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against risk in a dryland region of Portugal**

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Abstract

This research develops a mathematical programming model to maximize the expected utility of the farmers' wealth-producing cereals in the Alentejo dryland region of Portugal, and it is used to determine the premium rate that crop farmers are willing to pay for reducing the variability of their incomes, and the Portuguese government subsidy of the premium rate in the case where the farmer is not willing to pay the totality of this.

Key words: Expected utility, Risk Aversion, Risk Premium, Asking Price, Area-Yield Crop Insurance Program, Premium Rate

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1. Introduction

Agricultural activity is, by nature, a business that involves risk. Farmers face a variety of price, yield and resources risks, which make their incomes unstable from year to year. Crops and livestock production may be destroyed by natural hazards such as floods, fire, drought, etc. The risk can be reduced through several techniques of farm management, such as the diversification of the agricultural production activities or the transfer of the agricultural risk to other sectors of the economy, such as insurance (Hazell, 1986).

The problem under study in this research work is the decrease in and the variability of the income of the farmers producing crops in the Alentejo dryland region of Portugal. This research work studies the implementation of an area-yield crop insurance program, as an instrument for risk management. This insurance program, proposed by Miranda in 1991, includes all of the factors of climatic origin responsible for crop production decreases. The indemnity payments are based on the average production of an agricultural area that includes farmers with insurance and farmers without insurance (Serrão, 1991). This insurance program, when assuming the risks for a certain production level, allows that, faced with the occurrence of a casualty, the farmer is indemnified independently of his crop production, but in accordance with the average productivity of the agricultural area. The program was introduced in 1993 in the U.S.A. for wheat and soybeans, working with more than 100 insurance areas. In 1994, it was enlarged to more than 1,200 insurance areas and to other cultures such as cotton, corn and barley (Goodwin et al, 1995).

This research work seeks to attain two objectives. The first objective intends to determine the maximum premium that the crop farmers are willing to pay to reduce the risk originating from the variability of their incomes, and to analyze the crop farmers' behavior after the purchasing of the insurance. The second objective intends to determine the financial contribution of the Portuguese government in a crop insurance program.

2. Methodology

The expected utility assumes that the individual, when evaluating different risk situations, substitutes the monetary values of the wealth for the utility of the wealth. This procedure, which gives rise to the expected utility criterion, modifies the wealth values, substituting them for the utility of the wealth and it does not alter the probabilities of the occurrence of events. The expected utility function is known as " von Neumann - Morgenstern utility ". In an analysis

consistent with the axioms of the expected utility theory and where only the final wealth matters, it is assumed that each individual has a utility function that allows investment appraisal. If this criterion is adopted, it is natural to ask the question: how much certainty wealth would provide a decision-maker with the same satisfaction level as that proportioned by the sum of the initial wealth together with an agricultural product portfolio of uncertain income \tilde{x} ? This concept is denominated certainty equivalent, and it can be expressed through the following expression (Eeckhoudt et al, 1995):

$$U(W^*) = \int U(W_0 + \tilde{x}) f(x) dx \quad (2.1)$$

Where:

W^* - Certainty equivalent;

W_0 - Initial wealth;

\tilde{x} - Agricultural product portfolio of uncertain income added to the initial wealth;

$U(\cdot)$ - Expected utility of the crop farmer's wealth; and,

$f(\cdot)$ - Density function of \tilde{x} .

This equation shows what should be the certainty wealth level without risk that originates the same utility level as an investment with risk. Can the individual now ask what are the fair terms of exchange between uncertainty ($W_0 + \tilde{x}$) and certainty (W^*)? This is the asking price concept of the investment, which can be defined in the following way:

$$P_a = W^* - W_0 \quad (2.2)$$

Where:

P_a - Asking price.

The asking price is the minimum price for which the individual is willing to sell the investment. If a buyer was found who was prepared to pay more than P_a , the owner commits himself to the transaction. If willing buyers do not exist to offer P_a , the owner retains the investment. A positive asking price means that the investment has a positive effect on wealth, so the decision-maker evaluates it positively. A negative asking price means that the individual is prepared to pay whoever is willing to take the investment. This notion of negative asking price

corresponds to the insurance concept, since the individual gets rid of an initial risk for the payment of a certain monetary amount. The risk premium can be defined in the following way:

$$\pi = \mu - P_a \quad (2.3)$$

Where:

π - Risk premium of an additive investment; and,

μ - Expected value of the agricultural product portfolio of uncertain income.

