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Revealing the willingness to pay for income insurance in agriculture

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SUMMARY A stable agricultural income is often regarded as a way to achieve a better environmental performance in this sector. However, conventional income stabilization tools have been showing recently signs of exhaustion. Under this critical juncture, EU institutions have encouraged the expansion of agricultural insurance. With different degrees of public support, insurance systems against several risks have been successfully developed across the EU and have adopted increasingly comprehensive forms. Eventually, EU institutions have started to assess the development of a comprehensive income insurance framework. Income insurance covers a wider variety of risks and has higher costs than conventional single risk or combined insurance. This demands an in depth knowledge of farmers' Willingness To Pay (WTP) for this product. The following pages present a methodology that calculates the WTP for different degrees of income protection using a Revealed Preferences Model and the Certainty Equivalent theory. The methodology is applied in a drought prone area in southeastern Spain. Results show that WTP for income insurance in this area is higher than observed insurance premiums. This may play in favor of the development of sustainable income insurance systems, though additional evidence is required.

Keywords: Insurance, income, agriculture, Certainty Equivalent, Revealed Preference Models.

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1. INTRODUCTION

In spite of its minor and decreasing share in EU Member States' (MS) GDP, agriculture still has 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 security (FAO, 2007; IEEP, 2011, 2010; OECD, 2013, 2008). During the last decades, climate change and morphing dynamics in agricultural markets have made surprise and crisis in this sector more regular occurrences, with negative impacts over these outcomes. Consequently, the EU has put much effort in guaranteeing a stable agricultural output.

Traditionally, this has been done through the protection of private agricultural income from negative shocks. Until only a few years ago, domestic agricultural prices were guaranteed through a strong public intervention within the framework of the Common Agricultural Policy (CAP). Agricultural input subsidies were also (and still are) widespread in order to lower the prices that farmers paid for their inputs (such as fertilizer, water for irrigation, seed, and equipment) below the often unstable market prices (OECD, 2013). In addition, farmers are protected against yield losses resulting from natural hazards in many ways. This includes an incipient insurance market, but especially expensive public works such as the construction of major infrastructures to reduce risk exposure (e.g., dykes to prevent floods or large reservoirs to cope with drought events) and *ex-post* emergency responses (Hassan, 2010; Meuwissen et al., 2003).

In recent times, this policy mix has been challenged by increasing complaints regarding the fairness of the CAP, the negative environmental impact of some agricultural practices and budgetary concerns stemming from the current financial crisis. CAP subsidies on prices have been largely removed because they posed an obstacle to free trade and imbalanced some agricultural markets, with negative effects in many non-EU countries [1] (EC, 2011). In addition, some public works to protect agriculture have paradoxically favored the ascent of more intensive farming practices that are often associated with negative environmental outcomes[2], up to a point where the financial and environmental costs of some of these policies (e.g., reservoirs in some water stressed areas) have begun to exceed the financial benefits of agriculture in the margin (Randall, 1981). Finally, budgetary constraints resultant from the financial crisis have also increased the opportunity costs of some traditional agricultural policies, delaying or preventing their implementation.

All these problems demanded an innovative approach to the challenge of agricultural income stability that does not hamper the environment, dwarves the public budget or generates trade distortions. Amidst this debate, EU authorities have encouraged the expansion and development of agricultural insurance schemes (Bielza et al., 2008a, 2008b; EC, 2011). Agricultural insurance schemes pose a series of advantages as compared to traditional income protection measures: agricultural insurance is often less costly and (at least partially) privately funded, releasing pressure over public budgets (Meuwissen et al., 2003); if properly designed, it does not distort trade (EC, 2011); it encourages the adoption of more sustainable farming practices in order to reduce risk exposure and thus prevent high risk premiums (water saving technologies, the avoidance of plantations in rows following the slope to reduce runoff and flood risk, etc.) (Surminski, 2009; Warner et al., 2009); finally, while uninsured losses drive the subsequent macroeconomic costs of natural catastrophes, sufficiently insured events are inconsequential in terms of foregone output (Von Peter et al., 2012).

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[1] It has been argued, however, that the higher prices stemming from the liberalization of the EU agricultural market will worsen the terms of trade of some LDCs that do not produce goods in competition with those previously protected by the CAP.

[2] Including soil erosion, chemical use and contamination, pollution of ground and surface water, loss of genetic diversity, pesticide resistance, loss of ecosystem services (including reduced water quantity and quality), decrease of wild fish populations, poor soil quality and even air pollution from pesticides, dust, and allergenic pollens (Dale and Polasky, 2007).

However, agricultural insurance systems are not exempt of design challenges. The most important are the asymmetric information and systemic risk problems typically associated to natural hazards insurance, which often result in high premiums that arise acceptability and equity concerns[3] (Bielza et al., 2009; ISMEA, 2011). This problem has been addressed through extensive *ex-ante* (through premium subsidization) and *ex-post* (through public reinsurance systems) public subsidization (Bielza et al., 2008b). Insurance subsidization often coexists with other types of subsidies that altogether may result in overcompensation (EC, 2011). Overcompensation falls outside WTO's *green box*, meaning that it is a trade distortion tool subject to reduction commitments due to its negative environmental and financial impact (EC, 2011; OECD, 2013). Cross subsidization-led overcompensation has been recently exacerbated by the fact that agricultural insurance in the EU does not cover income, but yields. Consequently, the exposure of domestic agricultural markets to higher international prices has produced in many cases the paradoxical outcome of farmers with income gains, in spite of their yield losses, being compensated (Bielza et al., 2008a; EC, 2011). Obviously, the current scheme will eventually generate the opposite outcome during years with low prices and high costs.

