent of damages, issues the decree which entitled farmers to ask for compensation.

Compensations are then paid based on criteria that are determined by the Ministry of Agriculture, depending on the availability of funds and on the actual extent of damages. The criteria according to which compensation aids are provided by the Ministry of Agriculture is the decrease in the value of production below a specified threshold. The correlation between actual damages and compensations received is therefore very weak. The lack of an objective criteria that allows a proper assessment of the real causes and extent of damages has led to a persistent discrepancy between the amount of compensations claimed by the farmers through the regional representatives and the amount of compensation actually paid.

Table 1: comparison between damage evaluation by Regions and real State expenditure for compensation aid in Mln/€

Year	Assessment of damages according to the Regions' administrations	Compensation aid paid
2002	1,208	204
2003	1,380	127
2004	-	100
2005	947	100
2006	659	50

[1] The various laws concerning the FSN have only modified the damage threshold that defines an exceptional event, to make it consistent with the guidelines on State aids in agriculture and with the provisions of the Uruguay Round Agreement on Agriculture. Decree no. 102 of 2004 has set the damage threshold at 30% of normal average production.

2.2 Subsidised crop insurance

The current crop insurance system in Italy, as defined by the Legislative Decree n° 102-2004 and the subsequent Ministerial decrees related to specific questions, has the following main features:

- Insurable events concerning crops: hail, wind, frost, drought, excess of rain, flood. For what concerns farm structures, the insurable events are: hail, snow, wind, tornados, hurricanes and lightning;
- Regarding insurable crops, the Ministerial Decrees which define the Annual Insurance Plan have extended to almost all crops the entitlement to premium subsidy. The structures that can benefit of public subsidy are hail nets and greenhouses. Starting from 2006, subsidised insurance is allowed also for losses deriving from cattle disease.
- According to Legislative Decree n° 102-2004 the insurance schemes entitled to state subsidy are: single-peril, combined/named perils, and finally, multi-peril policies depending on the fact that the insurance contracts covers one or more predetermined perils. The last two insurance schemes are considered on an experimental basis. This implies that they benefit of 80% premium subsidy. Starting from year 2007 the related annual crop insurance plan, as a consequence of the fact that the European Commission has not recognised the exception in favour of multi and named peril that the Italian government has introduced in its crop insurance system, has established the end of the experimental phase for all perils except drought and floods. This means that farmers who have not subscribed any kind of insurance scheme against drought and/or floods could still benefit of compensation aids.

From year 2007 on, State contribution is granted up to a maximum of 80% of the premium and only to those policies which pay an indemnity when at least 30% of the average production is damaged, thus eliminating the threshold of 20% if losses occurred in disadvantaged areas.

The total amount of State intervention is defined in the annual insurance plan and depends on public budget and on the number of farmers who have subscribed policies. The terms through which public subsidy is granted are subordinated to the actual availability of public resources (Ministerial Decree of 15th of July 2004). In order to adapt public subsidy to real risk exposure of single areas and regions, State financial requirements are defined annually on the basis of parameters. State contribution varies according to different elements: type of insurance scheme; area; weather event, insurance cover; type of crop and/or structure.

Starting from the 1st of January 2005, farmers are obliged to subscribe crop insurance for the whole area devoted to the crop they want to insure that falls within the borders of the township they belong to. Subscription of policies can be both on an individual and on a collective basis (through Consorzi di Difesa, cooperatives and their operating consortiums).

The current legislation also allows farmers to create mutual funds. They operate in favour of insured crops and structures and for those crops and structures which have been damaged and are not included in the annual insurance plan. The condition for acceding to payments is that loss regards at least 30% of crop production. Aids can consist of different kind of intervention, such as: investment grant, five year graduated payment loans, national insurance contribution, credit operations deferment.

2.3 Diffusion of crop insurance in Italy

2005 represents the first year of full implementation of Reform of the Italian crop insurance system because, starting from the 1st January 2005 the obligation of insuring the whole production of a certain crop is in force.

For what concerns the spread of crop insurance after the reform of the system, available data do not seem to show a significant change in comparison with the past situation: the number of contracts subscribed has not increased radically.

In terms of insured hectares there has been an increase that is due to the obligation of insuring the entire cropped area of a certain commodity. In 2004, there has been an increase of insured production value but again in 2005 this value has not shown a positive growth.

