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Assessing the demand for hydrological drought insurance in irrigated agriculture

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A R T I C L E I N F O

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A B S T R A C T

Concerns about hydrological drought risk and irrigation water supply reliability have grown in recent years due to the increasing demand for water for irrigation and other uses, and the decline in water availability due to climate change. Hydrological drought insurance hedging against water supply gaps can be a key instrument for adapting irrigated agriculture to this new scenario, since it improves the resilience of the irrigation sector, which is having to cope with increasing uncertainty and vulnerability. The objective of this paper is to assess farmers' willingness to pay (WTP) for index-based hydrological drought insurance under different policy designs, considering several different amounts of insured capital, insurance deductibles, and contract terms. To that end, it uses a discrete choice experiment as the valuation method and the Sector BXII irrigation district (southern Spain) as a case study. The results show that farmers would be willing to pay for the proposed hydrological drought insurance, stating a higher preference for policy designs with lower amounts of insured capital, lower deductibles, and shorter contract terms. Moreover, the results also show the existence of heterogeneity among farmers' preferences, depending on their socio-economic characteristics. Finally, we compare the distribution of farmers' WTP for different policy design options of the proposed insurance with the commercial premium estimated using actuarial analysis. The comparison confirms that only the options with lower levels of insured capital present a mean WTP below the commercial premium, while the rest of the policy design options would need to be subsidized like other agricultural insurance schemes to make them attractive to most farmers.

1. Introduction

Irrigated agriculture is exposed to multiple production risks. Notable among them are those related to hydrological droughts (i.e., below-normal instream flows and reservoir levels) involving irrigation water supply gaps (Ronco et al., 2017). Under these climate events, irrigators cannot fully satisfy their crop water needs, leading to significant losses for individual farmers (production and income) as well as problems for society as a whole (drops in wealth generation and rural employment, and water theft exacerbating the overexploitation of water bodies) (OECD, 2016).

In recent years, concerns about hydrological drought risk and irrigation water supply reliability have grown, especially in Mediterranean-climate agricultural regions. The first explanation for this is the increasing demand for water for irrigation and other uses (e.g., tourism), aggravating the scarcity of water resources and making irrigated agriculture—currently the predominant use of water—more vulnerable to drought (García-Ruiz et al., 2011). The second reason is climate change: its impact on these regions is reflected in the progressive decline in rainfall (lower water availability), gradual increase in temperatures (higher crop water needs), and greater frequency and intensity of drought periods, all of which lead to a less reliable irrigation water supply (Garrote et al., 2015; Bisselink et al., 2018).

The heightened awareness of water supply gaps explains a widespread interest among farmers in reducing the uncertainty associated with their irrigation water allotments (i.e., the corresponding uncertainty in farmers' income). In fact, several studies (e.g., Rigby et al., 2010; Mesa-Jurado et al., 2012; Alcón et al., 2014; Guerrero-Baena et al., 2019) have found that irrigators show a significant willingness to pay to reduce this uncertainty. This evidences the need for new management instruments to cope with hydrological droughts risk in irrigated agriculture (Garrido and Gómez-Ramos, 2009; OECD, 2016). Among the alternative instruments suggested to date, drought insurance has been pointed out as one of the most promising for this purpose (Rey et al.,

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2018; Guerrero-Baena and Gómez-Limón, 2019). Indeed, drought insurance is viewed as a key instrument for adapting irrigated agriculture to climate change since it improves the resilience of the irrigation sector, which is having to cope with increasing uncertainty and vulnerability due to changing global conditions (Garrido et al., 2012; Varela-Ortega et al., 2016).

Although agricultural insurance is widely used in developed countries (Meuwissen et al., 2018), the risk of hydrological droughts in irrigated agriculture is not covered anywhere. Multiple factors that hinder the development of this kind of insurance scheme (for a detailed explanation, see Guerrero-Baena and Gómez-Limón, 2019) explain why irrigators cannot take out insurance policies to protect themselves against financial losses resulting from water supply gaps. However, recent literature has suggested the implementation of index-based hydrological drought insurance schemes (i.e., where indemnities are calculated according to the value of an objective and non-manipulable index correlated with the losses caused by the water supply gaps) as a suitable option to minimize the key problems related to this kind of schemes, such as moral hazard, adverse selection, and high administrative costs for in-field damage evaluations or conflict resolution (Jensen and Barrett, 2017).[1] The proposals developed by Zeuli and Skees (2005), Brown and Carriquiry (2007), Leiva and Skees (2008), Buchholz and Musshoff (2014), Maestro et al. (2016), or Guerrero-Baena and Gómez-Limón (2019) are good examples of this kind of insurance scheme tailored to irrigated agriculture sectors worldwide.