In order to attain an effective, efficient and equitable agricultural insurance system, MS shall ensure that both overcompensation and large income losses are avoided in the sector. Consequently the European Commission, national entities, the academic world and market players have started a wide and exhaustive debate on what to do to update agricultural insurance (AGROSEGURO, 2012; Bielza et al., 2009, 2008a, 2008b; EC, 2011, 2010, 2001; ISMEA, 2011; Meuwissen et al., 2003; Pérez-Blanco and Gómez, 2013). The outcome of this collective effort suggests that it is necessary to progressively unify income stabilization tools in agriculture into a comprehensive insurance framework.

[3] In fact, although private companies have historically offered single insurance products against hail and fire without public support, insurance against systemic risks such as droughts may become affordable for farmers only with government subsidies and/or public reinsurance (Bielza et al., 2009).

This demands innovation in the insurance sector, in particular by expanding the existing guarantees and by protecting farmers not only from production (yield insurance), but also from market risks (price and cost insurance). In order to make this system acceptable, guarantee a fair reallocation of available resources and prevent a significant impact over the already exhausted EU public budget, this system requires a more selective subsidizing mechanism (localizing subsidies on highly exposed and/or low income areas/farmers) and the transfer of a larger share of the insurance costs to the farmers with the capacity to afford it (Meuwissen et al., 2003).

All the above makes necessary an in depth knowledge of both insurance costs and farmers' actual Willingness To Pay (WTP) for agricultural insurance. However, while relevant advances have been made regarding the costs and impacts of natural hazards during the last years (Martin et al., 2001; Pérez-Blanco and Gómez, 2013), little or none research at all has been focused on the WTP for income security (Gómez et al., 2013).

This paper wants to help bridge this gap. The following pages present a methodology that calculates the WTP for income security using a Revealed Preferences Model (RPM) and the Certainty Equivalent (CE) theory. The methodology is applied to the Noroeste Agricultural District (AD) in the water stressed and drought exposed Segura River Basin (SRB) in southeastern Spain. Results show that WTP for income insurance in this area is higher than observed insurance premiums. This may play in favor of the development of sustainable income insurance systems, though additional evidence is required.

The paper is structured as follows: section 2 introduces the area where the case study is applied, the Noroeste AD in the Spanish SRB. Section 3 presents a method to calculate the WTP for income insurance. Section 4 shows and discusses the results obtained. Section 5 concludes.

2. CASE STUDY BACKGROUND: NORORESTE AD, SRB, SPAIN

Spain has the most developed agricultural insurance system in Europe (Bielza et al., 2008b). Spanish companies mostly offer agricultural insurance through *combined insurance schemes*, which are packages that provide simultaneous coverage against a varied range of natural hazards (droughts, hail, floods, etc.). All companies operate within a pool and assume the risk in a co-insurance regime, which is in turn re-insured by the public sector through the *Insurance Compensation Consortium*. The Consortium assumes cover for the extraordinary risks on a subsidiary basis and will pay indemnifications when a private insurer has assumed cover and it is subsequently not able to settle claims. The Consortium is funded via a surcharge on risk premiums paid by insured agents and with public funds.

Although the Spanish Pool of agricultural insurance companies has systematically expanded the range of natural hazards it covers during the last years, it still focuses on yield insurance and does not offer income insurance (AGROSEGURO, 2012) [4]. Nonetheless, Spain has exceptionally enabling conditions for the development of a comprehensive agricultural income insurance. This paper assesses the feasibility of this system in the particular case of the profitable and risk exposed Noroeste AD in the SRB.

[4] Due to this institutional constraint, although income insurance is regarded as an attractive option (EC, 1999; Meuwissen et al., 2003), its development has been deemed feasible only in the medium-long run (EC, 2001). Nonetheless, this has been challenged by several authors that noted that the historical failure of many insurance systems in the past was largely owed to their static behavior and their reluctance to extend insurance protection to other risks rather than the opposite (see for example AGROSEGURO, 2012; ISMEA, 2011; Meuwissen et al., 2003). Actually, there are many MS in which agricultural systems have already reached a maturity that permits the progressive introduction of income insurance. Italy, Austria, France and Spain have insurance systems where comprehensive combined insurance schemes prevail, comprising a wide and increasing variety of risks (AGROSEGURO, 2012; Bielza et al., 2009; ISMEA, 2011). In addition, these MS have precautionary clauses that demand a progressive implementation and recurrent testing of novel insurance systems, avoiding a large negative chain reaction if design problems are made evident. In the case of Spain, for example, this clause has been embodied in a law enforced for over 30 years (BOE, 1978).

The SRB in southeastern Spain has significant competitive advantages for agriculture because the land is abundant and cheap and few alternative uses for the land exist. Furthermore, solar radiation is guaranteed and, apart from the abundance of cheap labor, many of these areas are located near high demand markets (Gómez and Pérez-Blanco, 2012). However, the SRB has also the most overexploited water bodies in the EU, which makes agriculture a highly exposed and vulnerable sector prone to suffer losses during drought events (EEA, 2009). In addition, flushing floods are frequent and may also cause damages to agricultural income (SRBA, 2013). Other relevant sources of income variation include hail and frost (AGROSEGURO, 2012), the instability of input prices (OECD, 2013) and the volatility of agricultural prices observed since 2007 (World Bank, 2013).

The Noroeste AD in the SRB is a large mountainous area to the northwest of the SRB that comprises 9,881 ha of agricultural land. Agriculture is largely extensive with the most relevant crops being fruit trees (57.8% -particularly apricot trees, representing 38.1% of the total surface), horticulture (13.8%), cereals (13.7%) and olive trees (8.9%). Average agricultural income equals 1,869 €/ha, much below that of the coastal areas in the SRB but still well above the national average (MAGRAMA, 2009).

Apart from sporadic hail and frost events, droughts and floods are the most important threats to agricultural income in the Noroeste AD. Although water is relatively more abundant here than in the rest of the SRB, droughts are frequent and intense and may have significant impacts over agricultural income, as happened during the 2005-2008 drought (SRBA, 2008a). On the other hand, in spite of the presence of perennial rivers that reduce the potential impact of flushing floods over agriculture as compared to coastal areas, this area comprises several flood risk areas (SRBA, 2010).