State contribution is constantly increasing annually, unfortunately, this is not due exclusively to the increase of policies but depends also on the rise of unit prices of agricultural products and the increasing share of combined perils policies that by law can benefit of the maximum public subsidy to premiums (80%). Tariffs show a significant reduction between 2003 and 2004, but in 2005, compared with the previous year, there has not been a reduction maybe because of the increasing subscription of combined/named perils policies (Table 2).

In 2006, insured value has diminished. This is partly due to the decrease in agricultural products prices but also to the stagnation in the number of subscribed policies. The only change happened is the different distribution of policies among the different insurance schemes. Namely, hail policies have diminished in favour of an increased number of named perils policies, most of all "wind and hail" policy (table 3). Another important element to be considered is loss ratio (indemnities/premiums) which is well below 1. This means that the amount of premiums paid is almost double respect to indemnities received by farmers. Even if administrative, management and survey costs were included, the profit margin of insurance companies is extremely high with reference to their agricultural portfolio. If we look at loss ratios in countries where the supply side of the insurance market is sufficiently fragmented and the ratio between indemnities and premiums is the result of a competitive market, the ratio value is very close to 1.

Table 2: Evolution of the subsidized crop insurance market in Italy (vegetable production)

		2003	2004	2005	2006	Var. %
Policies	n°	213,293	212,231	212,383	211,444	-0.4
Insured Production	.000 t	14,359	14,894	14,833	14,805	-0.2
Insured Plants	.000	172,761	184.218	260,585	308,153	18.3
Insured hectares	.000 ha	950	982	1,074	1,125	4.7
Insured value	Mln €	3,334	3,582	3,637	3,521	-3.2
Premiums (P)	.000€	277,050	267.862	268,164	262,479	-2.1
Indemnities (I)	.000€	116,647	177.439	159,771	145,291	-9.1
State Contribution*	.000€	112,000	152,165	176,756	174,879	-1.1
Average tariff	%	8.3	7.5	7.4	7,5	1.1
I/P	**%**	**42.1**	**66.2**	**59.6**	**55,4**	**-7.1**

Source: Own calculations on Ismea/Sicuragro data.

Table 3: Share of the different crop insurance schemes

	2004	2005	2006
Single peril (hail)	92.0	84.0	77.4
Combined/named perils*	7.7	14.4	19.6
All risk	0,3	1,7	2,9
TOTAL	100	100	100

*) this insurance scheme does not include coverage against hail, tornados, snow, hurricanes and lightning

Source: Our elaboration on Ismea data

Looking at loss ratio data relating some of the main regional and provincial Consorzi di Difesa in Italy, ranked in terms of insured value, we can see that data are consistent with national average and the discouraging aspect is that only three Consorzi out of seven show tariffs which are below national average.

Table 4: Insurance indicators concerning the main Consorzi di Difesa in terms of insurance value

		2001	***2002***	***2003***	***2004***	***2005***
		Percentage values				
TOSCANA*	I/P	93.19	110.80	88.99	78.40	66.47
	AVERAGE TARIFF	3.12	3.83	4.36	4.19	4.56
PROVINCE OF CUNEO	I/P	80.42	122.28	27.43	93.05	55.20
	AVERAGE TARIFF	12.64	13.15	12.76	10.41	9.33
PROVINCE OF PAVIA	I/P	248.21	51.37	6.64	125.10	28.23
	AVERAGE TARIFF	4.10	4.82	4.92	4.08	4.13
PROVINCE OF VERONA	I/P	96.31	46.09	20.34	85.94	196.46
	AVERAGE TARIFF	12.13	12.62	12.81	10.73	10.22
PROVINCE OF FERRARA	I/P	129.30	136.33	33.31	49.94	57.00
	AVERAGE TARIFF	10.83	11.70	12.42	10.54	9.85
PROVINCE OF PERUGIA	I/P	25.31	184.51	18.75	35.35	17.63
	AVERAGE TARIFF	6.85	6.46	7.90	6.69	7.24
PROVINCE OF FOGGIA	I/P	37.03	93.94	34.47	50.13	84.50
	AVERAGE TARIFF	5.90	5.54	6.13	4.54	4.56

*) In Tuscany there is a single consorzio covering all provinces

Source: Ismea/Sicuragro

The ratio between insured value of production and crop gross production value is a good indicator of the level of diffusion of crop insurance. This ratio has reached its highest value, during the last five years, in 2005 (14%). According to estimates, during year 2006, insured value was 16% of gross crop production. This percentage does not differ significantly from the previous, most of all if we think that insurance is the only available tool for production risk management in case of adverse weather conditions (Table 3).