Nevertheless, implementing the proposed insurance schemes in a real-life setting requires additional empirical studies, both from supply-side and demand-side perspectives. Studies based on the former approach are needed to calculate the commercial premiums that ensure the schemes under analysis are profitable for the insurance firm (i.e., the aggregate revenues from the premiums collected are higher than the sum of the aggregate expected indemnities and other related management costs). Meanwhile, demand-side studies are needed to assess irrigators' willingness to pay (WTP) for the insurance policies proposed. The commercial viability of the proposed schemes can only be confirmed by comparing the results of both kinds of studies; only when a significant share of potential insurees reports a WTP for the insurance policies proposed that exceeds the commercial premium demanded by the insurance firms can the insurance scheme under analysis be considered ready for implementation.

To date, however, most drought insurance studies have focused on the supply side (i.e., the cost of the policy); examples include the papers by Pérez-Blanco and Gómez (2013, 2014), Maestro et al. (2016), and Gómez-Limón (2020). Of the small number of drought insurance studies that assess the demand side (e.g., Leiva and Skees, 2008; Buchholz and Musshoff, 2014), only a few actually assess farmers' WTP for this kind of insurance policy. Examples of such studies are the ones by Quiroga et al. (2011), who estimated farmers' WTP for hydrological drought insurance as a percentage of the crop yield for the case of corn growers in Spain, and Rey et al. (2016), who assessed the WTP for this kind of insurance depending on farmers' risk aversion levels in the Segura Basin (southeastern Spain).

In this sense, this paper aims to contribute to the development of hydrological drought insurance schemes by implementing a new demand-side analysis assessing the irrigators' WTP for different policy designs possible for this kind of insurance.

Most studies assessing farmers' WTP for taking out an insurance policy have relied on the expected utility theory (EUT) as the dominant paradigm explaining decision-making under uncertainty. Following the EUT, farmers' decisions have been modeled using a von Neumann Morgenstern utility function that allows the calculation of the 'certainty equivalent' for any risky situation; that is, the guaranteed amount of money that the individuals would accept now, rather than taking a chance on a higher, but uncertain, return in the future. Thus, farmers' WTP for taking out insurance policies has been calculated by comparing the sums of money characterizing the insured scenarios (if they take out the policy) and the uninsured scenarios (if they do not). In certainty equivalent terms, the difference between these scenarios is always positive for risk-averse farmers, and is considered their maximum WTP for taking out the insurance. A relevant example of the implementation of this approach can be found in the study by Pérez-Blanco et al. (2016), who explicitly calculated farmers' WTP for farm income insurance considering different deductible values in a drought-prone area in southeastern Spain.

However, recent evidence shows that farmers' decisions about taking out insurance are not generally consistent with expected utility maximization. Assuming that farmers are risk-averse and subsidized premiums are set below actuarially fair levels, the EUT rationale holds that all farmers should buy the highest level of coverage possible so long as subsidies are maximized at this level. However, Du et al. (2016) showed empirical evidence contradicting this theoretical inference, and demonstrated that the probability of taking out an insurance product declines as the premiums increase, even though higher values of these expenditures increase farmers' expected utility. Similar conclusions that decisions about taking out insurance are generally not consistent with expected utility maximization have been reported by Babcock (2015) and Carter et al. (2015), who suggested the prospect theory (PT) as an alternative theoretical framework to better understand farmers' insurance decisions.

This calls for the use of other valuation techniques that are not based on stringent assumptions regarding the shape of farmers' utility functions, such as those imposed by the EUT or the PT. Possible options include techniques based on stated preferences, such as the contingent valuation method (CVM) or the choice experiment (CE). Although these methods have already been used to analyze the demand for other types of agricultural insurance (e.g., Liesivaara and Myyrä, 2017; Doherty et al., 2021), they have not yet been applied to assess irrigators' WTP for taking out hydrological drought insurance policies.