3. METHODOLOGY

Agricultural insurance transfers the cost of uncertainty to the farmer, who pays in a regular basis a predetermined amount of money (risk premium) to a risk insurance firm that assumes the risk exposure for her/him. This system is viable because while farmers are risk averse individuals that are ready to pay in excess of their expected loss in order to have a more secure income, insurance firms are risk neutral (Binici et al., 2003; Kim and Chavas, 2003; Lien and Hardaker, 2001; Pérez-Blanco and Gómez, 2013; Tobarra-González and Castro-Valdivia, 2011). Although this assertion is widely acknowledged, the actual WTP for agricultural income security is largely unknown.

This section develops a methodology to estimate farmers' WTP in order to guarantee a minimum share of their expected income. The section is divided in two parts. The first subsection presents a RPM that shows the motivations behind farmers' decisions through the estimation of their utility function. The steps to calibrate this utility function and to estimate its calibration errors are also introduced.

The second subsection introduces the CE theory into the model. The CE is the guaranteed amount of money that an individual would view as equally desirable as a risky asset. Using the utility functions obtained in the first subsection and the CE theory, the authors estimate the amount of money that farmers would be willing to pay to guarantee a minimum share of their expected income (i.e., the WTP for income insurance).

3.1 THE REVEALED PREFERENCES MODEL (RPM)

Agents' preferences may be shown in two ways: either through RPMs or through stated preference models. Stated preferences are those voiced by agents when asked. They are based on survey research and are certainly useful when the necessary information for data intensive RPM is not available. However, agents' stated preferences often do not match their actions. This is why economists generally prefer to work with "hard" data (i.e., observable behavior) instead of "soft" data (i.e., declared behavior).

This subsection presents a RPM able to calibrate observed decisions with a procedure rooted in basic microeconomic theory. In this model, agents decide on their crop portfolio trying to maximize their utility, which is a function of a set of relevant attributes that may contain expected profit, risk avoidance, management complexities and/or others. It is assumed that the explanation of any decision, consisting in a distribution of the available land among the different crop options, relies on an underlying utility function formed by the many attributes that agents use to assess all the alternatives they have, given crop prices and costs, resource availability and other relevant economic, agronomic and policy constraints. According to that, it is assumed that observed decisions respond to a decision problem as follows:

$$\underset{x}{\mathrm{Max}}\, U(x) = U(z_1(x);\ z_2(x); z_3(x) \ldots\ z_m(x)) \qquad [1]$$

$$\text{s.t.:} \quad 0 \leq x_i \leq 1 \qquad [2]$$

$$\sum_{i=1}^{n} x_i = 1 \qquad [3]$$

$$X \in F(x) \qquad [4]$$

$$z = z(x) \in R^m \qquad [5]$$

Where $x \in R^n$ is the decision profile or the crop portfolio (a vector), showing one way to distribute the land among crops, and each x_i measures the share of land devoted to the crop i, including a reservation option (x_n) consisting of rainfed agriculture. From the agent's perspective any particular crop may be considered as an asset with a known present cost and an uncertain value in the future (as crop yields are not known in advance). As the available land is taken as given, this investment may be represented as a percentage (x_i) of the available land. $F(x)$ represents the space of feasible decision profiles, given the different constraints[5]: policy, economic, agronomic and environmental. Finally, the vector z contains the attributes that farmers value. For example, farmers might prefer decisions with high expected profits, highly predictable income (i.e., with low risk) and not too many managing actions apart from planting and harvesting. To accept taking high risk and complex options, risk averse farmers will ask for a compensation, for example, higher expected profits. The model is flexible and other attributes could be included.

From now on it is assumed that there is an observed decision profile and the whole set of constraints defining the feasible decision set are known. It is also assumed that the set of potentially relevant decision attributes are measurable, including, for example, the expected profit, the variance of the expected profit, the hired labor demanded, the cost of inputs over the total cost and all the variables that might be relevant from the farmers' point of view. Then, the first problem to reveal farmers' preferences is to know which among the potentially relevant attributes are actually relevant to explain the observed decision. The way to answer this question consists in assuming that the relevant set of attributes is the one to which the observed decision is closest to the attributes possibility frontier. In real situations this efficiency frontier cannot be defined analytically with a closed mathematical function and the only way to represent it is by numerical methods. One practical solution consists in extending a ray from the origin, passing through the observed decision attributes and extending them as far as possible in the space of feasible attributes. This way it possible to measure the distance from the observed attributes to the efficiency frontier attributes. This procedure can be repeated for any set of potentially relevant attributes and the best candidate to reveal farmers' preferences will be the one whose observed values were closest to its associated efficiency frontier. Formally, this problem must be solved for

[5] In our model we consider the following constraints: land availability, available water resources, agricultural vocation (crops that have not been planted in an area before cannot appear in that area in the short run), crop rotation, CAP restrictions and ligneous crops restrictions (the surface of ligneous crops cannot change significantly in the short run).

every member of the Power set (P(z), which comprises all the possible combinations of potentially relevant attributes for the farmer) and for its associated observed attributes in the Power set ($P(z_o)$) [6].

The solution of this problem is an application assigning a distance φ_l $(l = 1, \dots, 2^m)$ to each member of the power set $P(z)$. Each member of the power set (i.e., each possible combination of potentially relevant attributes) is denoted by $\tau(x)$, and its associated observed attributes by $\tau_o(x)$. The relevant set of attributes (τ^*) will be the one with the lower distance to the efficiency frontier measured by the parameter $(\varphi - 1)$. Summing up, the preference eliciting problem can be presented as:

$$\underset{\tau}{\mathrm{Min}}\ \varphi_l - 1 \qquad [6]$$

Where: $$\varphi_l = \mathrm{ArgMax}\left[(\varphi)\ \mathrm{s.t.}\ \tau(x) = \varphi\left(\tau_o(x)\right);\ 0 \le x_i \le 1;\ \textstyle\sum_{k=1}^{n} x_k = 1;\ X \in F(x); \text{for all}\ \tau \epsilon P(z)\right] \qquad [7]$$

$$l = (1 \dots .2^m) \qquad [8]$$

By solving this problem the set of attributes that better explains current farmers' decisions (τ^*) is obtained. Among the many factors that might be of relevance in farmers preferences, this set of attributes is the one which takes the observed decision closer to the attributes efficiency frontier.