Table 5: Value/Gross crop production value (Ml/€)

	2001	*2002*	*2003*	*2004*	*2005*
Gross crop production value	26.852	27.291	27.182	29.453	26.928
Insured value	3.232	3.216	3.406	3.716	3.797
Insured value/ Gross crop production value	**12,0%**	**11,8%**	**12,5%**	**12,6%**	**14,1%**

Source: Own calculations on Ismea and Istat data.

To give an example of the diffusion of crop insurance per single product, we have chosen some fruit products. Given that these products are not storable and that they do not benefit of the CAP single farm payment, fruit products are expected to show a higher share of insurance if compared with the value of production. Unfortunately, except for apples, whose insured value is increasing during the years, the other products are characterised by values that express a scarce interest of producers towards insurance.

3 Protecting agricultural income through weather derivatives in an Italian province

Many authors have discussed the mechanism of hedging production risk through weather derivatives (TURVEY: 2000; BERG *et al*: 2006; HARTELL *et al.* 2006), and therefore we would not repeat the details here.

We follow Hartell *et al.* in identifying the steps to be made in designing a risk management strategy as follows:

1. Identifying significant exposure of an agricultural producer to weather;
2. Quantifying the impact of adverse weather on their revenues;
3. Structuring a contract that pays out when adverse weather occurs; and
4. Executing the contract in optimal form to transfer the risk, either to another party or to the international weather market.

Each of these steps will require careful analysis and will present its specific challenges, yet the only truly essential precondition for such a mechanism to be devisable is that there exists an objectively measurable weather index which is highly correlated (either positively or negatively) with farm returns or with returns from one specific crops.

In this paper, we apply the procedure to the case of the Italian province of Grosseto, for which detailed weather data are available through the web site of the Tuscany's Agenzia Regionale di Sviluppo e Innovazione in Agricoltura (ARSIA-Toscana) and from the Laboratory of Agro-Meteorology Modelling (LAMM) of the Consiglio Nazionale delle Ricerche (CNR).

To determine farms' exposure to weather conditions, one could proceed by analyzing experimental models of crop growth, in which the effects of various environmental conditions (such as air and soil temperature, humidity, sunlight, wind, etc) are assessed, or by referring to expert opinion of agronomists, or even by surveying farmers' to collect their opinion on which ones are the most relevant weather parameters.

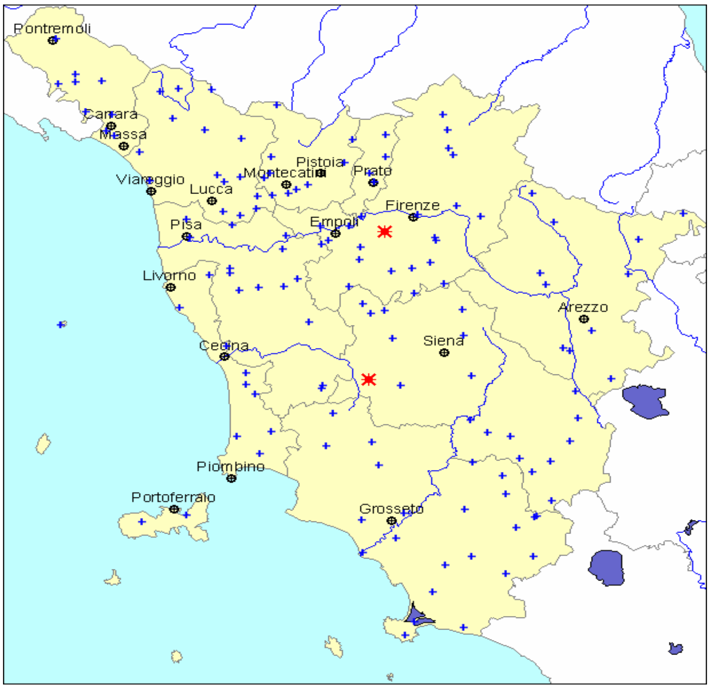
Although highly informative, these experiments and data will mostly assess the *ex ante* potential impact of weather on crop yields, neglecting the host of possible practical responsive actions that farmers can take to control the specific conditions in their farms, often at a very low cost[2]. We decided therefore to refer to actual data on farm yields and production as

[2] Indeed one of the problems with large part of the economic literature on farm risk management has been precisely that of neglecting the possibility of farmers' own response (see CAFIERO, 2003).

recorded by official statistics (Istat, Rica) to have an indication of the residual variability in yields and income that needs to be hedged after all other responses by farmers have already been considered, and for which a potential demand for insurance might exist, and to regress them on some index of weather conditions.

