A Fair Value actuarial model for natural disaster risk in agriculture

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1.1. The role of agriculture in Italy

A series of phenomena have affected the agricultural sector all over the world in the last five years, causing concern and raising many questions about the future. The events which have specially and most of all influenced the sector were the rise in the production costs, the volatility of prices and, more generally, the international financial and economic crisis that affects all the productive sectors.

In the year 2009, Italy entered a phase of economic recession, like most countries in the world, and its GDP decreased by 5.4% in real terms, thus recording the sharpest contraction since the post-war period. All the major productive sectors contributed to the GDP contraction. However, while the industrial sector had the worst added value performance in terms of factor costs (- 15 % in real terms) the other sectors recorded more limited drops. In particular, in the farming sector, the lower contraction rate of the real added value to the factors cost in respect with overall economy, was counterbalanced by a much higher decrease rate of the added value expressed in current market terms (-4% always at factor cost, compared to -2.5% for the whole economy). Therefore, the primary sector contribution to the GDP creation fell slightly, dropping to 2.2%, while the food sector reached 1.9%.

Agriculture still has, however, a fundamental and strategic role in terms of food supply independence, habitat and landscape protection, soil conservation, water basins management, carbon dioxide sequestration, biodiversity conservation and food safety.

In the following years the Italian agricultural system will face an important and delicate challenge, due to the need to tackle a new reference framework, both economic and institutional. Business' competitiveness will be more and more influenced by new variables. It is then necessary to find a way to manage the business risk.

1.2. The first thirty years of activity of the National Solidarity Fund

Italy was one of the first European Countries to face risk management in agriculture in a systematic way, by introducing, as early as 1970, a useful instrument such as National Solidarity Fund, (hereafter indicated as NSF). Thanks to the NSF the principle of solidarity for businesses that suffer losses due to uncontrollable variables has been institutionalised.

For many decades the strong actions provided for in the CAP policy virtually cut back or even eliminated many risk sources, such as, for example, the market risk, thus allowing the NSF to focusing on the productive risk and especially on the losses caused by natural and weather disasters.

Before 1970 in fact, in order to help and economically support the farms damaged by exceptional disasters, with serious repercussions on business profitability, it was necessary to resort to special measures to determine aid and allocate the required financial resources. Such action was not systematic, nor prompt and certain, thus partially thwarting the effectiveness and efficiency of the public intervention, with further serious consequences for the profit-making farms in the affected areas. Moreover, in the Sixties, the hail insurance market was stagnating and only a minority of farmers stipulated insurance policies, mainly because of high premiums. Only a few projects realised by the insurance companies together with the local authorities, also with public aid for premiums, managed to increase the insurance volumes.

In 1970, the Italian Parliament, aware of the difficulties farmers had to face in case of weather and natural disasters, in order to cope with the inefficiency of the special measures, and considering the insurance projects and facilitations provided for by some local governments, enacted the Law n. 364 establishing the NSF. The latter, still operating, has been for more than forty years a permanent instrument and a fundamental legislative reference for aid, especially for the multiple actions supporting agricultural gains. In fact, apart from having an annual separate financial allocation, provided for by the finance act, it made prevention and insurance actions possible, in addition to aid by way of damage compensation in the affected areas, enabling the economic and productive recovery of the damaged farms. The NSF then plans both ex-post interventions, for loss compensation, and ex-ante ones, providing for active collective protection and subsidized insurance policies.

The NSF regulation went through several amendments and reforms, as a result of a series of other measures, some organic (Law n. 590 of October 15, 1981, Law n. 185 of February 14, 1992, Legislative Decree n. 102 of March 29, 2004) and some specific (Presidential Decree n. 324 of May 17, 1996; art. 127 of the Law n. 388 of December 23, 2002; Decree-law n. 200 of September, 2002 turned into the Law n. 256 of November 13, 2002, the Legislative decree n. 82 of April 18, 2008).

The compensation measures were aimed at helping the economic recovery of farms in the areas affected by losses due to natural disasters for at least 35% of the gross saleable production. The aid that could be granted can be summed up as follows:

- capital-account and interest-rate contributions to restore the lost working capital;
- interest-rate contributions on operating loans to support the production recovery;
- capital-account and interest-rate contributions to restore the facilities (tree planting and premises)

Easy terms for the development of joint projects for active protection were aimed at protecting the crops by preventing or neutralizing the negative effects of disasters through the implementation of projects and the use of tools that can neutralize or reduce the negative effects of climatic events, such as for example frost fans, anti-hail rockets and the placing of nets on the trees plantations.

Finally, public contribution to insurance policy premiums was aimed at preventing risk, that is mainly handled in a collective way at a provincial level through the protection organizations. Every organization negotiates with the insurance companies the production risks coverage for their members, while the State pays a part of the farmers' premiums. At first, insurance expense support was only intended to the members of agricultural co-operative organizations called "consortiums for the passive protection of farming production", which negotiated group policies. Later, from 1996 on, with the Presidential Decree n. 324, the insurance demand was totally liberalized, so that even

the farmers who stipulated policies individually, without being members of protection organizations, can benefit from the State contribution.
In particular, the legislation prior to the Law n. 185/1992 provided for a national negotiation of the conditions specified in the insurance policies that could receive State contributions. This negotiation was conducted between ASNACODI (the Protection Consortiums National Association) and CIRAS (the Italian Consortium for Special Agricultural Risks). Since a monopoly in the insurance offer was ascertained which dramatically hindered the expansion of the market and adequate insurance costs according to farmers' the above mentioned national negotiation and CIRAS were abolished by Law n. 185/1992. Moreover, while initially subsidized insurance coverage conceived for the sole intensive and quality crops such as the cultivation of fruit and grapevine, the legislative amendments that followed extended subsidized insurability to most of the crops.

As a whole, more than 70% of the public spending devoted to the interventions of the NSF in the first 30 years of activity, was used for compensation and active protection aid, while only a minority share was initially devoted to insurance policies. As a matter of fact, the spending for compensation constantly increased until the beginning of the Nineties, while afterwards the spending for such aid started to suffer a continuous decrease, with a few exceptions. From the Eighties on, instead, the insurances and the related public facilitations constantly increased from a small quantity to a sizeable one up to the veritable "revolution" of the sector which followed the deep NSF reform established by the Government Decree 102/2004, regulating the "Financial aid to support farms", as provided for by Law n. 38 of March 7, 2003.

1.3 The reform of the NSF as per Legislative Decree 102/2004 and its effect on the insurance market

The experience of the previous decades and the combined work of Public Administration, social partners and market players created the necessary preconditions for developing and approving the Legislative Decree 102/2004. The Decree, not only grouped, summed up and substituted decades of laws, but updated the national legislation on agricultural risks management, and related tools, in compliance with the new Community guidelines. In fact, the Decisions of the Commission C(2003)2048 of July 9, 2003 and C(2003)4328 of December 16, 2003 ruled that some interventions provided for by the Law n. 185/1992 did not comply with the Community guidelines on State aid for agriculture. In particular, the discrepancy was found in the concept of natural disaster which allows the farm to have access to aid. Moreover, there was the adoption of the Commission Regulation (EC) n. 1/2004 of December 23, 2003 regarding the application of articles 87 and 88 of the Treaty which establishes that the European Community makes the decisions regarding State aid to small and medium enterprises in the sector of production, processing and marketing of specifying terms, with no need to notify every single case and defines the events that can benefit from subsidized policies must comply with the Community guidelines.

Legislative Decree 102/2004 essentially confirms both the previous ex-ante tools for the promotion of insurance coverage, through public subsidies for the payment of premiums, and the post ante ones, through compensatory measures for production and farm premises losses and for restoring the infrastructures. It also introduces important new operational aspects such as public subsidy levels for insurance premiums determined according to loss thresholds, as established by the related Community legislation, and the obligation to insure at least all the crops in the municipal area of the product the farm wishes to cover under the umbrella cover.

The conditions for granting aid to farms are then defined by Legislative Decree 102/2004 in compliance with the Community legislation. In particular, there are basically two kinds of interventions the NSF can support: measures for increasing negotiation of production and premises damage insurance policies. Such interventions include incentives for mutual-based initiatives; compensatory measures, exclusively for non insurable risks, in order to favour the economic and productive recovery of those farms which underwent losses due to natural disasters.

Beneficiaries of such interventions can be farming entrepreneurs, both individual or associated, taking out insurance policies or participating in mutual-based initiatives both individually or collectively. The maximum aid to be granted is: 80% of premium cost for insurance contracts providing for compensation for damages due to adverse climatic events definable as natural disasters, in case the loss amounts to at least 30% of the insured production; 50% of premium cost in case the insurance contract also covers other damages due to adverse weather events outside the range of natural disasters, or due to plant or animal diseases. Moreover, the Farm Insurance Plan a measure for identifying the policy types, the territorial areas, the products and all the other variables to be considered for grants and deciding the amount of public aid for premiums is to be adopted every year, upon the assessment of proposals discussed by a specific Technical Commission by Decree of the Minister of Agricultural, Food and Forestry Policies.

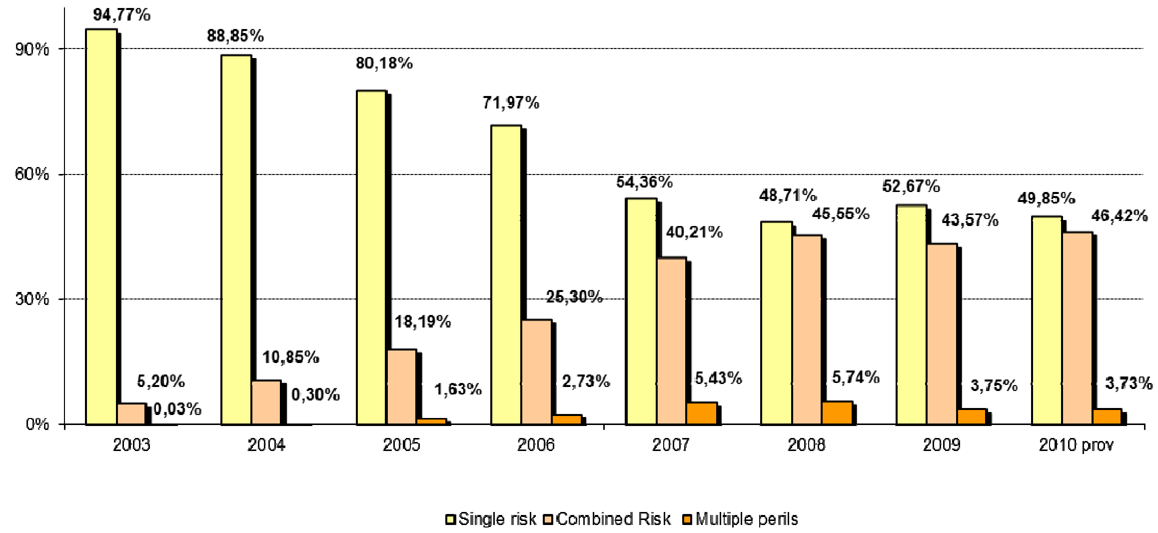
In accordance with the economic policy guidelines on risk management in agriculture adopted by both European and non EU Countries (United States and Canada in particular), the priority goal of the NSF reform, introduced by Legislative Decree n. 102 dated March 29, 2004 and subsequent amendments, is to replace public interventions and the related resources allocated for ex-post compensation measures for natural disaster damages with an ex-ante protection system based on insurance. The new laws, established by the above mentioned decree, provide for a progressive reduction of compensatory subsidies, so that the national insurance system will have the important function of stabilizing the farmers' revenues in case of destructive effects caused by climatic disasters. Furthermore, the insurance instruments are evaluated according to other countries' experiences and the research carried out by the European Commission. The aim is to adopt a risk management system that gives farmers greater awareness of their responsibilities and, at the same time, rationalizes public resources.