Once a farmer's decision is shown as close as possible to the efficiency frontier, the second problem consists in obtaining the farmers' preferences that explain the observed decision as a utility maximizing choice. Taking into account the relevant decision attributes obtained in the calibration stage, the multi-attribute utility function is the one that is able to represent farmers' preferences in such a way that the observed decision becomes the optimal choice. Using basic economic principles and knowing the efficiency frontier in the surroundings of the observed decision allows one to

[6] A power set P(z) is the set of all the 2^m subsets of Z and the power set $P(z_o)$ is the set formed by the 2^m subsets of the numerical set of observed attributes.

integrate such a utility function. Rational decisions imply that in equilibrium farmers' marginal willingness to pay in order to improve one attribute with respect to any other is equal to the marginal opportunity cost of this attribute with respect to the other. In other words, the marginal transformation relationship between any pair of attributes over the efficiency frontier ($\mathrm{MTR_{kp}}$) is equal in equilibrium to the marginal substitution relationship between the same pair of attributes over the indifference curve tangent to the observed decision ($\mathrm{MSR_{kp}}$).

Then the relative opportunity cost of each one of the relevant attributes with respect to the others is obtained. This opportunity cost is measured by the marginal transformation relationship between any pair of attributes ($\beta_{\mathrm{kp}} = \mathrm{MTR_{kp}} = \mathrm{MSR_{kp}}$). This value can be obtained numerically by solving partial optimization problems in the proximity of the observed decision (as for example, searching by how much expected profits would need to be reduced in order to have a 1% less uncertainty or, equivalently, what is the maximum expected profit attainable with a slightly lower risk level). The numerical results of the marginal relationship of transformation of any pair of attributes in a reference point over the efficiency frontier (β_{kp}) are the basic information to integrate the farmers' utility function. Provided that farmers act rationally, in equilibrium, the value representing the relative opportunity cost of any attribute in terms of any other (β_{kp}), is equal to the marginal substitution relationship between the same pair of attributes (which represents the farmers' willingness to pay for marginal improvement of a given attribute in terms of any other). In other words, in equilibrium, decisions over crop surfaces are such that:

$$\beta_{\mathrm{kp}} = \mathrm{MTR_{kp}} = \mathrm{MSR_{kp}} = -\frac{\partial \mathrm{U}/\partial \mathrm{z_p}}{\partial \mathrm{U}/\mathrm{z_k}}; \mathrm{p, k} \in (1, \ldots \mathrm{l}); \mathrm{p} \neq \mathrm{k} \qquad [9]$$

This information for the reference point over the efficiency frontier is enough to integrate a utility function leading to the observed decision as the optimal decision given the existing resource, economic, balance and policy constraints. For example, if we assume a constant returns of scale utility function such as the Cobb-Douglas utility function below:

$$U(\tau) = \prod_{r=1}^{l} z_r^{\alpha_r}; \quad \sum_{r=1}^{l} \alpha_r = 1 \qquad [10]$$

Then the marginal substitution relationship among any pair of attributes is:

$$-\frac{\partial U / \partial z_p}{\partial U / z_k} = -\frac{\alpha_p}{\alpha_k}\frac{z_k}{z_p} \qquad [11]$$

And the parameters of the Cobb-Douglas utility function are obtained from the following system:

$$-\frac{\alpha_p}{\alpha_k}\frac{z_k}{z_p} = \beta_{kp} \qquad [12]$$

$$\sum_{r=1}^{l} \alpha_r = 1 \qquad [13]$$

The results section uses this type of function, which offers the advantage of having a unique solution according to the Walras' Law (a condition which is guaranteed by the constant returns of the utility function represented above). Then the model is calibrated for the Noroeste AD. Although the high data requirements of RPMs have made difficult their use as a policy assessment and project analysis tool, the recent proliferation of microeconomic databases in several EU countries now make their implementation feasible. This paper relies on the high quality microeconomic data available in MAGRAMA (2012a, 2012b, 2009) and SRBA (2013). These databases contain information on land use, yields, market prices, water use, irrigation efficiency, employment (both hired and family labor), machinery and equipment, other direct costs and indirect costs for every crop and for 81% of the agricultural surface of the Noroeste AD for a period of at least 15 years. All prices and costs were measured in constant values of 2008.

3.1.1 CALIBRATION ERRORS

Farmers' decisions are simulated in accordance to the observed crop portfolio, which is the crop portfolio that maximizes the representative farmer's utility function in accordance to a set of relevant attributes. Therefore, deviations of the model's crop portfolio (x_i^*) from the observed crop portfolio (x_i^o) during the calibration stage may result in prediction errors in our model, and this is our first calibration error (e_x). The second source of error is the distance between the observed attributes and the attributes' efficiency frontier (e_f). A large distance would mean that our representative farmer is actually taking a sub-optimal decision, and this goes against our main assumption that farmers are individuals that seek to maximize their utility. Finally, the third calibration error (e_T) is the distance between the observed attributes (z_r^o) and the calibrated ones (T_r^*). If this distance is large, it would mean that we are not capturing the real source of utility for the representative farmer, and therefore the model would be simulating someone else's utility function.