Within this context, the first objective of this paper is to assess irrigators' WTP for index-based hydrological drought insurance under different policy designs, considering several amounts of insured capital, insurance deductibles, and contract terms. For this purpose, the index-based hydrological drought insurance scheme proposed by Guerrero-Baena and Gómez-Limón (2019) is considered for implementation in a real-world setting, using CE as the valuation technique. This objective is achieved empirically by providing a quantitative example in the Guadalquivir River Basin (southern Spain). The results from this valuation exercise will illustrate the heterogeneity of irrigators' preferences regarding hydrological drought insurance and, thus, the potential insurance adoption rate depending on the potential insurance premiums established for taking out these policies.

Moreover, it is worth pointing out that the second objective of this paper is to compare the demand-side results obtained here with the supply-side results reported by Gómez-Limón (2020), who used actuarial analysis to calculate commercial premiums for this hydrological drought insurance scheme in the same irrigation district considered in this paper as a case study. Matching these two studies will allow an exploration of the commercial viability of the insurance scheme proposed.

The achievement of these two objectives will contribute to the existing literature by providing further insights into how to fine-tune drought insurance policies, supporting efficient decision-making regarding the most suitable design for this agricultural insurance scheme. In so doing, this study aims to be useful for further developing a risk management instrument that can act as a buffer against the

[1] However, other major drawbacks affecting hydrological drought insurance remain unresolved in index-based schemes, such as considering droughts as a systemic risk and the uncertain performance of this insurance due to climate change. Both features involve a higher cost of reinsurance and thus give rise to affordability issues.

microeconomic effects of water supply gaps due to hydrological droughts. Ultimately, the goal is to help improve the economic, social and environmental performance of irrigated agriculture, while guaranteeing its resilience in the face of global change.

2. Case study

2.1. The Sector BXII irrigation district

The Sector BXII (SBXII) is an irrigation district covering 14,673 ha located on the left bank of the Guadalquivir River (southern Spain), near its mouth into the Atlantic Ocean. This area was converted to irrigation during the 1980 s, as its Mediterranean climate (mild, wet winters and warm, dry summers) makes this district suitable for irrigated agriculture. In any case, the irrigation infrastructure and techniques have since been updated; nowadays, the SBXII is a valuable example of modern, highly-profitable irrigated agriculture production.

The SBXII is operated by 569 farmers (average farm size of 25.8 ha) who are organized into a water user association (see *www.crsectorb12.es*). This association holds the collective right to 6000 cubic meters of water per hectare and year (full water allotment) granted by the river basin agency (*Confederación Hidrográfica del Guadalquivir*, CHG). The association manages the distribution of the water among all its irrigators, to which end it uses a fully-modernized pressurized pipe network that allows for an on-demand irrigation system.

The main crops currently grown in the district are cotton (45% of the total area), tomato (22%), other vegetables such as onions, peppers, and carrots (14%), sugar beet (7%), and cereals (corn, wheat, and quinoa, accounting for 6%). These crops are mainly irrigated by sprinkler irrigation (71% of the total area), although drip (28%) and surface irrigation (1%) techniques are also used, depending on the crop. Nevertheless, it is worth noting that there is wide heterogeneity in terms of productive profiles at the farm level, with these profiles being based on both productive features (size and crop mixes) and farmers' socio-demographic characteristics (age and educational level).

The main problem faced by irrigators in the SBXII is their vulnerability to water supply gaps (i.e., water shortages during hydrological drought periods). Like most of the irrigation districts in the Guadalquivir River Basin (GRB), the only source of water for the farmers in the SBXII is the supply of surface water provided annually by the CHG (annual water allocations). In normal hydrological years, when all water rights can be satisfied with the water stored in the reservoirs, the CHG allows the irrigators in the SBXII to use up to 6000 m^3/ha (annual water allocations equal to the full water allotment), a volume that fully meets farmers' water needs. However, this is not always the case. The GRB is characterized by a typical Mediterranean climate, with an average annual rainfall of 573 mm, but this precipitation is rather heterogeneous across years, leading to frequent hydrological drought events. In these drought years, when aggregate water availability (i.e., water stored in the GRB reservoir network) is lower than aggregate full water allotments, the CHG has to ration water supply to irrigation districts, following the proportional rule as established in the drought management plan (CHG, 2018).