A mathematical programming model that maximizes the expected utility value of the crop farmer's wealth is developed in this research work. This model uses an objective function, presented by Saha, of the von Neuman-Morgenstern type, with decreasing absolute risk aversion and increasing relative risk aversion. This model also describes production, managerial, marketing and financial aspects of Alentejo farmers under two nature states (accident state and no-accident state). The expected utility of the farmer's wealth is maximized subject to the following constraint set:

$$\text{Max} = E(U(W)) = \sum_{i=1}^2 \delta_i \left(\lambda - \text{EXP}(-\phi W_i^\eta) \right) \quad (2.4)$$

$$\text{s.a. } X \in F_d$$

Where:

δ_i - Probabilities of the events for each nature state ($i = 1,2$);

W_i - The crop farmer's wealth in each nature state ($i=1,2$);

$E(\cdot)$ - Expected value;

$U(\cdot)$ - Utility function;

X - Decision variable vector of the model;

F_d - Opportunity set of the model;

EXP - Exponential; and,

λ, ϕ, η - Parameters of the utility function.

The parameters have the following restrictions: $\lambda > 1, \phi \neq 0, \eta \neq 0, \phi \eta > 0$.

The parameter λ does not influence the risk attitude characterization and the optimum choice determination and it only guarantees the positiveness of the utility function. Similar to other studies, this research work was attributed with the value 2. The parameter ϕ has an effect essentially linear in the absolute risk aversion coefficient, when the parameter η is constant. Therefore, variations of this parameter allow that the magnitude of the risk aversion coefficient is different, without altering the solutions (Saha, 1993). The larger the parameter is, the larger is the sensitivity of the model faced with alterations to the parameter η , because the aversions levels to the risk are higher. This research work opted to fix the parameter ϕ as 0.01 so that it was possible to vary the parameter η , which has a non-linear behavior relative to the absolute risk aversion coefficient, when ϕ is constant. As the wealth is more sensitive to alterations in this parameter than in the former, this research work opted to vary this parameter of the interval] 0 ; 1 [, in agreement with the presupposition of decreasing absolute risk aversion and increasing relative risk aversion.

3. Data and Information

The Alentejo dryland region of Portugal includes various agricultural areas and crop production systems. Because of the impossibility of studying all of the crop production systems, a representative farm in the Alentejo dryland region was chosen. Even so, it was necessary to collect a quantity of data and information. The data were collected from the Farm Accountancy Data Network, Agricultural Statistics, the Bank of Portugal, Crop Farmers' Associations, agricultural technicians and researchers.

The representative farm is of a type producing cereal in the Alentejo dryland region, whose agricultural production also includes other crop and livestock products. The farm activity is subject to a set of production, marketing, financial and fiscal constraints representing the decision-making process. The representative farm area was divided into two units according to the capacities of soil use, each one of 250 hectares. The first unit comprises good soils (soils type A and B) and the second one medium soils (soils type C). The model includes 16 types of crop rotations chosen according to the use capacity of each soil type and to technical criteria. The production constraints include limitations with respect to land use, labor, use of capital, and use of tractor and combine. The farm income was collected from the crop and livestock accounts. The risk analysis demanded the construction of a series of crop accounts for seven years. The farm income was deflated for 1994/95 through the GDP index.

The financial constraints include limitations with respect to current assets, owners' equity and current liabilities. The final farmer's wealth is calculated in a restriction by the sum of the initial wealth together with farm incomes after taxes.

The premium rate is calculated exogenously to the model and individually for each crop, assuming that the insurance market is a market in perfect competition (null pure profits), where the expected value of the indemnity payments is equal to the pure premium rate. The productivity by hectare follows a normal distribution and the critical point, starting from which the indemnity payments come into place, is the mean less a quarter of the standard deviation.

4. Results

In the first place, it is necessary to determine whether the farmers are willing to pay the premium rate for area-yield crop insurance demanded by the insurance companies. Two types of models make this evaluation. The models without insurance intend to determine how willing the farmer is to pay for area-yield crop insurance. The models with insurance intend to confirm the results of the previous models, and to verify whether the farmer benefits from the purchasing of area-yield crop insurance. In these models, several crop production alternatives were considered, representing different expectations of the crop farmer's production and two states of nature, the accident state and the no-accident state. Through observations conducted in proximity to the farmers, it was verified that they, through a set of subjective probabilities, overvalue the loss probability, and that the mean of the observations corresponded to the established critical point in the insurance proposal. As agricultural production follows a normal distribution, the occurrence probability of each one of the states is 0.5. The results are valid for an interval of variation of the parameter η of the function objective between 0.3138 and 0.5347.

4.1. Results Without Area-Yield Crop Insurance

The certainty equivalent gives the income level without risk for which the individual obtains the same satisfaction as an application with risk. The analysis of the certainty equivalent reveals that if the value is less than the initial wealth (259,375 Euros), the investment with risk has a negative effect on wealth, and the farmer is willing to pay to be liberated from it.