We collected the series of physical yields of the main crops in the area (wine grapes, fruits, cereals, industrial crops) from 1990 through 2004, and measured the correlation of such series with contemporaneous indexes of weather conditions, whose choice has been guided by regression analysis. In practice, we first reduced the number of weather dimensions through a principal component analysis (PCA), and then run a linear regression of the annual yield on the identified principal components of weather indexes.

Figure 2: Map of available weather stations in Tuscany



Source: http://www2.arsia.toscana.it/RilDati/Default.htm

In this paper we present the results relative to wine grapes, soft and durum wheat yields in the province of Grosseto, in Tuscany. For each of the 18 weather stations in the province for which we have data, and for each of the months between January and August (for grapes), or between August of the previous year and May (for wheat) we considered the following weather data:

- v_1: maximum daily temperature of the month;
- v_2: minimum daily temperature of the month;
- v_3: average of the maximum daily temperatures in the month;
- v_4: average of the minimum daily temperatures in the month;
- v_5: average of the average daily temperatures in the month;
- v_6: average of the maximum daily humidity in the month;
- v_7: average of the average daily humidity in the month;
- v_8: total millimeters of rain in the month
- v_9: number of rainy days in the month

This gives us a total of 18 x 8 x 9 = 1296 (for grape) and 18 x 9 x 9 = 1458 (for wheat) weather variables, some of which are highly correlated among themselves.

Of the 14 possible principal components, the first 9 capture most of the variability in the set of weather data, accounting for about 86.2% of the total variance in the case of grapes, and

86.6% in the case of wheat. We then run a regression of the average province's yields of wine grapes, soft wheat and durum wheat on the nine identified principal components and obtained the results summarized in table 6 below and illustrated in figures 2, 3 and 4.

The yield are obtained from two official sources: the Rica sample for the years 1990 through 1998, and Istat for the years 1999 through 2004.[3]

Table 6: Weather indexes highly correlated with average yields in Grosseto

crop	Index*	R^2
Wine grapes	$94,599 + 15,386\ x_1 – 7,306\ x_2 + 8,282\ x_3 – 2,339\ x_4 – 10,177\ x_5 + 9,619\ x_6 + 11,361\ x_7 – 19,844\ x_8 – 8,129\ x_9$	**0.904**
Soft wheat	$28,262 + 3,280\ x_1 – 1,313\ x_2 – 2,023\ x_3 + 1,657\ x_4 + 0,957\ x_5 – 1,980\ x_6 -2,926\ x_7 -1,121\ x_8 -0,078\ x_9$	**0.834**
Durum wheat	$30,266 + 3,973\ x_1 + 0,605\ x_2 -2,432\ x_3 + 0,174\ x_4 – 1,467\ x_5 – 0,811\ x_6 - 2,984\ x_7 -2,939\ x_8 + 1,571\ x_9$	**0.684**

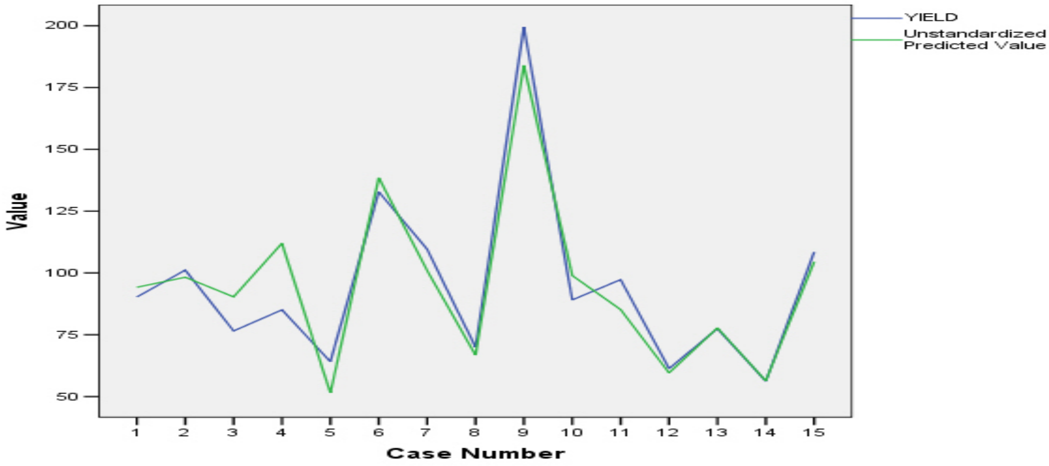
*) x_1 through x_9 are the factors extracted through the PCA