Considering current demand and supply constraints and the institutional framework set out in the Guadalquivir River Basin Management Plan (CHG, 2015), the distribution of the annual water allocations for the case study irrigation district is shown in the histogram in Fig. 1.

Under hydrological drought circumstances, annual water allocations provided by the CHG are not enough to fully meet farmers' water needs. Moreover, since there is no possibility of alternative water sources in this irrigation district (e.g., groundwater extracted from wells), irrigators in the SBXII cannot reduce their vulnerability to hydrological drought. Thus, when there are water supply gaps, they have to adapt crop water needs to the lower water availability (e.g., reducing the area actually irrigated). These cuts in water allocations involve significant income losses for all these farmers. That said, the resulting losses differ notably among irrigators, with much greater losses hitting more intensive farming (i.e., those farmers specialized in high-value crops such as tomato or other vegetables).

Moreover, it is worth noting that cyclical water shortages in the SBXII irrigation district are becoming more frequent and intense because of climate change (Bisselink et al., 2018). Therefore, the already high and increasing vulnerability to irrigation water supply gaps evidences the need for hydrological drought insurance as a new management instrument to cope with this risk, justifying the choice of this case study for the empirical analysis proposed here.

Based on official statistics and data provided by local technicians, a study on the profitability (income and expenses) of the crops grown in this irrigation district was carried out. The information collected shows that all crops in the SBXII are cultivated similarly throughout the study area, with a similar profit structure. Table 1 shows the average data regarding the profitability and the water needs for the main crops.

The characterization of irrigated farms in the SBXII was carried out by means of a survey conducted specifically for this study. For this

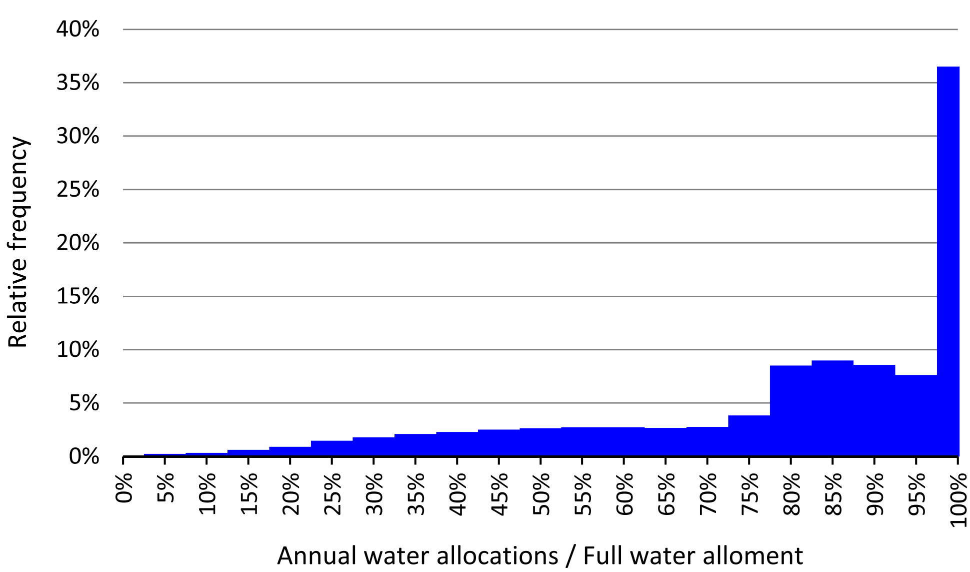

Fig. 1. Distribution of the annual water allocations for the SBXII.
Source: Stochastic hydrological model for the GRB developed by Gómez-Limón (2020).

Table 1
Main crops in the SBXII: economic variables and water needs.