The main novelties, gradually introduced by the Farm Insurance Plans in the last six years, include the enlargement of the product categories (crops, premises and livestock farming) and climatic events for which provision is made for subsidies in a wider number of territorial areas.

The calculation of the insurance parameters was also updated. These are used for calculating the maximum insurance cost allowed for receiving subsidies and then establishing the public aid percentage on the farmers' insurance premiums.

The legislation on subsidized agricultural insurance issued in the last years enabled a modernisation of the Italian insurance system, thus increasing the opportunities for the farms which reacted positively to the change. Since the first year of (partial) implementation of the reform, in 2004, policies with and without damage threshold were for example negotiated, with a variable public aid covering a maximum of 50% or 80% of the premium. These first changes caused a substantial increase in the insured value and a proportional reduction in the national average rate.

Figure 1: Insured value market shares by insurance type (crops and premises)



Insured value - *.000€*

2003	2004	2005	2006	2007	2008	2009	2010 prov
3.333.901	3.710.212	3.810.222	3.789.132	4.379.809	5.436.140	5.131.045	5.312.829

The increase in insured values as illustrated in figure 1 mainly resulted from Legislative Decree n. 102 of March 29, 2004, establishing that crops and premises damages benefiting from subsidized insurance cannot be granted compensation. During the last years, this principle also caused a dramatic reduction in Public Administration's costs intended for ex-post interventions. Nonetheless, in 2008 public aid for insurance premiums touched the highest absolute value ever (237 billion euros, corresponding to 70% of premiums) whereas in 2004 it was 152 billion euros (equivalent to 57% of premiums).

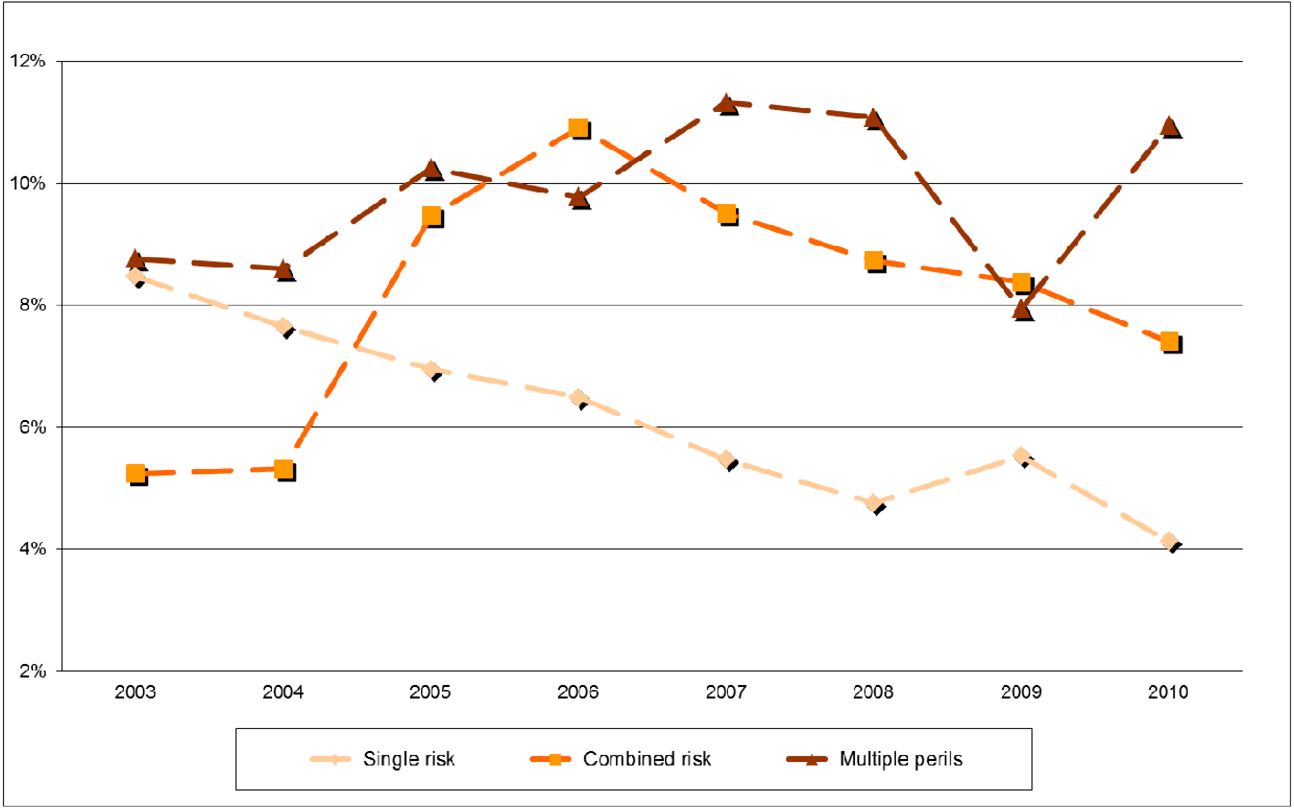
The above mentioned principle and the subsequent rationalization of public spending has thus made the farmers more aware of their responsibilities, by rewarding those who consciously choose to face the productive risks by negotiating insurance contracts rather than relying exclusively on possible compensatory interventions.

It is especially important to note that at least three goals were achieved. The first is the widening, through innovative tools, of combined risk and multiple perils policies, of insurance protection against adverse weather events that, until a few years ago were (almost) totally excluded by the insurance company's offers. Secondly, the increase of insured production types, with subsidized coverage including the farm premises, cattle and swine animal production and crops, totally excluded until a few years ago. Third, the dissemination of agricultural subsidized insurance coverage, both traditional and innovative, within national geographical areas such as, for example, Liguria, where they were (almost) totally lacking.

As illustrated in detail in figure 2, while average insurance costs for hail single risk policies constantly decreased over time, with the only exception being the subsidized campaign of 2009, the average costs of innovative policies, both combined risk and multiple perils, registered a variable trend.

This is mainly due to the innovative nature of combined risk and multiple perils policies and, most of all, to the increase, in the last seven years, in adverse events covered by the above mentioned contracts. This increase made it more complicated to set rates that could grant both economic balance and financial advantage for the farmers. In this regard, as explained above, the research in the present text represents one of the necessary steps for improving combined risk policies rating, in order to favour their dissemination and consolidate the related economic outocomes.

Figure 2: Development of average insurance costs by coverage type (crops)



Before the subsidized campaign in 2004 was started, in fact, the only adverse weather event insured with a substantial coverage was hail, while today there are important insurance coverage levels even for other events, such as frost, wind, heavy rain, flood, drought, in different combinations. The new events were insured, in almost all cases, with innovative insurance contracts with a 30% loss threshold.

Moreover, as previously highlighted, the dissemination of the above mentioned guarantees strongly favoured the progressive reduction in public allocations for ex-post compensation.

As for the other result, the total product types insured in 2002 amounted to 58, while the more recent insurance campaigns have reached almost three times that number, thus determining the subsidization of almost every crop, the active protection system and cattle and swine farming.

In the light of the above stated figures and considerations, the outcome of the implementation of the reform introduced by Legislative Decree102/2004 has shown to be positive. In the last few years the insurance volumes have grown, new insurance types have been proposed, the number of insurable products and guarantees have increased (in particular for animal husbandry and premises), the regional areas allowed to benefit from facilitations have widened, the farms are taking care of cost restraint, and there is a higher competition level in the national market thanks to more insurance companies dealing with the "agricultural branch".

On the other hand, our farming insurance system has not yet solved some long time critical issues, such as the heavy territorial concentration of the insurance volumes, new guarantees in particular, in some provinces in the North of the country and the poor attraction farms still show towards insurance companies. So much so that the growth of insurance volumes observed in the last years is only little due (especially for animal husbandry and premises) to the inclusion of productive realities that had never previously used such instruments.

Finally, the policies presently available to farmers can only adequately cover the production risk caused by adverse weather events and natural disaster, while other risk sources, such as, for example the market risk, have no suitable management tools.

1.4 The Agricultural Risks Reinsurance Fund and the Italian Co-Reinsurance Consortium against natural disasters in agriculture

The Agricultural Risks Reinsurance Fund, constituted by article n. 127, paragraph 3 of the law n. 388 of 200, also played a determining role in the achievement of the above mentioned goals. Since its first year of activity in the subsidized campaign in 2004, in fact, the Fund aimed at promoting innovative Combined risk and Multiple perils policies for the coverage of crop yields, by implementing reinsurance, thus allowing to reduce the insurance company exposure. The reinsurance systems are actually two: non proportional reinsurance for combined risk policies, thanks to a Stop Loss treaty, in order to protect the company budget, while for multiple perils policies the type of proportional reinsurance is established with the Quota Share system, that provides for the proportional co-participation of insurer and reinsurer for all the insured risks within a given contract.

In particular, the operational procedures of the Fund's aid were defined by the Decrees of the Minister of Agricultural, Food and Forestry Policies of November 7, 2002 (Regulation), of February 7, 2003 (first reinsurance plan) and February 27, 2008 (second reinsurance plan). Moreover, the European Commission, with a decision of July10, 2003 – State aid n. 758/2002 – and with a subsequent decision of December 21, 2007 – State aid n. 381/2007 – authorized the Reinsurance Fund to reinsure policies covering natural calamities or comparable weather disasters, provided that the contracts are in accordance with the community legislation on State aid.