Although each of the components of the index could be interpreted, based on the specific weather variables that enter in the principal component with high coefficients, the purpose of this exercise is not to "understand" the reasons for residual yield variation, rather to provide an objectively measurable index that "happens" to be highly correlated to the yield. Again, the reason why we decided to do so is because knowledge of the specific mechanism through which weather variables affect yields, while interesting on its own, is almost irrelevant to the purpose of defining an index to be used to design a possible weather derivative to be used to hedge yield risk: the only thing that truly matters is the correlation between the index and the yield.

As measured by the R^2 of the regressions (see table 6) and as can be observed from the graphs in figure 3, 4 and 5, this correlation is quite high for the index we formed, although the close fit is in part due to the low number of degrees of freedom that results from a relatively low number of observations (15) compared with the number of explanatory variables included in the regression (9).

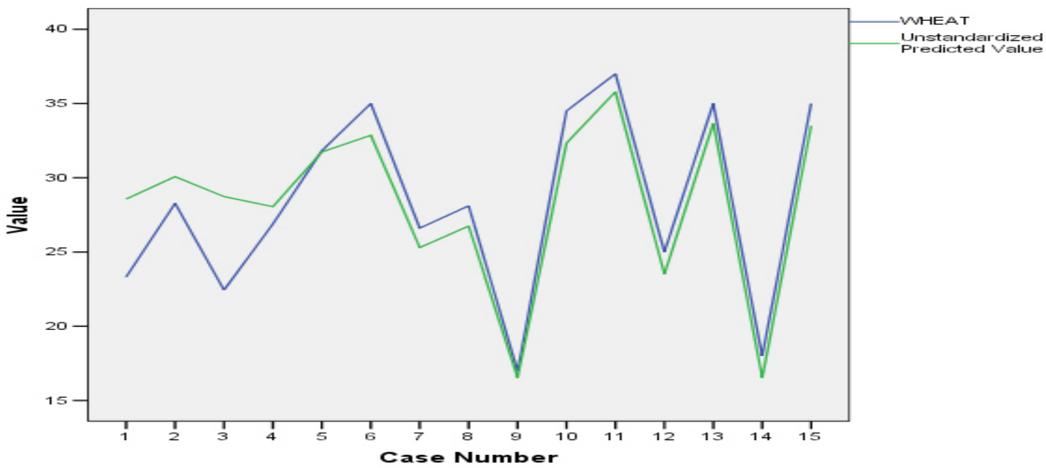
[3] We are actively exploring the possibility of accessing the average yields at the sub-provincial level from the Rica archives, which should give us a reliable series of yields from 1980 through 2005.

Figure 3: Comparison between grape average yield and weather index



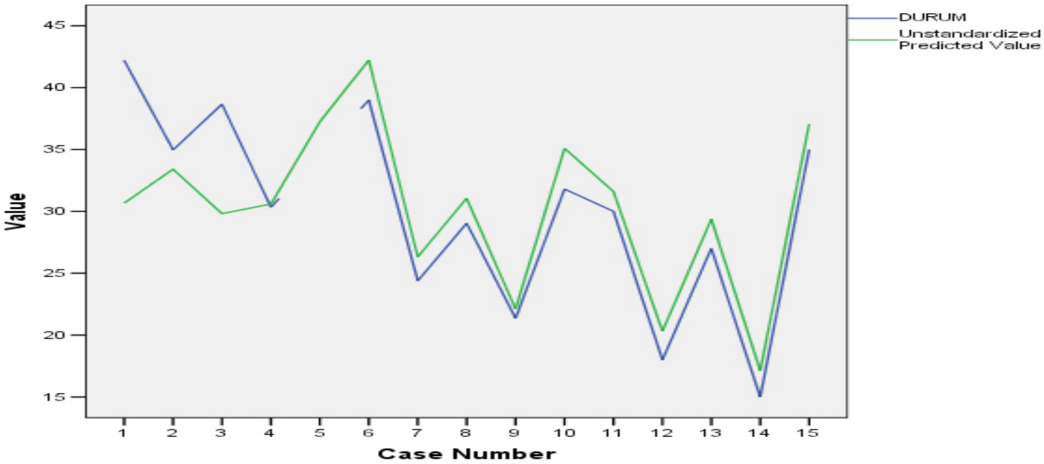
Source: Own representation.