	Cotton	Tomato	Onion	Pepper	Sugar beet	Corn
Expected income (€/ha)	2531	6424	17,649	21,440	3899	2364
Variable costs (€/ha)	1418	3907	2436	6529	2052	1741
Expected gross margin (€/ha)	1114	2517	15,213	14,912	1847	624
Variable costs May 1st (€/ha)	775	1443	2124	3925	1170	1157
Water needs (m^3/ha)	6048	6104	6104	6104	3730	6621
Water productivity (€/m^3)	0.18	0.41	2.49	2.44	0.50	0.09

Note: Crop features considering full water allotments.

survey, a representative sample (n = 202) of farmers in the study area (N = 569) was drawn. Individuals were randomly selected, accounting for farm size quotas. Questionnaires were completed through face-to-face interviews between February and March 2022, with interviewers collecting data on: a) farm structure (size, land ownership, labor), b) crop mix, c) irrigation systems, d) water management, e) farmers' socio-demographic characteristics (age, gender, education, household income), f) farmers' opinion about previous experience with agricultural insurance, and g) the implementation of the valuation method used (see Section 3). The main characteristics of the farms and farmers sampled are reported in Table 2.

Data gathered from irrigators show heterogeneity among farms in terms of crop mixes and thus profitability. This means the capital to be insured by the proposed hydrological drought insurance should also be heterogeneous, as explained in the following sections.

2.2. The hydrological drought insurance

In this section, the index-based hydrological drought insurance scheme proposed by Guerrero-Baena and Gómez-Limón (2019) and Gómez-Limón (2020) is summarized, pointing out the different design options worth considering for assessing irrigators' demand for this kind of insurance.

Table 2
Farm and farmers in the SBXII: main characteristics.

Metric variables	Average	Minimum	Maximum	S.D.
Farm area (hectares)	34.9	4.0	250.0	41.70
Owned area (hectares)	27.5	0.0	200.0	32.08
Cotton area (hectares)[a]	15.7	0.0	85.0	14.92
Tomato area (hectares)[a]	7.5	0.0	120.0	11.32
Sugar beet area (hectares)[a]	2.1	0.0	45.0	6.09
Onion area (hectares)[a]	1.4	0.0	28.0	4.10
Pepper area (hectares)[a]	1.0	0.0	36.0	3.69
Corn area (hectares)[a]	0.9	0.0	12.0	1.29
Surface irrigation (%)	1.4%	0.0%	100.0%	0.10
Sprinkler irrigation (%)	70.9%	0.0%	100.0%	0.18
Drip irrigation (%)	27.7%	0.0%	100.0%	0.17
Age (year)	54.1	26.0	78.0	8.90
Percentage of labor time devoted to farming	97.0%	0.0%	100.0%	0.17
Percentage of household income from farming	95.0%	0.0%	100.0%	0.22
Hired labor as a percentage of total labor	19.3%	0.0%	100.0%	0.40
Coeff. Constant Relative Risk Aversion (CRRA)[b]	2.08	0.00	4.92	1.94
Categorical variables			**Percentage**	
Gender	Male		97.0%	
	Female		3.0%	
Education	Primary school		73.3%	
	Secondary school		14.9%	
	University		11.9%	
Has another source of income	Yes		13.4%	
	No		86.6%	
Hires labor for farming	Yes		12.9%	
	No		87.1%	
Usually takes out crop insurance	Yes		85.1%	
	No		14.9%	

[a] Crop mixes considering full water allotments.
[b] The CRRA was assessed using the experimental method developed by Eckel and Grossman (2008) based on a lottery-choice task. For further technical details, interested readers can consult the work of Gómez-Limón et al. (2020).

The proposed hydrological drought insurance aims to protect the insured farmers against losses from irrigation water supply gaps. Thus, the first key attribute of the insurance to be defined is how to calculate the *insured capital* (*IC*).