More generally, the Fund's aim has always been to promote competitiveness among farms, favouring the reduction in weather risks consequences. The goal was pursued with the strategic use of reinsurance for subsidized agricultural risks taken by the insurance companies. The Fund has actually started an active collaboration between public and private sector. Up to today, it contributed to further disseminate the insurance products among the farmers, thus creating scale economies, that could reduce the cost of the premiums paid by the farmers. The activity of the Fund involved, and still directly concerns, the insurance companies which offer innovative insurance guarantees, as well as indirectly concerning the farmers who can benefit from the economic advantages of stipulating innovative insurance guarantees.

In 2007 the Co-Reinsurance consortium against natural disasters in agriculture was also founded. It was positively judged by the Anti-trust Authority and in accordance with the Community legislation on the subject. Its aim was to promote the introduction of innovative insurance policies against natural disasters and comparable weather disasters in the agricultural market, through the apportionment of risks among the consortium members, in order to offer the farmers new insurance tools to protect production.

The added value of the Consortium, thinking of a partnership between public and private, is the improvement in the technical regulation for the management of the new insurance coverage, distributing among the Consortium members the risks coming from the implementation of innovative insurance coverage and promoting the exchange of information and data, thus sharing the technical progress with the members. A further possibility for the Consortium is to have reinsurance coverage for the international markets. The results obtained until today, besides the promotion of new insurance products, have been the increase in the invested capital, the standardization of terms and contractual conditions, the definition of a governance on claims through procedures and inspections and the reinsurance rate also with the use of actuarial criteria.

1.5 Community facilitations for insurance premiums and the future of CAP

Starting from the agricultural insurance campaign of 2010, community facilitations have been added to aid on premiums. The community legislation on agricultural risk management is actually going through a deep reform, aiming at the modernization of the tool for the stabilization of farmers' revenues, also in view of the new CAP after the year 2013. This implies significant changes in the ways public aid will be implemented for facing the agricultural sector risks, thus pushing the Member States to modifying the institutional organization and operational aid forms.

From the Nineties on, in fact, the European Commission, in collaboration with Community bodies, national entities, the academic world and the market players started a wide and exhaustive debate on what to do to update the risks management tools in agriculture, which produced a series of detailed research documents. Focusing on insurance policies, the more interesting ones included: "Risk Management Tools for EU Agriculture, with a special focus on insurance" of 2001 and "Agricultural Insurance Schemes" of 2006.

The above mentioned researches have shown it is necessary to urge innovation in the insurance sector, especially by expanding the existing guarantees and by introducing new tools suitable for meeting the farmers need to be protected from productive and market risks.

From an operational point of view, since 2010 there are two new aid measures for the subsidized coverage of agricultural risks, coming from different community funds. One refers to article n. 68 of the EC regulation n. 73/2009 and the other is the CMO (Common Market Organization) in wine based on regulation n. 1234/2007. The new measures integrate the previous equivalent aid measures of the NSF and CMO in fruit and vegetables. From 2010, then, the following insurance facilitations, supported by public aid are available for the farmers' risk coverage:

- insurance policies on crops, animals, plants, in compliance with EC regulation n. 73/09, article 68, paragraph 1, letter D), as defined by the article n. 70 of the same regulation;
- insurance policies on wine grapes' crops, in compliance with EC regulation n. 1234/2007 – CMO wine;
- insurance policies on vegetable production, animals, plants, farm premises, in accordance with Title I, of the Government Decree n. 102/2004 and subsequent amendments;
- insurance policies on fruit and vegetable production crops within the operational plans of the producers' associations, in compliance with the EC Regulation n. 1580/07, articles n. 89 and 90 – CMO fruit and vegetables.

As for the future, there are many important issues under discussion at a community level:

- inability to prevent market's negative trends because direct payments to farming businesses have become the main element to the detriment of tools supporting the single product's markets, and the lack of an efficient system for income protection;
- the financial strengthening of rural development interventions and the related growing number of measures and objectives under its competence: sector, environment and territory;
- the search for a new legitimacy for the CAP, as a policy ensuring the production of public goods with the support of the primary sector and the rural areas;
- the entrance of new Member States and the consequent adjustment of the decision-making balance.

An important achievement of the above mentioned discussion is the Communication of the Commission to the European Parliament, the Council, the European Social and Economic Committee and the Committee of the Regions, in November 2010.

Specifically, the communication gives a central role to risk management procedures. In fact it explicitly suggests that it is necessary to reduce the variability of agricultural gains and contribute to guarantee farms' earnings, which are mainly threatened by the growing volatility of prices and the adverse weather conditions. Besides, among the modalities of risk management and income protection, it clearly also mentions insurances and mutual risk-sharing agreements.

1.6. The contribution of ISMEA in the creation of a risk-based rate for combined risk coverage

Based on what has been described above and the precious experience acquired until now and with the aim of favouring a more efficient and successful allocation of the financial resources used for reinsurance, in 2008 ISMEA started, in collaboration with the Association for Actuarial Consultancy and Research (ACRA) and the University of Rome La Sapienza, an actuarial study aimed at defining and implementing a risk-based rate model for combined risk coverage. The methodological details and the experimental results achieved will be discussed in chapter 2. In this paragraph we will, instead, briefly explain the work carried out by the research team.

The methodological approach for fixing combined risk rates is the risk-based actuarial model, consistent with Solvency II principles and based on the definition of the fair value of the insurance guarantee. The rate creation process involves a series of preliminary statistical analysis that were carried out starting from the combined risk insurance coverage data relative to the observation period 2004-2009. Such analysis made it possible to classify the municipal areas and the agrifood products investigated according to appropriate risk classes.

The rate's model was developed with a multiphase approach structured as follows. The first operational step was aimed at the rationally reducing the great number of agrifood products to a set of profiles, each one characterised by a relative homogeneity of the biologic characteristics of the products it includes. In this way, the whole universe of the products that can be insured has been reduced to a subset of 14 profiles (see table 1).

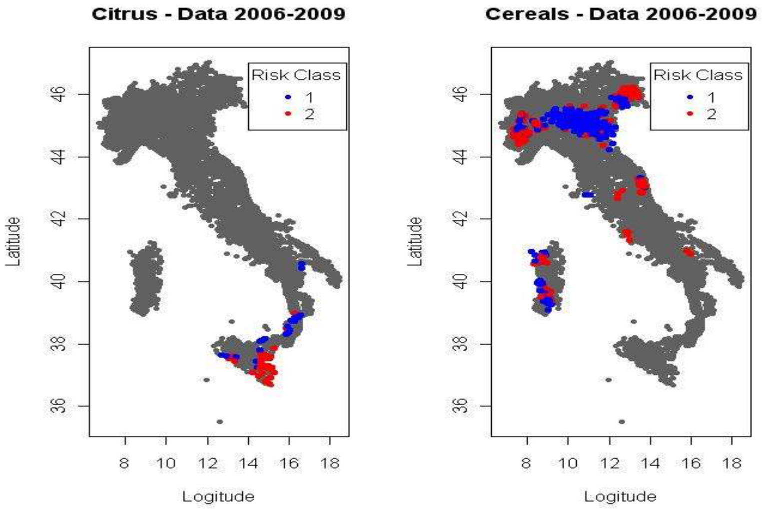
Table 1: Agrifood products

Product profiles Agrifood	Agrifood product
1	Citrus fruits
2	Cereals
3	Other fruits
4	Vegetables and other products
5	Tomato
6	Wine grapes
7	Kiwi fruit
8	Cherries
9	Apples
10	Rice
11	Olives
12	Pears
13	Peaches
14	Plums

The second operational step was to analyse the quality of the data base information and discern how far back in time it went, also to ascertain its consistency and coherence with reference to the dimension under analysis. Some dimensions required estimate procedures, also because of other existing information.

The third operational step was to select the rate variables with a high information content, for classification purposes, too, by homogeneous risk groups, of the municipalities and the insured crops present in the area. To carry out the selection, univariate and multivariate statistic techniques were used. The charts in figure 3 show the risk classes dividing them by colour.

Figure 3: Example of risk classification



The last operational step involved the creation of an actuarial model of the premium rate with evidence of identification coefficients of risk profile. To this end, coherently with the "quantile approach", a premium rate was fixed according to a specific risk measure (percentile−α) with respect to a selected distribution set of high probabilities, properly identified among the skew ones. Table 2, below, shows the premium rate of two product profiles.

Table 2: Premium rates – Minimum deductible 30%

Risk Class	Product	
	Citrus fruits	Cereals
1	1,23%	6,42%
2	2,92%	8,95%

The ex-post analysis performed according to an appropriate process of tariff validation, has given encouraging results loss ratio is concerned.

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2. A risk-based approach for the calculation of the weather rate in agriculture

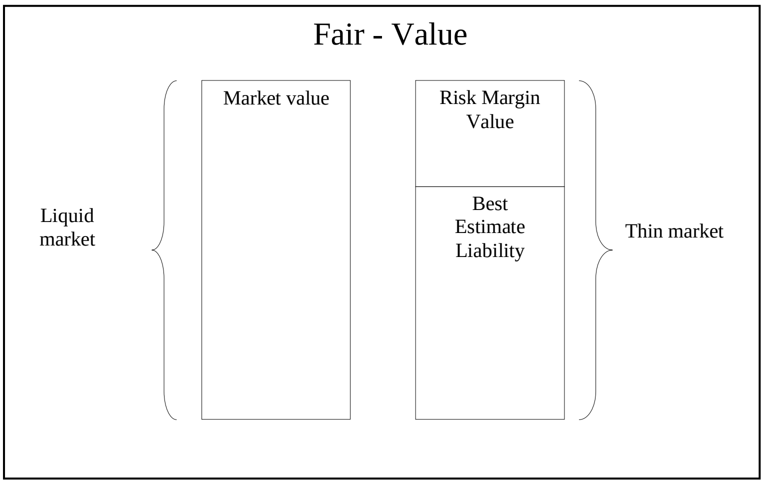
2.1. Introduction

The aim of the study was to examine the definition, implementation and experimentation of an actuarial model of reinsurance rate covering agricultural production damages due to natural disasters. The methodological approach proposed can be classified into the class of risk-based actuarial models and is consistent with Solvency II principles. It is based on a fair-valuation of insurance liabilities as a sum of two components called respectively the best estimate liability and the risk margin value.