The analysis of table 4.1 allows reinforcement of the idea that the farmer is averse to the risk. The risk premium is always positive, which means that the farmer does not value the risk of the investment, and its marginal utility decreases.

Table 4.1 – Results without insurance

	$\eta = 0.3138$	$\eta = 0.5347$
W *	254,696 Euros	254,295 Euros
π	217 Euros	619 Euros
P _a	-4,679 Euros	-5,080 Euros
Aa	0.000 015 27	0,000 043 56

Source: Model Results, the authors' calculations

Notes: Initial wealth = 259,375 Euros.

Where:

η - Parameter of risk aversion of the utility function;

W * - Certainty equivalent;

π - Risk premium;

P_a - Asking price of the investment;

Aa - Absolute risk aversion coefficient; and,

One Euro is equal to US\$0.9163 (April 27,2000)

The asking price is negative, which means that the investment has a negative effect on the crop farmer's wealth and that he is willing to pay to the value of the asking price to be liberated from the risk of the investment. As the risk premium increases, the premium rate that the farmer is willing to pay for the area-yield insurance also increases. The premium rate will be between 4,679 Euros and 5,080 Euros, depending on the aversion degree to the farmer's risk. The higher the risk aversion is, the higher the premium rate for area-yield crop insurance that the farmer is willing to pay.

4.2. Results With Area-Yield Crop Insurance

After the calculation of the premium rate that the farmers are willing to pay for purchasing a contract for area-yield crop insurance, it is necessary to verify whether the premium rate demanded by the insurance companies equates with what the farmers are willing to pay. The introduction of the insurance premium rate demanded by the insurance companies into the different models gave rise to the solutions previously presented, which means that the premium rate demanded by the insurance companies is larger than the premium rate that the farmers are willing to pay. Therefore, the Portuguese government should subsidize the premium rate of the area-yield crop insurance, so that the farmers are willing to buy it. To confirm the premium rate that the farmer is willing to pay in each one of the models, the premium rate demanded by the

insurance companies was successively reduced in percentile terms to the point where the farmer buys the insurance. The results are presented in the following table:

Table 4.2 – Results with insurance

	$\eta = 0.3138$	$\eta = 0.5347$
W *	262,900 Euros	262,661 Euros
π	2 Euros	5 Euros
P _a	3,525 Euros	3,286 Euros
Aa	0.000 014 82	0.000 042 81

Source: Model results, the authors' calculations
Notes: Initial wealth = 259,375 Euros.

Where:

- η - Parameter of risk aversion of the utility function;
- W * - Certainty equivalent;
- π - Risk premium;
- P_a - Asking price of the investment;
- Aa - Absolute risk aversion coefficient; and,
- One Euro is equal to US\$0.9163 (April 27,2000)

The comparison of this table with table 4.1 allows the conclusion that the certainty equivalent is larger in the models with insurance than in the models without insurance. The crop farmer is willing to change the investment with insurance for an investment without risk since the return for this investment plus the initial wealth is larger than the value of the certainty equivalent, that is, with area-yield crop insurance, the farmer values his investments positively, since they have a positive effect on his wealth.

The risk premium is located very close to zero, which means that the farmer abdicates additional compensation for assumed risk and has behavior very close to neutrality to risk. The farmer chooses crop production activities associated with a higher risk. When the farmer buys an area-yield crop insurance, he is willing to assume higher risk. Therefore, the marginal rate of substitution of his preferences between expected income and risk (represented by the isoutility curve) is moved, a portfolio at the efficient frontier with higher risk being chosen. The farmer stops managing the risk through management techniques, in this case through a greater diversification which gives rise to a choice of crops with smaller risk and smaller income, and prefers to transfer the risk to other economic sectors. The asking price of the investment becomes positive, indicating that the farmer starts to value the investment positively.

4.3. Government Financial Support

The premium rate of area-yield crop insurance demanded by the insurance companies is greater than the premium rate that the crop farmers are willing to pay for the insurance. In this case, the intervention of the Portuguese government as a funding entity is necessary. The Portuguese government should subsidize the difference between the premium rate defined by the insurance company and the premium rate that the farmers are willing to pay.

Table 4.3 - Government financial support

Description	Premium rate	Farmers more		Farmers less	
		Averse to the risk		averse to the risk	
		Farming	Government	Farming	Government
Durham wheat	112.56	23.07	89.49	21.95	90.61
Wheat/ good soils	207.99	42.64	165.35	40.56	167.43
Wheat/ medium soils	176.80	36.24	140.56	34.48	142.32
Barley (used in brewing)	139.52	28.60	110.92	27.21	112.31
Common barley	119.15	24.43	94.72	23.23	95.92
Oats	84.41	17.30	67.11	16.46	67.95
Tritical	146.67	30.07	116.60	28.60	118.07

Source: Model Results, the authors' calculations.