As in any other Mediterranean-climate irrigated area, agricultural operations in the SBXII usually begin in fall or winter, depending on the crop, with farmers preparing the soil for sowing, taking advantage of the existing soil moisture from rainfall during the wet season (fall and winter). Thus, crops are grown throughout the spring and summer, and harvested in early fall. Irrigation operations usually start in May, at the beginning of the dry season (late spring and summer). Under this agricultural calendar, crop mix decisions are taken by farmers at the beginning of the agricultural year (fall or winter). However, these decisions are made under uncertainty since information about water allocations for irrigation is not available until May 1st, when the CHG sets annual water allocations depending on the water stored in the reservoirs at the end of the wet season. By May 1st, when water allocation decisions are known, irrigators in the SBXII have little leeway to cope with any water supply gap. In fact, the only option they have for dealing with the water constraints is to stop irrigating and cultivating a share (or the whole) of their irrigable land and leave it fallow (Gómez-Limón, 2020). Under these circumstances, the insured capital could be defined considering three alternatives:

1. The sum of all variable costs already spent on the irrigated crops by May 1st (IC1). With this insured capital, the indemnity received by the farmers would compensate only the working capital invested in the irrigated crops until May 1st, when a share or the whole irrigated area would be left fallow.
2. The aggregate expected gross margin (income minus variable costs) considering full water allotment (IC2). This definition of the insured capital involves payment of indemnities to compensate farmers for the profit (proxied by the aggregate gross margin) foregone due to irrigation supply gaps. Thus, it would partially compensate farmers for the losses in expected income (i.e., under full irrigation water allotment circumstances), since they would bear the costs of the working capital invested until May 1st in the crops that they have to stop irrigating because of water allocation gaps.
3. The aggregate expected gross margin considering full water allotment plus the sum of all variable costs by May 1st (IC3). This definition of the insured capital involves payment of an indemnity to cover both the profit foregone and the investment in working capital. This is the only definition of the insured capital that actually guarantees the farmers' income remains fully stable despite water supply gaps.

The several alternative amounts of insured capital can be easily estimated on a farm-by-farm basis by accounting for their crop mix and the average variable costs and gross margins for each irrigated crop within the irrigation district (see Table 1).

Considering the three abovementioned levels (IC1, IC2, and IC3)

Table 3
Alternative amounts of insured capital for different farm types in the SBXII.

	Low-value farm type	Average farm type	High-value farm type
IC1: Sum of all variable costs by May 1st (€/ha)	972	972	2234
IC2: Aggregate expected gross margin considering full water allotment (€/ha)	1480	2204	8790
IC3: Aggregate expected gross margin considering full water allotment plus the sum of all variable costs by May 1st (€/ha)	2453	3176	11,023

allows us to analyze the role of the amount of the insured capital in farmers' WTP for the proposed insurance, and check for the possible existence of non-linear relations between the two variables. This analysis would be useful for informing the final design of the policy to be offered. In any case, it is assumed that once the final policy has been designed (i.e., with just one option for the insured capital), farmers would not be given a choice about the amount of capital to insure.

Table 3 illustrates the heterogeneity in the amounts of insured capital, showing the calculations considering the crop mixes of three farm types: a) average farm type, based on the average crop mix in the SBXII, b) high-value farm type, based on a crop mix of 50% tomato and 50% other vegetables (peppers and onion), and c) low-value farm type, based on a crop mix of 50% cotton and 50% sugar beet.

For the insurance proposed, the occurrence of a *loss* is verified when the annual water allocation set by the CHG is lower than the full water allotment. In order to calculate these losses in a similar way for all insured farms, it is assumed that farmers behave rationally as profit maximizers when choosing which crops to stop irrigating, and that they therefore progressively abandon those with the lowest water productivity.[2] This assumption lets us estimate the crop mixes for any annual water allocation lower than full water allotment, thus enabling the calculation of the losses depending on the chosen insured capital; that is, based on the difference between the scenario with full water allotments and the scenario with the reduced annual water allocations (i.e., only considering the crop area that can be actually irrigated).

In index-based insurance, losses (and indemnities) are calculated according to an objective and non-manipulable index value. In the case of the proposed hydrological drought insurance, the most suitable index value is the amount of water stored in the reservoir network at the beginning of the irrigation season (WS_{May_1st}), measured as a percentage of the total storage capacity of the network (Guerrero-Baena and Gómez-Limón, 2019).