Figure 4: Comparison between soft wheat average yield and weather index



Source: Own representation.

Figure 5: Comparison between durum wheat average yield and weather index



Source: Own representation.

The next step is to explore the feasibility of an insurance scheme based on such an index, that is a contract that would pay an amount of (I* – I) each time the index I falls below the value I*.

As an example consider the value I* = 75 quintals for the wine grapes case. Owning such a contract, the farmers in the sample, as a group, would have been able to eliminate the risk that their yield fell below 75 q/ha, an event that occurred four times over the period considered. From the graph above, it can be seen that each time the average yield has been below 75, also the index value has fallen below 75. Compared to a "pure" yield insurance, such a contract would have slightly overcompensated the representative farmer of the group in 1994, 1997 and 2001.

The feasibility of a market for such an insurance contract would depend on the difference between farmer's willingness to pay for such a contract and the foreseeable premium, which in this case would likely be very close to the actuarially fair premium, given the absence of administrative costs due to loss adjustments, monitoring, etc.

The actuarially fair premium could be determined as the expected indemnity (in the example, equal to 7,15 quintals of wine grape) if the distribution of yields and of weather variables observed in the years 1990-2004 were the long-run, invariant one.

Farmers' willingness to pay, on the other hand would depend both on the farmers' degree of risk aversion and on the subjective distributions they hold on the yield and on the index. If we had a perfect correlation, that is, if the historic distribution of yields and of the index were the same, a risk neutral farmer's willingness to pay would equal the actuarially fair premium. Any degree of risk aversion would make the farmers' willingness to pay higher than the actuarially fair premium. An advantage of this kind of index insurance is, in fact, that farmers who hold better information on their ability to control yield might actually express a willingness to pay larger than the actuarially fair premium, if they know that they can adopt corrective measures in case the index falls below the threshold, and so prevent the yield to fall accordingly. In other words, such a mechanism for yield risk protection would manifest a "virtuous" selection, in that the low risk farmers would have a higher incentive to participate, as opposed to the usual adverse selection that plagues traditional yield crop insurance, where it is high risk farmers that have the highest incentive to participate.

The precise distribution of an identified weather index could be better characterized if one could count on long series of data available through the weather stations, and therefore an actuarially fair premium could be determined as the expected revenues from the contract over a very long period, assuming, for the index, the empirical distribution detected, for example through a kernel analysis.[4]

By the date this draft has been prepared, we have yet to receive the long series of data from the CNR, which we know are available for many of the considered stations from 1950. In the meantime, we estimate the underlying distribution of the index based on the available data, either as a normal distribution with the same mean and variance, or by re-sampling from the realized values, and calculate the actuarially fair premium through simulation, which gives us the value of 5.51 and 4.69 respectively for the wine grape contract (I* = 75), 0.21 and 0.46 for the soft wheat contract (I* = 20) and 0.18 and 0.19 for the durum wheat contract (I* = 20).

Given such premiums, we determine the series of yields that a producer in the area would have had on one hectare over the 14 years for which we have data, both with and without the hedge provided by the weather index contract.

Then, we measured the change in certainty equivalent that this would have implied for three different degrees of risk aversion, assuming a CRRA utility function. The results for wine grapes, soft wheat and durum wheat are reported in tables 7, 8 and 9 below respectively.

[4] In all of the subsequent analysis, we assumed the price of the product constant and equal to one. We also normalized the average yield and average utility to 100, so that utility benefits can be interpreted in terms of percentage of the value of the product, i.e., a gain of 8.0 is to be read as a gain equivalent to 8% of the average returns from that crop.