Summing up, the RPM provides three types of calibration errors that give an idea of the accuracy of the model's adjustment:

-The relative distance between the observed crop pattern and the model's one:

$$e_x = \frac{1}{n}\sum_{k=1}^{n}\left(\frac{\left({x_i^o}^2 - {x_i^*}^2\right)^{1/2}}{x_i^o}\right) \qquad [14]$$

-The distance between the observed attributes and the attributes' efficiency frontier:

$$e_f = (\varphi - 1) \qquad [15]$$

-The distance between the observed attributes and the calibrated ones:

$$e_\tau = \frac{1}{l}\sum_{r=1}^{l}\left(\frac{\left({z_r^o}^2 - {\tau_r^*}^2\right)^{1/2}}{z_r^o}\right) \qquad [16]$$

Finally, the mean calibration error is defined as a combination of these three calibration errors:

$$e = \frac{\sqrt{e_x + e_\tau + e_f}}{3} \qquad [17]$$

3.2 THE CE AND THE WTP FOR INCOME INSURANCE

3.2.1 THE CERTAINTY EQUIVALENT (CE)

Farmers are risk averse individuals that are reluctant to accept a bargain with an uncertain payoff rather than another bargain with a more certain, but possibly lower, expected payoff (Binici et al., 2003; Kim and Chavas, 2003; Lien and Hardaker, 2001; Tobarra-González and Castro-Valdivia, 2011). In order to simulate this tradeoff two attributes ($z(x)$) need to be introduced in the model to capture *expected income*[7] and *income variability*.

Agricultural income in the model is measured using the gross variable margin as a *proxy*. Gross variable margin is calculated as the selling price of the agricultural output, less the variable costs of the output sold, plus subsidies. For the observed crop decision vector x, the gross variable margin ($\pi(x)$) is obtained as follows:

$$\pi(x) = \sum_i x\pi_i \qquad [18]$$

Where π_i is the matrix of the observed gross variable margins per hectare for the year i. Therefore, $\pi(x)$ estimates the agricultural income that would have been obtained with the observed crop decision in the past. $\pi(x)$ follows a continuous probability density function $g(\pi(x))$ with the following moments:

$$E(\pi(x)) = \int_{-\infty}^{\infty} \pi(x) g(\pi(x))\, dx \qquad [19]$$

$$Var(\pi(x)) = \sigma^2(\pi(x)) = \int_{-\infty}^{\infty} \left(\pi(x) - E(\pi(x))\right)^2 g(\pi(x))\, dx \qquad [20]$$

From the equations above it is possible to define two attributes ($z(x)$) to capture income and income variability. Expected income ($z_1(x)$) is captured by the expected value of the gross variable margin, i.e.:

[7] In the EU insurance system, farmers are eligible for a compensation if the agricultural output observed is below a predetermined percentage of the average historical value (Bielza et al., 2008a). With large enough data series, this average should be close to the expected value.

$$z_1(x) = E\big(\pi(x)\big) \quad [21]$$

On the other hand, income variability is measured through *risk avoidance* ($z_2(x)$), which is obtained as the difference between the risk associated to the crop decision $\bar{x}$ leading to the maximum expected income ($\bar{\sigma}$) and the risk associated to the alternative crop decision x ($\sigma\big(\pi(x)\big)$):

$$z_2(x) = \bar{\sigma} - \sigma\big(\pi(x)\big) \quad [22]$$

Where $\bar{\sigma}$ is the standard deviation of the agricultural income of the crop decision $\bar{x}$ ($\pi(\bar{x})$), which follows a probability density function $h\big(\pi(\bar{x})\big)$.

Equation [10] can be now reformulated as follows:

$$U(\tau) = z_1^{\alpha_1} z_2^{\alpha_2} \prod_{r=3}^{l} z_r^{\alpha_r}; \quad \sum_{r=1}^{l} \alpha_r = 1 \quad [23]$$

Finally it is possible to define the CE, which is the amount of money (CE) with zero risk ($\sigma\big(\pi(x)\big) = 0$, i.e., $z_2(x) = \bar{\sigma}$) that an individual would view as equally desirable (i.e., with the same utility U) as the current (risky) asset:

$$U(\tau) = U_{CE}(\tau) = CE^{\alpha_1} \bar{\sigma}^{\alpha_2} \prod_{r=3}^{l} z_r^{\alpha_r} \quad [24]$$

After a simple transformation, the CE can be defined as[8]:

$$CE = \left(\frac{U(\tau)}{\bar{\sigma}^{\alpha_2} \prod_{r=3}^{l} z_r^{\alpha_r}} \right)^{\frac{1}{\alpha_1}} \quad [25]$$

3.2.2 THE WTP FOR INCOME INSURANCE

Agricultural income insurance guarantees a minimum income to farmers in exchange of a regular payment. This minimum threshold is generally below the

[8] The difference between the expected income ($z_1(x)$) and the CE can be interpreted as farmers' WTP for full income security (i.e., no income variability). It should be noted, though, that insurance companies only cover negative deviations from the expected income.

expected income, since insurance companies usually decline offering full income insurance and define instead a deductible ($\delta \in [0,1]$) over the insured product in order to avoid moral hazard. In the EU, δ ranges from 10% to 40% (Bielza et al., 2008a). In the particular case of Spain, where the case study area is located, this threshold ranges between 10% and 35% (Pérez-Blanco and Gómez, 2013). Accordingly, the minimum income guaranteed by agricultural insurance products can be defined as:

$$\underline{z_{1,\delta}}(x) = (1-\delta)E\big(\pi(x)\big) \qquad [26]$$

As a result, income insurance reduces risk exposure by guaranteeing a minimum income but does not completely remove it, being risk an incentive towards productive behavior. This will result in a higher expected income (excluding insurance premium) ($z_{1,\delta}(x) > z_1(x)$) and a lower risk exposure ($\sigma_\delta\big(\pi(x)\big) < \sigma\big(\pi(x)\big)$) in the scenario with income insurance (denoted by the subscript δ) as compared to the baseline scenario without income insurance described in the previous section.