Every year, once the value of WS_{May_1st} and the existing drought situation (normality, pre-alert, alert, or emergency) are known, the CHG sets the annual water allocations for irrigation following the guidelines established in the drought management plan (CHG, 2018). Considering this allocation rule, losses caused by hydrological droughts can be estimated for insurance purposes as a function of the water stored on May 1st, as follows:

$$Loss = f\left(WS_{May\_1st}\right) \quad (1)$$

The *indemnity* (*I*) is the cash amount that the insurance company pays insured farmers, which is equivalent to the value of the loss minus the *deductible* (*DED*) agreed in the policy (i.e., the percentage of the insured capital that the farmer is responsible for covering). In the case of the index-based insurance scheme proposed, the indemnity can be calculated after determining the value of the WS_{May_1st} index using the following expression (Gómez-Limón, 2020):

$$I = \begin{cases} 0 & \text{if } 0 < h\left(WS_{May\_1st}\right) < DED \times IC \quad \text{no loss} \\ h\left(WS_{May\_1st}\right) - DED \times IC & \text{if } DED \times IC \leq h\left(WS_{May\_1st}\right) \quad \text{no loss} \\ IC \times (1 - DED) & \text{if } h\left(WS_{May\_1st}\right) = IC \quad \text{total loss} \end{cases} \quad (2)$$

For analytical purposes, different deductible (*DED*) levels have been considered for the demand assessment: 0%, 10%, 20%, and 30%. This allows us to explore the relationship between the value of the deductible and farmers' WTP for the proposed insurance, and supports the final design of the policies that will eventually be commercially available.[3]

The proposed hydrological drought insurance is based on annual policies. These policies should be formalized by paying the annual premium in September every year. These contracts would be valid from the purchase of the policy to May 1st the following year, when the WS_{May_1st} index is calculated and, if losses have occurred, indemnities can be claimed. However, it is worth pointing out that during the contracting period, the potential insurees have information about the volume of water stored in the reservoir network at the beginning of the hydrological year (October 1st), potentially leading to some intertemporal adverse selection. In order to minimize this problem, which would jeopardize the viability of the insurance scheme, the condition should be established that if a pre-alert, alert, or emergency situation is declared during the contracting period (September), the proposed insurance can only be taken out by those who had drought insurance the previous year. Furthermore, farmers who wish to take out a policy for the first time could also be required to sign a commitment that they will renew their policies for the next three or five years. Thus, three different *contract terms* for new insurees have been considered for the demand assessment: one year,[4] three years, and five years.

3. Valuation method

3.1. Choice modeling approach: attributes, levels, and experimental design

To analyze farmers' preferences for taking out the proposed hydrological drought insurance, a hypothetical market has been created, using the stated preference method of the discrete choice experiment (DCE) as the valuation method. This method is based on Lancaster's consumer theory (Lancaster, 1966) and random utility theory (McFadden, 1974),

[2] There is ample evidence that farmers' decision-making can be more accurately simulated under the assumption that they are utility maximizers, accounting for profit within non-linear utility functions (e.g., EUT or PT) or assuming multi-attribute utility functions (MAUFs, i.e., those considering profit and other attributes such as risk or management complexity). However, it is worth explaining that assessing the losses in real-life agricultural insurance schemes requires a simple (i.e., easy to understand) method that is similarly applied to all farmers (i.e., regardless of the utility function they considered). This justifies the use of the profit maximization assumption as the criterion for switching from cultivation to fallow since: a) it is the most widespread strategy to cope with hydrological drought events; b) it is easy to understand for all farmers, and c) it leads to reasonable approximations of the losses experienced by farmers during droughts.

[3] A 0% deductible would not be suitable for a commercial insurance policy because it goes against the principle of risk sharing between the insurer and the insuree, and would involve unaffordable premiums. However, a zero deductible has been considered for scientific exploratory purposes since it allows us to isolate the effect of other attributes and to better analyze the relationship between the deductible and farmers' WTP for the proposed insurance.

[4] As in the case of the 0% deductible, a one-year contract would not be suitable for a commercial insurance policy due to adverse selection issues. However, as in the previous case, it is included for scientific exploratory purposes.

Table 4
Attributes and levels used in the DCE.