Table 7: Benefits to wine-grape farmers from hedging through a weather based index (threshold I* = 75)

year	Returns w/o hedge (R_1)	Return w/ hedge[(1)] (R_2) premium = 5.51	Return w/ hedge[(2)] (R_2) premium = 4.69
1990	90.3	84.73	85.61
1991	101	95.55	96.31
1992	76.6	71.01	71.91
1993	85.1	79.53	80.41
1994	64.1	82.04	82.89
1995	133	127.25	128.31
1996	110	103.95	105.31
1997	70	72.66	73.51
1998	199	193.85	194.31
1999	89.1	83.55	84.41
2000	97.3	91.75	92.61
2001	61.3	55.75	72.03
2002	77.5	71.95	72.81
2003	56.2	69.25	70.11
2004	109	102.95	104.31
Average	94.63	92.38	94.32
Standard Deviation	35.60	33.08	32.03
Coefficient of Variation	0.38	0.36	0.34
Δ Certainty Equivalent ρ = 1		0.08	0.93
Δ Certainty Equivalent ρ = 1.5		0.71	1.56
Δ Certainty Equivalent ρ = 3		2.55	3.42

Table 8: Benefits to soft wheat farmers from hedging through a weather based index (I* = 20)

year	Returns w/o hedge (R_1)	Return w/ hedge[1] (R_2) premium = 0.2054	Return w/ hedge[2] (R_2) premium = 0.4633
1990	23.31	23.10	22.85
1991	28.28	28.07	27.82
1992	22.44	22.23	21.98
1993	26.88	26.67	26.42
1994	31.82	31.61	31.36
1995	35.00	34.79	34.54
1996	26.61	26.40	26.15
1997	28.11	27.90	27.65
1998	16.98	20.25	19.99
1999	34.50	34.29	34.04
2000	37.00	36.79	36.54
2001	25.00	24.79	24.54
2002	35.00	34.79	34.54
2003	18.00	21.26	21.00
2004	35.00	34.79	34.54
Average	28.26	28.52	28.26
Standard Deviation	6.38	5.62	5.62
Coefficient of variation	0.23	0.20	0.20
Δ Certainty Equivalent ρ = 1		0.46	0.20
Δ Certainty Equivalent ρ = 1.5		0.59	0.32
Δ Certainty Equivalent ρ = 3		1.03	0.75

(1) Premium obtained by sampling from actual index values

(2) Premium obtained by assuming normal distribution of index value

Table 9: Benefits to durum wheat farmers from hedging through a weather based index (threshold I* = 20)

year	Returns w/o hedge (R_1)	Return w/ hedge(1) (R_2) premium = 0.1806	Return w/ hedge(2) (R_2) premium = 0.1917
1990	42.22	42.04	42.03
1991	34.96	34.78	34.77
1992	38.66	38.48	38.47
1993	30.33	30.15	30.14
1994	29.06	28.88	28.87
1995	39.00	38.82	38.81
1996	24.38	24.20	24.19
1997	29.04	28.86	28.85
1998	21.36	21.18	21.17
1999	31.80	31.62	31.61
2000	30.00	29.82	29.81
2001	18.00	17.82	17.81
2002	27.00	26.82	26.81
2003	15.00	17.70	17.69
2004	35.00	34.82	34.81
Average	29.72	29.73	29.72
Standard Deviation	7.76	7.40	7.40
Coefficient of Variation	0.26	0.25	0.25
Δ Certainty Equivalent ρ = 1		0.15	0.14
Δ Certainty Equivalent ρ = 1.5		0.25	0.23
Δ Certainty Equivalent ρ = 3		0.63	0.61

4 Discussion and suggestions for further research

Even if based on data from one province, the results we have presented suggest that there is the possibility of using the available data from a diffused network of weather stations in Italy to define measurable indexes on which to base contracts to insure yield risk.

Availability of data, at the moment, forced us to analyze yield risk only at the provincial level, which is likely not the most efficient way of exploiting the wealth of available weather data, and we plan in the immediate future to extend the analysis to the level of smaller, more homogeneous geographic areas. Nevertheless, even at the provincial level, we have been able to construct indexes that follows very closely the average yield of the years between 1990 and 2004, confirming that yield variation can be linked to objectively measurable weather characteristics.

The three crops on which we focused do not differ in terms of the residual yield risk manifested in official data, and therefore in terms of the potential benefits that farmers might receive from participating to an insurance plan of the type we envisage.