Formally, we may see income insurance as an intervention that truncates the probability distribution of the per hectare income of the crop decision x ($g\big(\pi(x)\big)$). Accordingly, the expected income ($z_{1,\delta}(x)$) and risk avoidance ($z_{2,\delta}(x)$) under an insurance system are defined as follows:

$$z_{1,\delta}(x) = \int_{\pi(x)=0}^{\underline{z_1}(x)} g\big(\pi(x)\big)\underline{z_{1,\delta}}(x)\,dx + \int_{\pi(x)=\underline{z_{1,\delta}}(x)}^{\max_{\pi(x)}} g\big(\pi(x)\big)\pi(x)\,dx \qquad [27]$$

$$z_{2,\delta}(x) = \overline{\sigma} - \sigma_\delta\big(\pi(x)\big) \qquad [28]$$

Where $\max_{\pi(x)}$ is the value of the variable $\pi(x)$ that make its cumulative density function equal to 1 (i.e., the probability of any value above this limit is zero). The risk associated to the alternative crop decision x with insurance ($\sigma_\delta\big(\pi(x)\big)$) equals:

$$\sigma_\delta\big(\pi(x)\big) = \left(\int_{\pi(x)=0}^{\underline{z_1}(x)} g\big(\pi(x)\big)\left(\underline{z_{1,\delta}}(x) - z_{1,\delta}(x)\right)^2 dx + \int_{\pi(x)=\underline{z_{1,\delta}}(x)}^{\max_{\pi(x)}} g\big(\pi(x)\big)\left(\pi(x) - z_{1,\delta}(x)\right)^2 dx\right)^{1/2}$$

[29]

Akin to equation [24], the utility function with income insurance ($\mathrm{U}_\delta(\tau)$) can be expressed as follows:

$$\mathrm{U}_\delta(\tau) = \mathrm{z}_{1,\delta}{}^{\alpha_1} \mathrm{z}_{2,\delta}{}^{\alpha_2} \prod_{r=3}^{l} \mathrm{z}_r^{\alpha_r}; \quad \sum_{r=1}^{l} \alpha_r = 1 \qquad [30]$$

And the CE with income insurance (CE_δ) can be defined as:

$$\mathrm{CE}_\delta = \left(\frac{\mathrm{U}_\delta(\tau)}{\bar{\sigma}^{\alpha_2} \prod_{r=3}^{l} \mathrm{z}_r^{\alpha_r}}\right)^{\frac{1}{\alpha_1}} \qquad [31]$$

The CE of the scenario with income insurance (CE_δ) is higher than the CE of the baseline scenario without income insurance (CE), since the former has a higher expected income and risk avoidance and these are attributes that agents value positively. The WTP for income insurance (WTP_δ) can be now obtained as the difference between the CE with and without income insurance:

$$\mathrm{WTP}_\delta = \mathrm{CE}_\delta - \mathrm{CE} \qquad [32]$$

By changing the value of the deductible δ it is possible to calculate the WTP for different degrees of income insurance, from the baseline scenario without income insurance in which $\delta = 1$ (and therefore $\mathrm{CE}_\delta = \mathrm{CE}$ and $\mathrm{WTP}_\delta = 0$) to full loss insurance ($\delta = 0$).

4. RESULTS

The methodology is now applied to the particular case of the Noroeste AD in the SRB, Spain. First, the RPM is calibrated and the calibration errors obtained. Then, using the RPM and probability density functions, the CE without (baseline) and with income insurance is estimated. Finally, the WTP for income insurance with different deductibles (δ) is obtained.

4.1 MODEL CALIBRATION

Farmers have to find their optimum crop portfolio subject to a set of feasible options. In section 3.2.1 it was assumed that farmers will choose the crop portfolio that maximizes income and minimizes risk. In addition to these, the following attributes ($z(x)$) capturing management complexities are also considered[9]:

i) Total labor avoidance, the first way to measure management complexities avoidance through the reluctance to use too much labor (both hired and family labor).

$$z_3(x) = \bar{N} - N(x) \quad [33]$$

Where $N(x) = \sum_i x_i N_i$ is the total labor used per hectare, being N_i the total labor required per hectare for a crop i, and $\bar{N}$ is the labor required to implement the crop decision leading to the maximum expected profit.

ii) Hired labor avoidance, the second way to measure management complexities avoidance through the reluctance to use too much hired labor.

$$z_4(x) = \bar{H} - H(x) \quad [34]$$

Where similar to previous case $H(x) = \sum_i x_i H_i$ is the total hired labor used per hectare, being H_i the total hired labor required per hectare for a crop i, and $\bar{H}$ is the hired labor required to implement the crop decision leading to the maximum expected profit.

The Cobb-Douglas Utility Function adapts the following form:

$$U(z_1, z_2, z_3, z_4) = z_1^{\alpha_1} z_2^{\alpha_2} z_3^{\alpha_3} z_4^{\alpha_4}; \quad \sum_{r=1}^{4} \alpha_r = 1 \quad [35]$$

Where there are five unknown variables ($\alpha_r; r = 1, \dots 4$). Following the methodology above, we assess the relevance of each attribute by estimating the values of the alpha coefficients for the Noroeste AD. These coefficients are used to calibrate the Cobb-

[9] Other attributes were explored (e.g., direct costs avoidance) but they were not relevant.

Douglas Utility Function. Finally, we also obtain the calibration errors. The results are displayed in Table 1:

Table 1. Alpha coefficients and calibration errors

Variable	α_1	α_2	α_3	α_4	e_f	e_τ	e_x	e
Value	0.18	0.11	0.30	0.41	8.31%	3.75%	5.30%	3.25%

Source: Own elaboration from MAGRAMA (2012a, 2012b, 2009) and SRBA (2008b).