For the nature of the insured events, it should be noted that the kind of coverage under analysis regards the contracts exposed to the risk within the same time window, which is the calendar year. Moreover, differently from third party insurance, there are no reserve problems at the balance sheet date because no payments are due in a long time after the damage has occurred, avoiding in this sense the burden that a long-tail payment could be involve insolvency procedures and then legal expenses, determining the boosting of the damage amount. Natural disaster risks also differ from the other property insurances for the evident identification of the event generating the damage, that is the adverse weather event already ascertained even before the insured party reports the claim.

2.2. Fair Value of insurance contracts: the theoretical context of reference

As a matter of principle, the fair value of assets/liabilities is equal to the value considered fair by the market, in other words it equals the price the market players are ready to pay/take to make the trade exchange. When the market is liquid enough, the fair value is equal to the market value; this is the case of bonds exchanged on the regulated market. In the insurance sector the market is thin and therefore the recourse to actuarial models to establish the fair value is necessary. In accordance with Solvency II framework, the actuarial models must be able to separate the best-estimate from the risk margin value component. The adopted approach is compatible with the percentile approach, widely discussed and accepted at the international debate. Such a method favours the fair value calculation by setting itself in respect of the α-percentile (typically 75% or 90%) of the probability distribution of the damage random variable and the risk margin value is the result of the difference between the fair value and the best estimate.



In the absence of a liquid market for insurance contracts and according to a market-consistent criteria, the premium for an insurance coverage can be established by the following equation:

$$FV(r,k,p;\alpha) = BEL(r,k,p) + RMV(\alpha) \qquad [2.1]$$

where:

- r: territorial risk class;
- k: agrifood product class;
- p: unit price class;
- α: percentile;
- BEL: Best Estimate Liability;
- RMV: Risk Margin Value;

The development of [2.1] required the implementation of a multiphase process that will be exposed in the following paragraphs.

2.3. Base-line data for agricultural risks

The theoretical approach behind ISMEA's rate is based on the principles recollected in the previous paragraphs. In the different work steps, choosing one method instead of another has been subordinated to the type and quality of the available information, seeking the best model for a goodness of fitting.

The base-line data analysed is referred to the combined risk coverage supported by State aid (registered by the Ministry of Agricultural, Food and Forestry Policies) in the 2003-2009 period. With reference to the single year of experience, the type of agrifood product, the district and the municipality the following variables were observed:

- Number of insurance certificates
- Number of claims
- Insured quintals
- Damaged quintals
- Compensated quintals
- Insured hectares
- Insured value in euros
- Compensated value in euros
- Total premium in euros

The variable "claim value" in particular is registered net of the compensation restrictions provided for by the insurance contract, typically minimum deductible and claim qualification threshold. Such restriction rules, thus remaining the same, were applied at different levels by year and agrifood product. In order to appreciate the longitudinal aspect of the information and thus comparing the different years observed, inverse formulas have been used to compute the "loss amount" as no information was available in the data. This variable has a crucial role in the calibration of parameters of the rate making actuarial model.

2.3.1. Claim settlement rules and damage estimate process

The lack of information on the base-line data has made it necessary to adopt a damage estimate process, on the basis of the existing information. Since in presence of a minimum deductible the claim settlement function is not invertible in all cases so specific hypothesis on the conditional probability distribution of the loss below the minimum deductible level have been introduced. Having to do with relatively slight damages, the hypothesis of a uniform distribution for a loss value approximation has been considered acceptable, for those amounts that do not exceed the claim settlement restriction. In formal terms, it is defined as:

- X : the claim value net of the minimum deductible

- V : the insured value

- d : the minimum deductible level (percentage of the insured value)

- Y : the damaged value (unrecorded quantity)

the claim settlement function can be determined with the two following equations:

$$X = f(Y) = \max\left[Y - d \cdot V, 0\right] \qquad [2.2]$$

$$f^{-1}(X) = \begin{cases} d/2 \cdot V & if \quad X = 0 \\ X + d \cdot V & if \quad X > 0 \end{cases} \qquad [2.3]$$

The equation [2.3] has been relatively easy to use, because it has been possible to retrace the contracts for which there was a damage with no claim. Some types of contracts provide for a claim qualification threshold in addition to the excess. Such a threshold corresponds to a share of the insured value and it restricts compensation only to the damage with a loss higher than the threshold. For the contracts providing for a threshold in addition to the minimum deductible (with s>d), the compensation function becomes the equation [2.4]:

$$f(Y) = \begin{cases} 0 & if \quad Y \le s \cdot V \\ Y - d \cdot V & if \quad Y > s \cdot V \end{cases} \qquad s > d \qquad [2.4]$$

$$f^{-1}(X)=\begin{cases} {}^{s}\!/_{2}\cdot V & if \quad X=0 \\ X+d\cdot V & if \quad X>0 \end{cases} \qquad [2.5]$$

For the contracts in which a minimum deductible depends on the degree of damage, the equations [2.2], [2.3], [2.4] and [2.5] can be extended through a partition of the abscissas axis whose cut-off points are the loss levels equivalent to changes in minimum deductible.

2.4. Calculating rates by means of a multiphase approach

The insurance of risks associated with natural disasters is characterised by the fact that the intensity with which the event occurs is closely related to geographic location and crop. The same climatic event causes damages of different intensity to two different agrifood products. It must also be considered that neighbouring territories have different levels of risk, if there is significant altitude gap. Also the quality of the product can affect the premium; it was in fact empirically demonstrated that the products with a higher unit price have a lower loss level. This hypothesis, first verified by statistics, has been then confirmed by the experts of the sector, who affirmed that the farmers devoted to more valuable crops, spend more money on technical equipment in order to contain weather losses as much as possible. The use of hail nets is emblematic.

The previous considerations caused the rate to be calculated according to a procedure involving different interdependent operational subprocesses, as it happens that the output of a subprocess is the input of the following one. The main steps can be summed up as follows:
a) homogenous grouping of crops according to agronomic characteristics (products): products chosen according to variety, growing season and resistance to weather events (table 1);
b) analysis of the statistical consistency of base-line data for each product and for each observation year. This type of analysis implied unifying the 2003 information with the 2004-one; the analysis has been therefore carried out with reference to the observation period 2004-2009;
c) selection of variables containing better information for the risk classification purpose; such selection has been carried out on the basis of the analysis of the correlation matrix, referred to ex-ante and ex-post variables[1]; the correlation matrix analysis for each observation year has made possible to identify the "Total premium", "Value insured", and "Quantity insured" as the most representative ex-ante variables, and the "Number of claims", "Compensation value" and "Quantity compensated" as the same for ex-post variables;
d) classification of territorial units into homogeneous risk groups. For each product type the clustering algorithm has been implemented with reference to municipal data observed in the period 2004-2009; the assignment of municipalities to risk classes was then validated by means of appropriate inter-territorial and inter-temporal persistency statistical indexes.
e) ex-ante classification of municipalities not hit by adverse weather events, with multivariate statistical techniques of discriminant analysis;
f) selection of theoretical probability distribution having the best performance of chi-square test;
g) development of an insurance rate model for each product, with premium customization techniques referring to the risk class and product quality, summed up in the insured unit price.

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[1] For the definition of ex-ante and ex-post variable see chapter 2.4.1

2.4.1. Cluster analysis and homogeneous risk classes

Classification techniques constitute a large part of the multivariate statistical analysis. They make it possible to group together a broad set of statistical unities, within which different magnitudes were recorded, gathered in a small number of mutually exclusive subsets (groups), meaning that a unity belonging to one group cannot be in another one and all the units must belong to a group. The main aim of cluster techniques is to form groups so that the units contained in a group are as similar to one another as possible and that the groups are heterogeneous among themselves.

A multivariate statistical analysis through cluster analysis technique has been carried out for every product class in order to classify municipal territorial units into homogeneous groups. The said groups are determined according to the derived variables observed, expressing ex-ante and ex-post risk in the weather events covered by insurance contracts.

Cluster analysis has been used in two phases of the process: first for the preliminary statistical investigation dealt with in paragraph 2.4.3, then for the identification of risk classes. In both cases the statistical units considered have been the municipalities recorded in the base-line data of combined risk policies which suffered at least one weather damage. The first cluster analysis implementation concerned the single observation years, while for the second the whole observation period 2006-2009. The variables considered for the cluster analysis implementation have been: the insured quantity, the reimbursed value net of minimum deductible and the number of lots reimbursed. These three variables have made it possible to develop an efficient distance measure expressed in terms of risk between the municipalities.

The cluster method used to classify the municipalities into territorial risk areas is a hierarchical agglomerative one: that is, starting from the single territorial units observed (municipalities) this technique is supposed to get to a limited number of groups or agglomerates or territorial units (territorial risk areas) that can be ordered in bottom up levels of aggregation, following a certain criterion based on the distances between the groups. The method will be better explained later in the text.

The hierarchical agglomerative methods distinguish themselves by the different criterion with which, after the *t-th* fusion or agglomeration the distances between the new groups are calculated. The method adopted for establishing ISMEA’s rate is Ward[2] or minimum variance method. It consists in bringing together, with each successive step in the process, the two groups from the fusion of which results the lower possible growth of the deviance within the new established group. In particular, expressed as $DEV_T = \sum_{s=1}^{p} \sum_{i=1}^{n} \left(x_{s,i} - \overline{x}_s \right)^2$, the total deviance of the observed population, where $\overline{x}_s$ is the mean value of the *s-th* variable among the *p* chosen for the purpose of classifying the n territorial units observed making up the whole population.

Given a partition into *g* groups containing various territorial units, such deviance can be broken down into:

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[2] Everitt (1974). The calculation was made using the statistics software R 2.10.1

$$DEV_{IN} = \sum_{k=1}^{g} \sum_{s=1}^{p} \sum_{i=1}^{n_k} \left(x_{k,s,i} - \bar{x}_{k,s} \right)^2 \qquad [2.6]$$

representing the deviance within the groups referred to the variables *p* and the group *k-th*, where $\bar{x}_{k,s}$ is the mean of the *s-th* variable in the same *k-th* group,

$$DEV_{OUT} = \sum_{k=1}^{g} \sum_{s=1}^{p} \left(\bar{x}_{k,s} - \bar{x}_s \right)^2 \cdot n_k \qquad [2.7]$$

which represents the deviance among the groups, having indicated with n_k the number of territorial units of the *k-th* group, being $n = \sum_{k=1}^{g} n_k$

As easily provable one can gather that

$$DEV_T = DEV_{IN} + DEV_{OUT} \qquad [2.8]$$

In passing from *k+1* to *k* groups (agglomerative process) DEV_{IN} increases, while DEV_{OUT} decreases. At every successive step the groups with the lower growth of deviance within the groups join together.