Note: Values in Euros / hectare; and,

One Euro is equal to US\$0.9163 (April 27,2000)

Farmers are willing to pay between 19.5% and 20.5% of the value of the premium rate demanded by insurance companies. Thus, the Portuguese government should subsidize between 79.5% and 80.5% of the value of the premium rate (Table 4.3). Despite the subsidy of the Portuguese government being fairly high, several benefits exist for the local community because of the implementation of an area-yield crop insurance program.

5. Conclusions

This research work studies the problem of the decrease in and of the variability of the farmers' production of cereals in the Alentejo dryland region of Portugal. The variability of the farmers' incomes can be lessened through the introduction of an area-yield crop insurance program. This research work analyzes the introduction of this insurance in agreement with two

objectives. The first objective determines the premium rate that the crop farmers are willing to pay for reducing the variability of their incomes and it analyzes the farmers' behavior after the purchasing of the area-yield crop insurance. The second objective intends to determine the Portuguese government subsidy of the premium rate in case the farmer is not willing to pay the totality of the premium rate

A mathematical programming model is developed to maximize the expected utility value of the farmers' wealth producing cereals in the Alentejo dryland region and it is used to determine the premium rate that crop farmers are willing to pay for reducing the variability of their incomes. Model results allow verification that the risk premium and the asking price have opposite behavior. The higher compensation demanded by the crop farmer for the assumed risk, the smaller the value that the crop farmer is willing to receive to sell the investment with risk. When the asking price is negative, it means that the crop farmer is willing to pay to avoid the risk of the investment. This value corresponds to the premium rate of the area-yield crop insurance that the crop farmer is willing to pay.

The introduction of the premium rate of the area-yield crop insurance demanded by the insurance companies in this model allows the conclusion that the crop farmer is not willing to pay the demanded premium rate. Faced with this conclusion, the premium rate was successively reduced in percentile terms, to the value in that the farmer opts for insurance. It is verified that, with the purchasing of the area-yield crop insurance, the farmer's absolute aversion to risk decreases in the same way as the risk premium which approaches zero. This indicates that the crop farmer abdicates additional compensation for assumed risk, the risk being much smaller because, through the recruiting of insurance, it is transferred to another entity, assuming the crop farmer behaves in a way very close to neutrality to risk. The asking price of the investment becomes positive, indicating that when the crop farmer buys the area-yield crop insurance, he starts to value the accomplished investment positively. Another immediate consequence of the purchasing of area-yield crop insurance is the choice of production technologies with larger associated risk.

The premium rate demanded by the insurance companies is greater than the crop farmers are willing to pay; so there is a need for the intervention of a third entity that harmonizes the interests of both. The Portuguese government can intervene as subsidizer, assuring the balance between supply and demand. The subsidy of the Portuguese government corresponds to the differential between the value demanded by the insurance company and the amount that the farmer is willing to pay. In this way, the Portuguese government subsidizes, through a system of

bonuses, to the premium rate of area-yield crop insurance, a percentage between 79.5% and 80.5% of the value of the premium rate.

The implementation of the area-yield crop insurance in the Alentejo dryland region brings a group of advantages that are enumerated next. For the insurance companies, it constitutes a new income source with lower risk, since it does not have the problems originating in the asymmetrical information that the crop insurance schemes currently have. At the same time, it reduces the administrative costs due to the simplification of the processes of treatment of data and of complaint in case of accident. The farmer, through area-yield crop insurance, gets to transfer a part of the risk to the insurance companies and this reduces the underlying risk to crop production in a dryland region. This has, as a consequence, the effect of decreasing the farmer's risk aversion, which reduces his compensation for the assumed risk and leads to the choice of alternative agricultural production technologies with larger risk. On the other hand, the crop farmer is not dependent on the aid of the Portuguese government in bad years to guarantee his survival; the insurance guarantees him a minimum income.

The Portuguese government, in spite of the subsidy being rather high, brings about other benefits to the community which are difficult in terms of accountancy. Area-yield crop insurance, while increasing the farmer's wealth, generates positive effects on the welfare of rural areas. It can have a positive effect in combating the imbalances between the interior and the coast of Portugal. When the farmer buys an insurance contract against calamity situations, the execution probability of the loans to the credit institutions increases, with a consequent decrease the interest rates to agriculture. Finally, the budget for the bonuses of the premium rate is estimated in advance, so the resolution of calamity situations is not dependent on the immediate readiness of budgets committed within the general budget of the Portuguese government for the resolution of farmers' problems.

This research work has some limitations. The greatest limitations concern the quality of the collected data and the type of the objective function. As a suggestion for future research works, it would be interesting to estimate a utility function of the crop farmer and to compare the results obtained with area-yield crop insurance with other approaches of risk management such as futures and options.

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