Results confirm our assumptions in Section 3.2.1 in the case of the Noroeste AD. The *alpha* coefficient for the expected profit (α_1) has a positive value of 0.18, showing that farmers in the Noroeste AD value high expected incomes. The positive value for the risk avoidance attribute ($\alpha_2 = 0.11$) confirms that farmers in this area are risk averse individuals and are willing to sacrifice part of their expected income as long as it becomes more secure. In accordance to the traditional extensive agriculture practiced in this area, results also show that farmers' decisions are largely driven by the avoidance of management complexities represented by total labor avoidance ($\alpha_3 = 0.30$) and hired labor avoidance ($\alpha_3 = 0.41$). The model shows low calibration errors for the Noroeste AD, with a mean calibration error of 3.25%.

4.1 CE AND WTP FOR INCOME INSURANCE

A normal probability density function is found to be the best fit function for agricultural income in the Noroeste AD. The value of the moments ($z_{1,\delta}(x)$ and $\sigma_\delta(\pi(x))$) and that of the attributes ($z(x)$) and the variables that constitute these attributes for the observed (x) and profit maximizing crop decisions ($\bar{x}$) are shown in Table 2 for deductible values of $\delta = 1$ (no insurance), $\delta = .4$, $\delta = .3$ and $\delta = .2$, which are those usually observed in agricultural insurance in the EU.

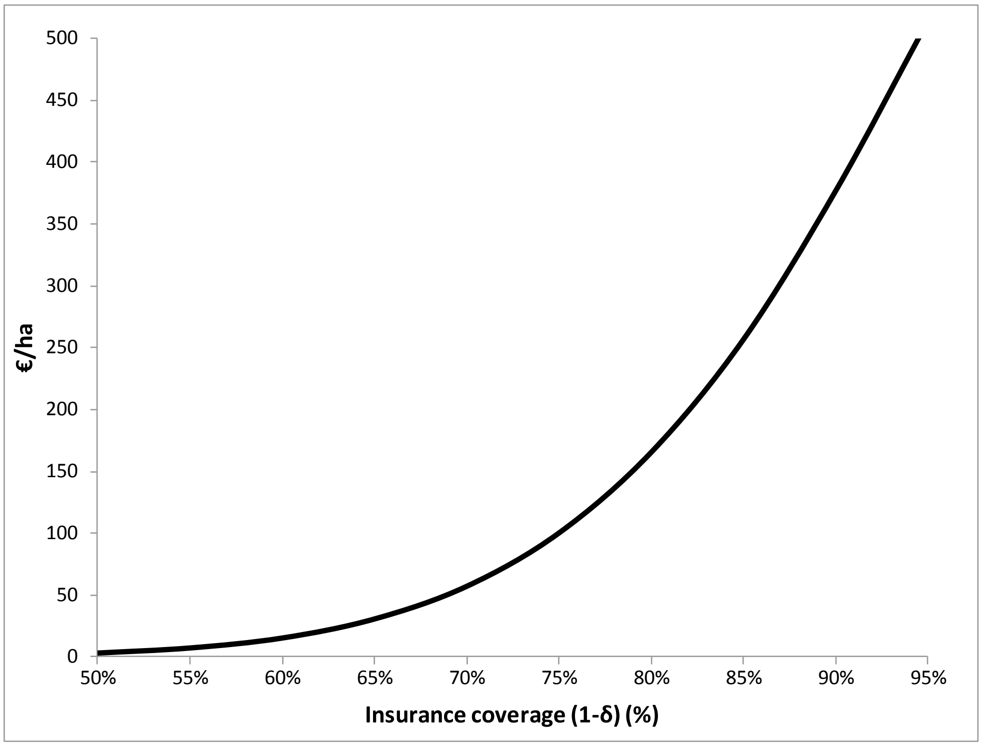
Table 2. Attributes' numerical values

Variable	No insurance *($\delta = 1$)*	$\delta = .4$	$\delta = .3$	$\delta = .2$
$z_{1,\delta}(x)$ (€/ha)	1869.2	1871.2	1876.3	1892.1
$z_{2,\delta}(x)$ (€/ha)	130.9	134.5	144.6	171.3
$\bar{\sigma}$	463.6	463.6	463.6	463.6
$\sigma_\delta(\pi(x))$	332.7	329	319	292.3
$z_{3,\delta}(x)$ (# daily wages/ha)	18.5	18.5	18.5	18.5
$\bar{N}$	32.3	32.3	32.3	32.3
$N(x)$	13.9	13.9	13.9	13.9
$z_{4,\delta}(x)$ (# daily wages/ha)	4.1	4.1	4.1	4.1
$\bar{H}$	10.4	10.4	10.4	10.4
$H(x)$	6.3	6.3	6.3	6.3

Source: Own elaboration from MAGRAMA (2012a, 2012b, 2009) and SRBA (2008b).

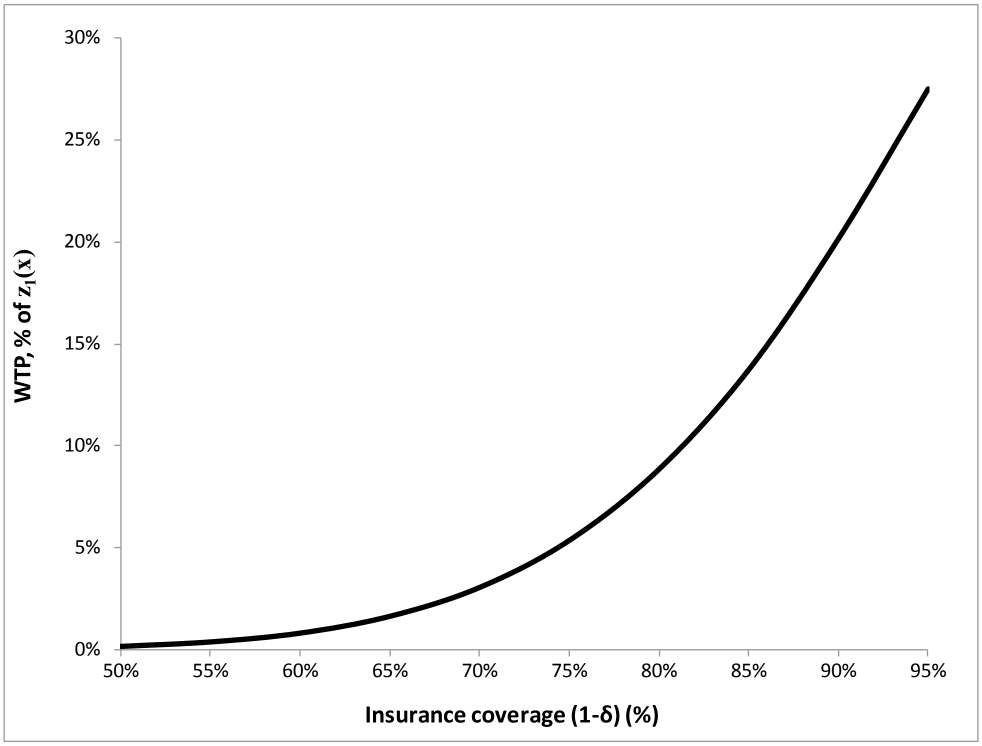
Figures 1 and 2 show the WTP for an income insurance product that offers different degrees of agricultural income coverage ranging from 50% ($\delta = .5$) to 95% ($\delta = .05$), in absolute terms (€/ha) (Figure 1) and as a percentage of the expected income (Figure 2).