The number of clusters has been chosen by first considering the fusion distance resulting from the dendogram (representation of the agglomerative process on a Cartesian axis): if in passing from *k* groups to *k+1* there is a significant increase in the fusion distance, the groups have to be divided at *k.*

As an example, for the product Pears (product code 13) and the observation year 2009, the cluster analysis results obtained first with four and then with two groups or risk classes are illustrated as follows:

Table 1: Cluster analysis - Product: Pears. Year: 2009

Cluster	**Number municipalities**	**Insured quantity (quintals)**				**Claim value (euros)**				**Number of claim settlements**			
		average	**mse**	**min**	**max**	**average**	**mse**	**min**	**max**	**average**	**mse**	**min**	**max**
1	**34**	**1.327**	**2.836**	**30**	**11.705**	**4.316**	**5.647**	**-**	**18.216**	**1,18**	**1,32**	**-**	**5**
2	**42**	**1.032**	**791**	**35**	**3.242**	**11.130**	**18.143**	**-**	**67.500**	**1,90**	**2,69**	**-**	**8**
3	**8**	**2.979**	**1.110**	**1.762**	**5.100**	**79.602**	**40.306**	**-**	**132.017**	**10,88**	**11,88**	**-**	**37**
4	**8**	**13.194**	**9.901**	**6.400**	**38.780**	**403.689**	**339.944**	**122.340**	**1.204.554**	**18,25**	**13,85**	**7**	**49**
Tot	**92**	**2.368**	**4.830**	**30**	**38.780**	**48.701**	**150.883**	**-**	**1.204.554**	**3,84**	**7,72**	**-**	**49**

Table 4: Cluster analysis – Product: Pears. Year: 2009

Cluster	Number municipalities	Insured quantity (quintals)				Claim value (euros)				Number of claim settlements			
		average	mse	min	max	average	mse	min	max	average	mse	min	max
1	**29**	**819**	**1.538**	**30**	**6.100**	**5.060**	**5.798**	**-**	**18.216**	**1,38**	**1,32**	**-**	**5**
2	**63**	**3.080**	**5.601**	**35**	**38.780**	**68.791**	**178.744**	**-**	**1.204.554**	**4,97**	**9,06**	**-**	**49**
Tot	**92**	**2.368**	**4.830**	**30**	**38.780**	**48.701**	**150.883**	**-**	**1.204.554**	**3,84**	**7,72**	**-**	**49**

2.4.2. Discriminant analysis for an a priori classification of insurable territorial units

The question of classifying a priori territorial units that had not been hit by adverse weather events has been approached by choosing a linear[3] discriminant analysis procedure as a classification method. Altitude, longitude and latitude have been used as the variables expressing the discriminant model. Such choice is due to the logical consideration that weather events are connected to the geophysical location of the municipality, hence to the severity of the production loss. The municipalities with the same geo-physical characteristics can then fall into a specific risk class and thus have approximately the same chance to be hit by a particular weather event, with the same loss severity for the same agrifood product.

In particular, because latitude and longitude can not be directly used for the implementation of the discriminant analysis in that they are angular measures, they have been trigonometrically converted through the sine function, thus measuring the angle width of a cathetus of a right-angled triangle with a single hypotenuse. The wider the longitude angle, the further the municipality is located to the east, and the wider the latitude angle, the further the municipality is located to the north.

From a theoretical point of view, the question of discriminant analysis can be summed up as such.

Considering a k-dimensional X sampling universe divided into g sub-population $X_1,...,X_g$ (in this case $k = 3$ and $g = 2$), the discriminant analysis techniques consent to assign a generic observation x to one of the g sub-populations. A new x unity is assigned to the *j-th* group, so the distance between the group averages and the values of the new unity is minimum. For the assignment error to be minimum, one does not have to work directly on the original variables but on an appropriate linear combination, in order to maximize the distance between the groups. The question is then reduced to the search for the k-length vector, by means of to proceed to the transformation. The matrix of the starting data is converted into a vector $Z = X \cdot a$, while the vector representing the statistical unity into a scalar $z = x \cdot a$.

Starting from the information given by the g samples $X_1,...,X_g$, i.e. the result of cluster analysis, the means' vector for each *j-th* sample is:

$$\overline{X}_j = (\overline{X}_{1j}, \ldots, \overline{X}_{kj}) \qquad [2.9]$$

while the matrix of variances and covariances can be broken down as such:

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[3] Discriminant analysis is a branch of multivariate statistics in which units are assigned to groups, on the basis of taxonomic characteristics observed both in the groups and in the units. The first application, by R.A. Fisher, dates back to 1936. In that circumstance it was used to classify fossil finds into the primate or humanoid category, according to certain anthropometric characteristics.

$$S = S_{(w)} + S_{(b)} \qquad [2.10]$$

where $S_{(w)}$ represents the variances and covariances matrix within the p samples given by:

$$S_{(w)} = \sum_{j=1}^{p} \frac{n_j}{n} S_j \qquad [2.11]$$

while $S_{(b)}$ is the variances and covariances matrix among p samples.

The vector a is obtained as a solution of the following *max* constraint problem:

$$\begin{cases} \max\limits_{a} a' S_{(b)} a \\ a' S_{(b)} a = 1 \end{cases} \qquad [2.12]$$

for which a closed form solution is obtained by using the method of Lagrange multipliers, thus maximizing:

$$L(a, \lambda) = a' S_{(b)} a - \lambda (a' S_{(b)} a - 1) \qquad [2.13]$$

it is demonstrated that λ corresponds to the biggest eigenvalue of the matrix $S^{-1}S_{(b)}$, while a is the eigenvector associated to it. In practice the unit x is assigned to the group j^* as follows:

$$\left| w - \bar{W}_{j*} \right| = \min_{j} \left| w - \bar{W}_{j} \right| \qquad [2.14]$$

The procedure illustrated above was carried out on the basis of the cluster analysis results, also keeping in consideration the variables identified as discriminant.

In tables 5 to 7, as for the pear crop in the observation period 2006-2009, the result of discriminant analysis is reported in order to assign a risk class to the municipalities that have not been hit by weather events and for the relative parallel with the municipalities hit by a weather event.

Table 5: Municipalities hit by adverse weather event.

Cluster	Municipalities	Altitude *		Latitude **		Longitude **	
		Average	**Mse**	**Average**	**mse**	**Average**	**mse**
1	90	153,87	202,63	0,7038	0,0139	0,1895	0,0309
2	61	124,11	227,79	0,6994	0,0212	0,1959	0,0269
Total	**151**	**141,85**	**213,65**	**0,7020**	**0,0173**	**0,1921**	**0,0295**

*Metres above sea level; **Trigonometric sine transform.

Table 6: Municipalities not hit by adverse weather event.

Cluster	Municipalities	Altitude*		Latitude**		Longitude**	
		Average	mse	Average	mse	Average	mse
1	54	127,72	184,95	0,7072	0,0058	0,1833	0,0245
2	1	44,00	-	0,6964	-	0,2121	-
Total	**55**	**126,20**	**183,60**	**0,7070**	**0,0059**	**0,1838**	**0,0246**

*Metres above sea level; **Trigonometric sine transform.

Table 7: Total municipalities.

Cluster	Municipalities	Altitude*		Latitude**		Longitude**	
		Average	mse	Average	mse	Average	mse
1	144	144,06	196,59	0,7051	0,0116	0,1872	0,0288
2	62	122,82	226,18	0,6994	0,0210	0,1962	0,0268
Total	**206**	**137,67**	**206,18**	**0,7034**	**0,0153**	**0,1899**	**0,0285**

*Metres above sea level; **Trigonometric sine transform.

Table 8 sum up statistical information about risk classes, with reference to ex-post variables analysed.

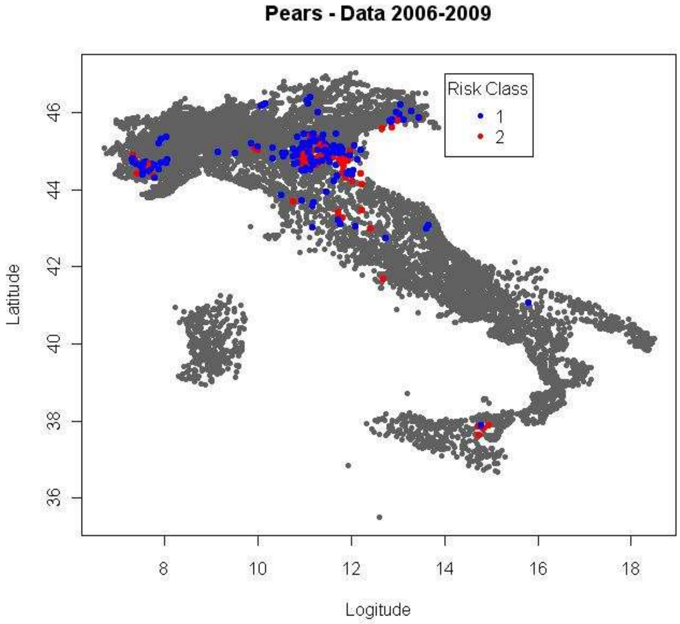
Table 8: Pears - Data 2006-2009

Cluster	Municipalities	Insured Value *		Claim value *		Damage degree	
		Average	mse	Average	mse	Average	mse
1	144	73.912	108.260	9.589	14.309	12,97%	17,98%
2	62	741.110	753.765	189.146	299.591	25,52%	16,72%
Total	**206**	**274.719**	**522.348**	**63.630**	**184.228**	**23,16%**	**17,66%**

*Values in euros

Figure 4 shows the risk classes mapping, obtained through the joint analysis of *cluster* and discriminant analysis.

Figure 4: Risk classification



2.4.3. Efficiency analysis in the classification of territorial units

In order to obtain an efficiency measure of the ex-ante risk assessment for each product class, a gap analysis between ex-ante and ex-post hierarchization with related risk class definition has been carried out. Such gap analysis has been based on the spatial comparison between numerosity and composition of the clusters obtained respectively with ex-ante and ex-post variables.

In this study ex-ante variables stand for "Total Premium" and "Insured Value". The definition ex-ante was chosen because it is referred to the potential assessment of the risk through the premium level. In like manner, ex-post variables stand for the variables "Number of compensation batches", "Compensated value" and "Insured quantity", expressing the result of the insurance risk observation.