Wine grape growers would receive a benefit of up to 1.5% of the average yield for a not uncommon degree of risk aversion, while the corresponding figures for soft and durum wheat growers would be of 1.0% and 0.6% respectively.

The limits of the results obtained so far are linked to the delay that we have experienced in accessing some of the data that we know are available. First, by limiting the characterization of the weather index to only 14 observations, those that are available from the public Arsia website, we do not fully exploit the advantage that these data have been collected and recorded at least from the 1950's for many weather stations. This makes the characterization of the principal components used to define the index and the estimation of the distribution of the index a little shaky. With more information we will surely improve on these two aspects.

Second, we have referred to the crops' yields at the provincial level which is not as homogeneous as we would like in terms of the characters of the agricultural production. A smaller geographical area, including only a few municipalities, similar for soil and weather conditions, would be ideal to the task of linking yields to current weather conditions.[5] Nevertheless, the fact that we find significant correlation of the province's average yield with weather indexes, opens the possibility that farmers' associations, at the provincial level, might exploit the possibility of using the index to hedge their common yield risk, while using other kinds of agreements (for example, through cooperatives or mutual funds) to hedge the more idiosyncratic components of individual farmers' yield risk.

Apart from the just mentioned extensions we are working on, many possible lines of further research stem from the preliminary results we present here.

For example, we limited our exploration of the indexes to simple linear combination of the weather principal components. A more extended and detailed exploration of other flexible forms might reveal indexes that follows more closely the lower tail of the yield distribution, which is basically what is needed for an index intended to protect against dramatic yield shortfalls. Also, there is a large potential for the fact that, once a system of yield insurance as the one we devise is in place, its financial exposure might be hedged by spreading the risk with other economic agents outside agriculture, who might hold opposite stances relative to the same or closely related weather indexes. One natural example comes to mind for territories where agriculture and tourism coexist, and it is reasonable to conceive that the sectors might have competing interests relative to, for example, rain in the summer. The obvious research task, then would be that of analyzing data on the effects of weather on other economic activities in the same areas, and to explore the performance of a joint fund, pooling all the areas' weather related risk together.

5 Conclusion

In this paper we have explored the possibility of constructing a weather index based insurance contract to protect yield variation of three crops in the Italian province of Grosseto. The data from 18 weather stations in the area have been used to construct indexes highly correlated with the measured provincial average yields, as reported by official sources.

The advantages of such an option over the current Italian system, based on a combination of subsidized crop insurance and ex-post compensation are numerous, thanks to the potential great reduction of transaction costs linked to the informational problems that plague traditional crop insurance, and to the much more easy practical implementation of a mechanism based on objectively measurable indexes, rather than on a complex mechanism of damage assessment. If it is true that, for many open field crops, the fundamental yield variation can be either directly or indirectly linked to weather condition (and our preliminary results provide strong evidence in this respect), then a mechanism based on weather indexes seems most appropriate.

To reiterate, the advantages would be linked to the facts that:

[5] We will explore this possibility in the next few weeks thanks to the data from the Rica samples that have been collected since 1980 and that can be classified at the level of the so-called "regione agraria".

a) no single farmer could strategically affect the value of the composite weather index, and therefore no costly damage adjustment would be needed;
b) farmers who hold better information on their ability to control yield might actually have more incentive to participate. A “virtuous” selection can be imagined, thus reducing the costs of providing the risk management service, as opposed to the adverse selection that plagues traditional yield crop insurance, where it is high risk farmers that have the highest incentive to participate;
c) the public nature of the weather information would stimulate competition among supplier of the risk management tools, in case there would be a profit to be made, therefore by reducing the problem of rent capturing that so often plagues the insurance industry;
d) yield risk management through weather index based derivatives could promote the culture of using such instruments among farmers, and financial instruments might soon be useful in the conditions of the European agriculture to hedge also price risk, now that the price stabilization effect implicit in the CAP has been eliminated;
e) most importantly, the development of such a system would require no major reform in the existing legislative framework in many European countries, to the extent that index based coverage could be included among the possible contracts offered by insurance companies to farmers (and, at the beginning, also entitled to public support, in accordance with the EU guidelines on state aids) or among the publicly provided risk management tools (for example, by linking ex-post compensation in an area to specific values of the composite index rather than to a complex and politically vulnerable mechanism of disaster declaration).

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