Figure 1. WTP for income insurance with different deductibles (δ), €/ha



Source: Own elaboration from MAGRAMA (2012a, 2012b, 2009) and SRBA (2008b).

Figure 2. WTP for income insurance with different deductibles (δ), % of the expected income ($z_1(x)$)



Source: Own elaboration from MAGRAMA (2012a, 2012b, 2009) and SRBA (2008b).

Higher income protection levels (i.e., low δ) are associated with proportionally larger WTP values in the model, resulting in a positive and increasing curve. This is explained because higher deductibles require high income losses in order to trigger the compensation mechanism, and this income losses have a low probability associated (they fall in the extreme of the left hand tail of the income probability density function, $g(\pi(x))$). As a result, even if they are not compensated, farmers prefer not to pay the insurance premium given the low probability of the event. On the other hand, a low deductible implies more likely compensations and higher WTP.

The WTP for income insurance with customary deductibles (i.e., $.1 \leq \delta \leq .4$) ranges between .8% ($\delta = .4$) and 20.2% ($\delta = .2$) of the expected agricultural income in the baseline ($z_1(x)$). Average premium rates as a percentage of the insured value (in this case, $z_1(x)$) in Spain range between 6% and 8%, of which 49% is paid through public subsidies (Bielza et al., 2009). Therefore, depending on the deductible chosen, there may be large room to reduce and/or redistribute public subsidization in favor of a higher private share in the funding of insurance premiums.

5. DISCUSSION AND CONCLUSIONS

In recent years, growing concerns regarding climate change and the increasing risk exposure and vulnerability of agriculture have led EU authorities to consider different formulas to develop and spread *ex-ante* risk management tools, particularly insurance, among farmers. This included, for example, the prohibition to grant *ex-post* aid after a disaster event if the risk could have been insured, or the possibility of integrating insurance in the CAP (EC, 2001). However, the adequacy of the current agricultural insurance system has been challenged lately by potential under-compensation and realized overcompensation problems. Overcompensation is neither Pareto-efficient nor equitable and therefore falls below the allocative efficiency, meaning that welfare gains can be obtained through a better redistribution of resources[10]. In order to avoid this drawback, a comprehensive income insurance has been proposed following the example of the most developed insurance systems worldwide, those of the US and Canada (Bielza et al., 2009). However, income insurance also faces implementation problems.

As happens with other insurance policies, a relevant impediment in the implementation of income insurance schemes is related to acceptability and equity

[10] In any case, this situation is still considered preferable to the expensive *ex-post* ad hoc emergency aids (Meuwissen et al., 2003).

issues. Under a private system, some agents may not afford the premiums or even not be insurable at all. The role of the public sector consists in reallocating available resources in order to find an equilibrium between acceptability and equity concerns, on the one hand, and financial sustainability, on the other. However, in the case of income insurance, this problem acquires a new dimension given the higher uncertainty and risk exposure, and thus the higher costs, related to this product. Therefore, the institutional challenge is how to develop an equitable, acceptable and financially sustainable income insurance that does not generate an unbearable burden over public budgets.

This paper presents a methodology that uses “hard” (i.e., observable) data and basic microeconomic theory to reveal farmers’ WTP for income insurance. Farmers’ WTP is a valuable information that may allow significant advances towards the development of a robust income insurance system that successfully addresses the problem above. Besides, this information may also contribute to develop an insurance system that addresses the disparities and efficiency problems that are frequently linked to agricultural insurance in the EU. For example, total subsidies to insurance amount 67% of the total premiums in Italy, while in Spain and Austria (with a similar or even more developed insurance system and varied risk coverage) this figure equals 49% and 46%, respectively (Bielza et al., 2009).

For example, the results above show that the WTP for income insurance with customary deductibles may be as high as 20.2% (for $\delta = .2$) of the expected income in the baseline. This figure is well above current insurance premiums in countries like Spain (6-8%), suggesting that income insurance would be implementable with a limited need for public support. Obviously, current premiums only refer to existing yield insurance and are to be recalculated if income insurance is finally developed, but evidence has shown that premiums tend to follow positive though decreasing trends and tend to stabilize as the number of risks covered is increased (AGROSEGURO, 2012; Bielza et al., 2009; ISMEA, 2014).

In spite of this promising results, it should be noted that income insurance is not a panacea for risk management problems. Instead, it is a creature of design. Moreover, its final outcome also depends on the context, i.e., on the policy mix and the institutional setup in which it develops. Finally, income insurance demands complementary policies (economic and/or command-and-control instruments) and an adequate policy sequencing in order to succeed. Further research on the side of the costs (especially transaction costs) and complementary evidence from the demand side are necessary before the implementation of income insurance becomes feasible.

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