To this end two statistical indicators have been created, respectively for spatial concordance and time persistency. As for the first indicator, established that *i* stands for year and *s* for the risk class, the municipalities of the ex-post *i* cluster with the same *k* risk level (observed) have been identified. The concordance index referred to the *i-th* year and *s-th* class of agrifood product has been defined as follows:

$$IC_i^s = \sum_{k=1}^{g} \frac{{}^sNCAP_i^k}{{}^sNCP_i^k} \quad \text{with} \quad 0 \le IC_i^s \le 1 \qquad [2.15]$$

where:

${}^sNCAP_i^k$ is the number of municipalities involved in the *i*-th year (i=2006,2007,2008,2009) for the *s*-th class of product (s=1,2,….,14) in the ex-ante cluster with risk level *k* (*k*=1,2) which are also comprised (with the same identification code) in the ex-post cluster with the same *k* risk level;

${}^{s}NCP_{i}^{k}$ is the number of municipalities involved in the *i*-th year (i=2006,2007,2008,2009) for the *s-th* class of product (s=1,2,….,14) in the ex-ante cluster with risk level *k*.

Table 9 shows an outline of the results of the spatial concordance index, based on the data of the observation year 2009.

Table 9: Spatial concordance index – year 2009

Product description	Disregarded risk class	Risk class confirmation	**Total**	**Concordance index**
Citrus fruit	9	12	**21**	**0,571**
Cereals	141	149	**290**	**0,514**
Other fruit	20	31	**51**	**0,608**
Vegetables & other products	22	60	**82**	**0,732**
Tomato	40	84	**124**	**0,677**
Wine grapes	77	85	**162**	**0,525**
Kiwi fruit	61	81	**142**	**0,570**
Cherries	45	75	**120**	**0,625**
Apples	69	46	**115**	**0,400**
Rice	1	3	**4**	**0,750**
Pears	38	54	**92**	**0,587**
Peaches	23	65	**88**	**0,739**
Plums	52	19	**71**	**0,268**
Total	**598**	**764**	**1.362**	**0,561**

The second indicator is based on the appropriate measurement of the migration between the risk classes of the territorial units investigated, with reference to each agrifood product. For every agrifood product the migration of municipalities from a cluster to another have been analysed; that is, once identified the municipalities that make up the clusters for every observation year, the time persistency index of each municipality has been surveyed ex-post.

The analysis has been carried out for the risk classes related to the ex-post variables and the persistency index in the risk class *k* was defined, for each municipality, in the following way:

$${}_{m}^{s}IP_{i}^{k} = \frac{{}_{m}^{s}T_{i}^{k}}{{}^{s}T_{i}^{k}} \qquad \text{with } 0 \leq {}_{m}^{s}IP_{i}^{k} \leq 1 \qquad [2.16]$$

where:

${}_{m}^{s}T_{i}^{k}$ is the persistence time of the *m-th* municipality connected to the *s-th* product class in the cluster with *k* risk level starting from the *i-th* year (*i*=2006, 2007, 2008);

${}^{s}T_i^k$ is the maximum persistence time in the cluster with level risk *k* starting from the *i-th* year (*i*=2006, 2007, 2008)

A synthetic measure of the annual persistency index in the same risk class has been then introduced, calculating a proper weighted average where the weightings are respectively the quantities and the insured value.

$$ {}^{s}_{QA}IP_i^k = \frac{\sum_m {}^{s}_{m}IP_i^k \cdot {}^{s}_{m}QA_i}{\sum_m {}^{s}_{m}QA_i} \cdot \text{ with } 0 \le {}^{s}_{QA}IP_i^k \le 1 \qquad [2.17] $$

$$ {}^{s}_{VA}IP_i^k = \frac{\sum_m {}^{s}_{m}IP_i^k \cdot {}^{s}_{m}VA_i}{\sum_m {}^{s}_{m}VA_i} \cdot \text{ with } 0 \le {}^{s}_{VA}IP_i^k \le 1 \qquad [2.18] $$

where: *m* is the number of the recorded municipalities;

${}^{s}_{m}QA_i$ is the insured quantity in the *i-th* year in the *m-th* municipality for the *s-th* class of agrifood product;

${}^{s}_{m}VA_i$ is the reimbursed quantity in the *i-th* year in the *m-th* municipality for the *s-th* class of agrifood product;

Tables 10 and 11 show an outline of the above mentioned index results:

Table 10: Persistency index weighted with the insured quantity. Product: Pears

Index	**Risk class**	
	1	**2**
${}^{s}_{QA}IP_{2008}^k$	0,4996	0,5004
${}^{s}_{QA}IP_{2007}^k$	0,3466	0,6534
${}^{s}_{QA}IP_{2006}^k$	0,2540	0,7460

Table 11: Persistency index weighted with the insured value. Product: Pears

Index	Risk class	
	1	2
${}_{VA}^{s}IP_{2008}^{k}$	0,4988	0,5012
${}_{VA}^{s}IP_{2007}^{k}$	0,3455	0,6545
${}_{VA}^{s}IP_{2006}^{k}$	0,2602	0,7398

The persistency index of the municipalities in the same risk class (temporally observed in the research period 2006-2009) and the concordance index between ex-ante expected risk and ex-post true risk (observed in the territory for all municipalities insured with combined risk policies) both referred to each agrifood product class, suggest the following considerations:

a. the premiums applied during the research period to agrifood products as a whole came out to be inefficient when compared to ex-post risk intensity;

b. the insured municipalities belonging to the riskiest classes have a higher migration frequency compared to those belonging to lower risk classes; a phenomenon which is unrelated to the agrifood product type considered;

c. the outcome of the analysis on the persistency and concordance indexes, also because of the poor number of communal unities in some risk classes with respect to certain products, brought the reduction of the risk classes from 4 to 2.

2.4.4. Selection process of risk probability distribution

To calculate the fair-value, and thus the risk margin, the behaviour of the random variable loss has to be known. Mathematically, it is necessary to define the probability space in which it is defined in order to be able to calculate the average value, in case of non linear compensation restrictions, in particular to find out the percentile for determining the unexpected loss and, consequently, a risk loading based on the percentile approach method.

For each agrifood product class a distribution among the following ones[4] has been chosen

- Extreme value;
- Exponential;
- Generalized extreme value;
- Gamma;
- Generalized Pareto;
- Log-Normal;
- Normal;
- Rayleigh;
- Weibul.

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[4] See the annex for synthetic technical specifications of each probability distribution.

To calibrate the parameters of the above mentioned distributions the estimation method based on maximization of the likelihood function applied to available data has been used. Theoretically, the problem can be formalized as such: consider a random variable X, where $f\ (x;\underline{\vartheta})$ is the density function depending on the parameters vector $\underline{\vartheta} = (\vartheta_1, \ldots, \vartheta_p)$. Given a vector of n observations $x = (x_1, \ldots x_n)$, the likelihood function is:

$$L(x_1, \ldots, x_n; \underline{\vartheta}) = \prod_{k=1}^{n} f(x_k; \underline{\vartheta}) \qquad [2.19]$$

The parameters are estimated by choosing the vector $\underline{\vartheta}$ which maximizes [2.19], i.e. solving the the system of equations obtained by means of partial derivatives:

$$\begin{cases} \frac{\delta}{\delta\vartheta_1} L(x;\rho) & = & 0 \\ \vdots & & \\ \frac{\delta}{\delta\vartheta_p} L(x;\rho) & = & 0 \end{cases} \qquad [2.20]$$

The system obtained with [2.20] is not necessarily a linear one. This depends on the form of the density function $f(x;\underline{\vartheta})$; when the system is not a linear one it is necessary to resort to numerical methods of resolution, arriving at an approximate solution. Among the methods used the most common one is the one known as Newton method.

As an alternative, instead of maximizing [2.19], it is possible to work on its logarithmic transform, and come to the same results for the parameters, in that it is an increasing monotone transformation.

Each agrifood product has been assigned to a distribution by means of the chi-square test. The hypothesis to prove is “the sample comes from a certain theoretical distribution”, versus the alternative one “the sample comes from a different distribution”.

For each product a probability distribution was chosen, among the ones in the list, on the basis of the chi-square test[5] and the choice goes for the best degree of match with empirical distribution. The *p-value* is matching measure used, which is obtained in the following way:

$$p - value = \Pr\left\{\chi^2_{[s-1]} > \chi^2_{oss}\right\} \qquad [2.21]$$

---

[5] The test statistic takes the following form:

$$\chi^2 = \sum_{k=1}^{s} \frac{(n_k - n \cdot p_k)^2}{n \cdot p_k}$$

the equation [2.21] has a distribution of the sort (s −1) degrees of freedom. In order to use [2.21] it is necessary to partition the real numbers interval into s subsets $\zeta_k = (x_{k-1}, x_k)$ so that it results $\bigcup_{k=1}^{s} \zeta_k \equiv \Re$ and, simultaneously $\bigcap_{k=1}^{s} \zeta_k \equiv \emptyset$

As for [2.22]:

- n is the amount of inspection;
- n_k is the number of sampling units comprised in ζ_k ;
- p_k is the theoretical frequency, i.e. $p_k = F(x_k) - F(x_{k-1})$, where $F(.)$ is the distribution function of the relevant random variable on which inference is made.

where $\chi^2_{[s-1]}$ and χ^2_{oss} are respectively the random variable with chi-square distribution and the value observed in correspondence of the sample.

On the basis of the chi-square test, for each agrifood product the distribution with the higher *p-value* was chosen. Following an intuitive line of thought it can be inferred that the more empirical frequencies are close to theroretical ones, the smaller the value of χ^2_{oss} and consequently the *p-value* is higher.

Considering the analysis carried out on the total of agrifood products surveyed, the Rayleigh and Weibull distributions have shown to be especially suitable to data.
In tables 12, 13, 14 and 15 for the variable “Compensated Value/Insured quantity”, observed for the product Pears in the 2006-2009 period the percentiles of the investigated distributions, the results of the chi-square test, the parameters of the probability distributions and the position and dispersion indexes are respectively reported.

Table 12: Distributions percentiles

	Distribution									
Percentile	**Observed**	**Extreme value**	**Exponetial**	**Gamma**	**Generalized extreme value**	**Generalized Pareto**	**Log-Normal**	**Normal**	**Rayleigh**	**Weibull**
75,00%	33,67	35,70	34,25	31,95	31,98	34,89	31,57	33,23	32,67	32,72
95,00%	47,60	46,10	74,02	49,95	47,67	51,95	55,96	45,48	48,02	47,43
99,00%	60,00	51,90	113,78	65,74	60,60	58,62	83,66	54,09	59,54	58,34
99,50%	60,00	53,79	130,91	72,21	65,62	60,04	96,93	57,24	63,86	62,42
99,90%	62,02	57,37	170,67	86,72	76,19	61,78	131,31	63,73	72,92	70,93

Values in euros/quintal

Table 13: Results of Chi-Square test

Test Chi-Square	**Extreme value**	**Exponetial**	**Gamma**	**Generalized extreme value**	**Generalized Pareto**	**Log-Normal**	**Normal**	**Rayleigh**	**Weibull**
pvalue	0,00%	0,00%	3,17%	0,08%	0,00%	0,01%	0,03%	70,61%	14,86%

Table 14: Distribution parameters

Parameters	**Extreme value**	**Exponetial**	**Gamma**	**Generalized extreme value**	**Generalized Pareto**	**Log-Normal**	**Normal**	**Rayleigh**	**Weibull**
P_1	31,2868	24,7073	3,4259	-0,0818	-0,5837	3,0541	24,7073	19,6183	27,9549
P_2	13,4985	-	7,2120	10,8028	36,7116	0,5901	12,6292	-	2,0757
P_3	-	-	-	19,1861	-	-	-	-	-

Table 15: Position and dispersion indexes

	Observed	Extreme value	Exponetial	Gamma	Generalized extreme value	Generalized Pareto	Log-Normal	Normal	Rayleigh	Weibull
Average *	24,71	23,50	24,71	24,71	24,61	23,18	25,23	24,71	24,59	24,76
S.q.m.*	12,63	17,31	24,71	13,35	12,59	15,75	16,28	12,63	12,85	12,52
Skewness**	0,51	-1,14	2,00	1,08	-0,72	nd	2,20	0,00	0,63	-2,81

*Values in euros/quintal; **dimensionless index

As premium rates must be expressed in insured value units, the selected distribution has been transformed by means of a scale factor given by the ratio between “Insured quantity/Insured value”, and such transformation does not influence the distribution shape.

2.5. Premium customization

The aspects analysed in the previous paragraphs lead us to conclude that the risks in the insured population have different profiles. For this reason, in order to be able to correctly calculate the fair-value the premium required for each insured subject must be different according to the objectively observable elements which have led to risk classes identification. The above mentioned does not necessarily imply that the purely “mechanical” application of cluster techniques is sufficient for determining risk classification. The rate model adopted is based on the customization principle which has been following in insurance practice for a long-time; that is identifying risk classes that could remain stable over time, so that the premium adjustment does not vary too much. On the contrary, if that happened, two errors would arise: the first one a technical one, that is the risk class identified was not fully homogeneous, the second, a commercial one, implying that insured subjects would not be willing to accept an excessive premium rise, so they would not renew the following year, loosing a large market share. The attempt has been made to avoid the risk of wrong classification through intertemporal migration analysis and persistency analysis described in the previous paragraphs.

The tariff model proposed has then made it possible to obtain premium rates differentiated by risk classes, price classes and product family. Parameters have been defined separately for each product macroclass, using the modified chi-square approach, which gives a perfect matching (apart from minimal entity approximations) with the rate requirements and also minimizes the squared value of the addition of the residual deviations. The customization procedure proposed can be expressed in the following way.

Let:

- $Y_{k,r,s}$ the claim value for the k-th risk related to the r-th risk class and the s-th price class, with $k = 1,\ldots, n_{r,s}$, where $n_{r,s}$ is the number of risks simultaneously related to the r-th risk class and the s-th price class;

- $W_{k,r,s}$ the insured value for the k-th risk related to the r-th risk class and the s-th price class, with $k = 1,\ldots,n_{r,s}$, where $n_{r,s}$ is the number of risks simultaneously related to the r-th risk class and the s-th price class;

- $\rho_{k,r,s} = \dfrac{Y_{k,r,s}}{W_{k,r,s}}$ the experience rate for the *k*-th risk related to the *r*-th risk class and the *s*-th price class, with k=1,…,$n_{r,s}$, where $n_{r,s}$ is the number of risks simultaneously related to the *r*-th risk class and the *s*-th price class.

The total amount paid by the insurer (for every single product) is then:

$$F = \sum_{r=1}^{c_1}\sum_{s=1}^{c_2}\sum_{k=1}^{n_{r,s}} Y_{k,r,s} = \sum_{r=1}^{c_1}\sum_{s=1}^{c_2}\sum_{k=1}^{n_{r,s}} \rho_{k,r,s} W_{k,r,s} \qquad [2.22]$$

where c_1 and c_2 are respectively the number of risk classes and the number of price classes.

Given $n = \sum_{r=1}^{c_1}\sum_{s=1}^{c_2} n_{r,s}$, the total number of risks by product under examination, the quantity $q = \dfrac{F}{n}$, called pure premium represents the average rate requirement, that is the average premium. The insurer comes to balance if the total of collected premiums equals exactly the *F* quantity. Obviously, in order to plan the requirement to successive business period/s, one has to take into account both inflation and insurance regulation amendments (coverage restrictions and/or minimum deductible).

The fair premium is expressed through the following three variable function:

$$f(r;s;W) = \bar{\rho} \cdot W \cdot \beta_r \cdot \lambda_s \qquad [2.23]$$

where:

- $\bar{\rho}$ is the expected value of the theoretical distribution chosen for the product insurance rate;
- *W* is the insured value;
- β_r is a coefficient characterizing the insured subjects belonging to the *r-th* risk class;
- λ_s is a coefficient characterizing the insured subjects belonging to the *s-th* price class.

To find out the solution for the vectors $\beta = \{\beta_1, \beta_2,\ldots, \beta_{c1}\}$ and $\lambda = \{\lambda_1, \lambda_2,\ldots, \lambda_{c2}\}$ it is possible minimizing the quadratic form (modified chi-square[6]):

$$Q[\beta,\lambda] = \sum_{r=1}^{c_1}\sum_{s=1}^{c_2}\sum_{k=1}^{n_{r,s}} \frac{\left[\rho_{k,r,s}\cdot W_{k,r,s} - \bar{\rho}\cdot W_{k,r,s}\cdot\beta_r\cdot\lambda_s\right]^2}{\bar{\rho}\cdot W_{k,r,s}} \qquad [2.24]$$

Then the optimal solution is get out solving the system of partial derivatives related to each β_r and λ_s :

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[6] Daboni(1993).

$$\frac{\delta}{\delta\beta_r}Q[\beta,\lambda]=-2\sum_{s=1}^{c_2}\sum_{k=1}^{n_{r,s}}\left[\rho_{k,r,s}\cdot W_{k,r,s}-\bar{\rho}\cdot W_{k,r,s}\cdot\beta_r\cdot\lambda_s\right]\cdot\lambda_s=0;\quad con\quad r=1,2,\ldots,c_1 \qquad [2.25]$$

$$\frac{\delta}{\delta\lambda_s}Q[\beta,\lambda]=-2\sum_{r=1}^{c_1}\sum_{k=1}^{n_{r,s}}\left[\rho_{k,r,s}\cdot W_{k,r,s}-\bar{\rho}\cdot W_{k,r,s}\cdot\beta_r\cdot\lambda_s\right]\cdot\beta_r=0;\quad con\quad s=1,2,\ldots,c_2 \qquad [2.26]$$

that is equivalent to:

$$\begin{cases}\beta_r=\dfrac{\sum_{s=1}^{c_2}\lambda_s\cdot Y_{\bullet,s,r}}{\bar{\rho}\cdot\sum_{s=1}^{c_2}\lambda_s^2\cdot W_{\bullet,s,r}} & with\quad r=1,2,\ldots,c_1\\[2ex] \lambda_s=\dfrac{\sum_{r=1}^{c_1}\beta_r\cdot Y_{\bullet,s,r}}{\bar{\rho}\cdot\sum_{r=1}^{c_1}\beta_r^2\cdot W_{\bullet,s,r}} & with\quad s=1,2,\ldots,c_2\end{cases} \qquad [2.27]$$

where:

$$Y_{\bullet,s,r}=\sum_{k=1}^{n_{r,s}}Y_{k,r,s}\qquad W_{\bullet,s,r}=\sum_{k=1}^{n_{r,s}}W_{k,r,s}$$

The $c_1 + c_2$ equations system is a non linear one; moreover, the particular connections between β and λ parameters make it impossible to define a formula for their calculation, so they are iteratively estimated using numerical procedures.

A premium including risk loading is instead obtained by substituting, in the fair premium function, the value $\bar{\rho}$ with the percentile ρ_α, where the latter is the value to which corresponds the sharing function of the random variable $\tilde{\mathrm{P}}$ “Claim value/Insured value” takes the value $1 - \alpha$, that is:

$$\Pr\left[\tilde{\mathrm{P}}\le\rho_\alpha\right]=1-\alpha \qquad [2.28]$$

therefore the premium function is the following one:

$$f(r;s;W)=\rho_\alpha\cdot W\cdot\beta_r\cdot\lambda_s \qquad [2.29]$$

with α identified such as $\bar{\rho}<\rho_\alpha$.

Table 16 and 17 report the results of the proposed model and thus the premium rates relative to the product “Pear”, usable in the insurance coverage year 2010.

Table 16: Premium rates – Average value – GOLD tariff

	Unit Value		
Risk Class	1	2	Tot
1	7,18%	8,42%	8,09%
2	14,30%	16,78%	16,21%
Tot	12,78%	15,27%	14,69%

Table 17: Premium rates – 75° percentile – GOLD tariff

	Unit Value		
Risk Class	1	2	Tot
1	12,68%	14,87%	14,28%
2	25,25%	29,61%	28,62%
Tot	22,55%	26,96%	25,92%

The GOLD tariff in particular provides for the restrictions reported in table 18.

Table 18: GOLD tariff restrictions

damage	minimum deduction	damage	minimum deduction
31%	30%	36%	20%
32%	28%	37%	18%
33%	26%	38%	16%
34%	24%	39%	14%
35%	22%	40%	12%
From 41 to 100%	10%		

2.6. Model validation

In order to validate the proposed rate model the base-line data already duly corrected in the basic information has been broken down into two sample subsets, in particular:

- the subset referred to the horizon 2006-2008, used as estimation sample of the model parameters and thus of the whole customized premium definition process;
- the subset referred to the year 2009, used as the trial sample of the rating model.

The validation process has been made on the ex-post analysis via back-testing procedure on two technical ratios picked up the loss data of the year 2009. In particular, in order to simulate the technical results of the business period 2009, they have been calculated for each risk class and for each agrifood product:

- the experience-rate obtained by the ratio between claimed value and insured value,
- the loss-ratio obtained by the ratio between claimed value and the premiums.

Such technical ratios have been calculated taking in account insurance restrictions, i.e. minimum deductible of 10% and 30% and with premium rate measured in correspondence to 75° percentile of the probability distribution, selected for each product.

Table 19: Back-Testing on 2009 data

Risk Class	**Premium rates measured over the 2006-2008 period**		**2009 data (milion euros)**			**Experience Rate**		**Premiums (million euros)**		**Loss Ratio**		**Tariff in force Year 2009 (million euros)**		
	md 30%	**md 10%**	**Insured Value**	**Claim Value md 30%**	**Claim Value md 10%**	**md 30%**	**md 10%**	**md 30%**	**md 10%**	**md 30%**	**md 10%**	**Premiums**	**Claim Value**	**Loss Ratio**
1	7,6%	13,2%	87,7	5,2	11,0	6,0%	12,6%	6,7	11,6	78,7%	95,0%	6,5	8,2	125,3%
2	9,8%	16,3%	104,8	7,4	15,7	7,1%	15,0%	10,3	17,1	72,1%	91,9%	8,8	12,3	140,9%
Total	**8,8%**	**14,9%**	**192,5**	**12,7**	**26,7**	**6,6%**	**13,9%**	**17,0**	**28,7**	**74,7%**	**93,2%**	**15,3**	**20,5**	**134,2%**

As can be verified in table 19, reporting simulation data compared between the proposed tariff and the one in force in the year 2009, the model elaborated determines on average for every type of agrifood product a good performance of the loss ratio which falls into a range between 74.7% and 93.2% with a franchise respectively of 10% and 30%, versus an average loss ratio per tariff in force of 134.2% .

Ultimately, the outcome of the validation procedure is a first proof of the elaborated tariff model's efficiency, for the purposes of climate risk assessment. The widening of the information basis to the years following 2009 will allow further research to find the tariff's technical balance.

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Annex A: Technical specifications

A.1 Normal distribution

Density function:

$$f(x) = \frac{1}{\sqrt{2\cdot\pi\cdot\sigma}} \cdot e^{-(x-\mu)^2/2\cdot\sigma^2\cdot x} \qquad -\infty < x < \infty$$

Position and dispersion indexes:

Mean: $E[X] = \mu$
Variance: $Var[X] = \sigma^2$
Skewness: $\gamma = 0$

A.2 Log-normal distribution

Density function:

$$f(x) = \frac{1}{\sqrt{2\cdot\pi\cdot\sigma}\;x} \cdot e^{-(\log x-\mu)^2/2\cdot\sigma^2\cdot x} \qquad 0 < x < \infty$$

Position and dispersion indexes:

Mean: $E[X] = e^{\mu+\frac{\sigma^2}{2}}$
Variance: $Var[X] = e^{2\mu+\sigma^2}\left(e^{\sigma^2}-1\right)$
Skewness: $\gamma = \left(e^{\sigma^2}+2\right)\sqrt{e^{\sigma^2}-1}$

A.3 **Exponential distribution**

Density function:

$$f(x) = \lambda \cdot e^{-\lambda x} \qquad 0 < x < \infty; \lambda > 0$$

Position and dispersion indexes:

Mean: $E\left[X\right]=\frac{1}{\lambda}$

Variance: $Var\left[X\right]=\frac{1}{\lambda^2}$

Skewness: $\gamma=2$

A.4 Gamma Distribution

Density function:

$$f(x)=\frac{1}{\theta^k\Gamma(k)}x^{k-1}e^{-\frac{x}{\theta}} \qquad 0<x<\infty;k,\theta>0$$

$$\Gamma(k)=\int_0^\infty t^{k-1}\cdot e^{-t}\,dt$$

Position and dispersion indexes:

Mean: $E\left[X\right]=k\cdot\theta$

Variance: $Var\left[X\right]=k\cdot\theta^2$

Skewness: $\gamma=\frac{2}{\sqrt{k}}$

A.5 Weibull Distribution

Density function:

$$f(x)=\frac{k}{\lambda^k}x^{k-1}e^{-\left(\frac{x}{\lambda}\right)^k} \qquad 0<x<\infty;k,\lambda>0$$

Position and dispersion indexes:

Mean: $E\left[X\right]=\lambda\cdot\Gamma\left(1+\frac{3}{k}\right)$

Variance: $Var\left[X\right]=\lambda^2\cdot\left\{\Gamma\left(1+\frac{2}{k}\right)-\Gamma\left(1+\frac{1}{k}\right)^2\right\}$

Skewness: $\gamma = \frac{\Gamma\left(1+\frac{3}{k}\right)\lambda^3 - 3 \cdot E(X) \cdot Var(X)^2 - \lambda^3}{Var(X)^3}$

A.6 Extreme-value Distribution

Density function:

$$f(x) = \frac{1}{\sigma} e^{-z-e^{-z}} \qquad \sigma > 0$$

$$z = \frac{x-\mu}{\sigma}$$

Position and dispersion indexes:

Mean: $E[X] = \mu - \sigma \cdot \delta$

Variance: $Var[X] = \frac{1}{6} \cdot \pi^2 \cdot \sigma^2$

Skewness: $\gamma = \frac{12 \cdot \sqrt{6} \cdot \zeta(3)}{\pi^3}$

Where δ is the Eulér-Mascheroni constant and equals around 0.577216, while ζ(3) is the Apéry constant and equals around 1.2020569.

A.7 Generalized Extreme-Value Distribution

Density function:

$$f(x) = \frac{1}{\sigma} \left\{1 + \xi \cdot z\right\}^{\left(-\frac{1}{\xi}\right)-1} \cdot e^{\left\{-\left(1+\xi \cdot z\right)^{-\frac{1}{\xi}}\right\}}$$

$$z = \frac{x-\mu}{\sigma}$$

Position and dispersion indexes:

Mean: $E[X] = \begin{cases} \mu + \sigma \cdot \frac{\Gamma(1-\xi)-1}{\xi} & se \quad \xi \in (0,1) \\ \mu + \sigma \cdot \delta & se \quad \xi = 0 \\ \nexists & se \quad \xi \geq 1 \end{cases}$

Variance: $Var[X] = \begin{cases} \sigma^2 \cdot (g_2 - g_1^2)/\xi^2 & se \quad \xi \in (0, \frac{1}{2}) \\ \sigma^2 \pi^2 / 6 & se \quad \xi = 0 \\ \nexists & se \quad \xi \geq \frac{1}{2} \end{cases}$

Skewness: $\gamma = \frac{g_3 - 3 g_1 g_2 + 2 g_1^3}{(g_2 - g_1^2)^{3/2}}$

$$g_k = \Gamma(1 - k \cdot \xi)$$

A.8 Generalized Pareto Distribution

Density function:

$$f(x) = \frac{1}{\sigma}(1 + \xi \cdot z)^{-\frac{1}{\xi}-1}$$

$$z = \frac{x-\mu}{\sigma}$$

Position and dispersion indexes:

Mean: $E[X] = \mu + \frac{\sigma}{1-\xi} \quad se \quad \xi < 1$

Variance: $Var[X] = \frac{\sigma^2}{(1-\xi)^2 \cdot (1-2 \cdot \xi)} \quad se \quad \xi < \frac{1}{2}$

A.9 Rayleigh Distribution

Density function:

$$f(x)=\frac{x}{\sigma^2}e^{-\frac{x^2}{2\cdot\sigma^2}}$$

Position and dispersion indexes:

Mean: $E[X]=\sigma\cdot\sqrt{\frac{\pi}{2}}$

Variance: $Var[X]=\sigma^2\cdot\left(2-\frac{\pi}{2}\right)$

Skewness: $\gamma\approx 0.631$

3. Conclusions and future perspectives

In conclusion, the experience of the NSF's forty-year activity, in the first seven years of intervention of the Agricultural Risk Reinsurance Fund and the research on definition, implementation and experimentation of an actuarial model of reinsurance rate covering agricultural production damages due to natural disasters, show that, in order to introduce innovative tools for the management of agricultural risks in agriculture, a series of fundamental conditions must be present. Such conditions are: public support, both through direct financing and the issuing of targeted regulations; collection and availability of qualitatively and quantitatively meaningful statistical data; the scientific competence to maximize the added value of the data and available information.

Moreover, it is also necessary to adequately combine, within a project that is consistent and constant over time, the above mentioned conditions, in a medium and long term perspective.

In particular, the specific and tangible case of combined risk policies shows how premium facilitations and reinsurance not only had beneficial effects on insurance coverage implemented in a specific year of intervention, but greatly contributed to creating an information resource which can be now exploited in a profitable way for the maximization of the tools used to date and help define new insurance solutions. The previously illustrated study can thus be considered the first fundamental step in making the desired improvements a reality.

Moreover, consistently with the evolution of the economic scenario and community guidelines on agricultural policy, further initiatives should be started in order to draw up a set of tools aimed at risk management, allowing a more efficient reaction towards income fluctuations and market instability. These phenomena heavily affect the farming sector's capacity to invest and remain competitive.

Even on the basis of other countries’ experiences up to the present day, both in the U.S. and in Europe, the major new potential for the modernization of the agricultural risk management system is thought to come from the new synergies to be developed between the insurance and credit sectors and with the creation of mutual funds. In particular, integration between insurance and credit could lead, thanks to information and credit synergies, to the reduction of credit cost for the insured farms and favour, at the same time, the rise in the number of insuring farms. The reduction of credit cost and the subsequent increase of credit access for the farms are required for our agriculture to be competitive on the international markets, thus continuing to improve the quality of the products.

Mutual funds, instead, could encourage the farmers to make use of the measures for income stabilization through ad-hoc solutions pertaining to the specific productive reality. This would favour, at the same time, a wider risk sharing, with the mutual funds providing recourse to some sort of reinsurance coverage, in order to contain the following systemic risk. Mutual funds will probably be chosen as the main focus in the next Agricultural Policy reform, in order to provide solutions for those farmers to whom the insurance market can not yet offer suitable products.

Finally, it is clear that there is also a need to properly harmonize and rationalize both public and private interventions and instruments applied up to today and currently being implemented. The goal is to avoid overlapping different measures and wasting resources that would eventually result in recourse to emergency measures, often entailing delays and preventing the empowerment of the farmers.

The information and experiences collected in this first study represent a good starting point for consideration and better designing insurance and reinsurance tools of climatic risk management in agriculture that can also be applied to different sectors.