Attribute	Levels
Insured capital (IC)	• the sum of variable costs until May 1st • the aggregate gross margin considering full water allotments • the sum of variable costs until May 1st plus the aggregate gross margin considering full water allotments
Deductible (% IC)	0%, 10%, 20%, and 30%
Contract term (years)	1, 3, 5
Premium (% IC)	2%, 4%, 6%, 8%, 10%, and 12%

and has been previously used in the assessment of farmers' preferences toward insurance policies (e.g., Aizaki et al., 2021; Doherty et al., 2021; Fu et al., 2022). A detailed description of this valuation method can be consulted in Hensher et al. (2015).

Four attributes were selected to implement the DCE method, three non-monetary and one monetary (see Table 4). With regard to the non-monetary attributes, the selected attributes correspond to the main characteristics of the hydrological drought insurance described in the previous section. These are: a) the *insured capital*, with three levels corresponding to the sum of variable costs until May 1st, the aggregate gross margin considering full water allotments, and the sum of variable costs until May 1st plus the aggregate gross margin considering full water allotments; b) the *deductible*, with four levels (0%, 10%, 20%, and 30%); and c) the *contract term*, with three levels (1, 3, and 5 years). With regard to the monetary attribute, it consists of the *premium* of the insurance, defined as a percentage of the insured capital, with six levels ranging from 2% to 12%. The levels of the monetary attribute were based on the actuarial analysis carried out by Gómez-Limón (2020).

An efficient design minimizing the D-error using Bayesian techniques (Rose et al., 2011) was employed for the experimental design. Due to the lack of prior information, the priors for all the attributes were set close to zero with a negative sign, except for the insured capital, which was set at zero due to the uncertainty associated with the behavior of the farmers with respect to it.[5] The efficient design obtained consisted of 32 choice cards, distributed in four blocks of eight cards each, with a D-error of 0.111. For the estimation of the experimental design, the NGene 1.2.1 software was used. A pilot of 60 interviews was conducted to assure the adequacy of the experimental design, where it was found to be satisfactory and was therefore maintained.

Before conducting the DCE exercise, the interviewed farmers were asked for information on the distribution of crops on the farm, which was used to estimate the three possible levels of the farmer's insured capital. The choice cards consisted of an insurance option with a combination of the levels of the four attributes and an opt-out option (no purchase of the proposed insurance). To ensure the insurance option proposed in each choice card was readily understandable, the cards included an illustrative graph showing the indemnities that the farmer would receive in the event of several reductions of his/her annual water allocation. These graphs were produced based on individual farmers' crop distributions and the characteristics of the insurance option (the level of insurance capital and the deductible). Although defined as a percentage of the insured capital, the monetary attribute was shown to the farmer as a premium in euros per hectare (€/ha), calculated as the product of the insured capital and the level of the monetary attribute corresponding to the insurance option. An example of a choice card is shown in Fig. 2.

Although it is recognized that the DCE method overcomes most of the limitations related to other stated preference methods (Hanley et al., 1998), it is worth noting that estimations using this valuation approach could be affected by hypothetical bias (Haghani et al., 2021a). The presence of this bias when using a DCE depends on the type of good (public or private), the type of measurement (WTP or WTA), and the familiarity or previous experience with the good or service (Guzman and Kolstad, 2007; Schläpfer and Fischhoff, 2012; Haghani et al., 2021a). Our case study values a private good (insurance policies), and assesses WTP by farmers who have previous experience with insurance; these features have been shown to be among those that are less susceptible to hypothetical bias.

Farmers were given a cheap talk before the start of the DCE exercise, reminding them their budget was limited and that the money spent on the insurance could not be spent on other expenses on or off the farm. Interviewed farmers were also reminded that they could opt not to purchase the proposed insurance (opt-out reminder). Furthermore, a self-assessment question regarding perceived consequentiality was included at the end of the valuation exercise to assess whether farmers believed that their answer would actually be considered in the design of the proposed insurance. Results show that most farmers did perceive consequentiality (i.e., they believed that their answers would be taken into account for the insurance design). As evidenced by Haghani et al. (2021b), the implementation of all these strategies minimizes the presence of hypothetical bias, increasing the reliability of the estimates obtained.

Following the exercise, a question was included for farmers who were not willing to buy any of the offered insurance policies. In these cases, farmers were asked about the reason(s) for not taking out any insurance policies, distinguishing between protest responses and real zero values. From the total of 202 farmers who fully completed the questionnaires, seven were considered to be protests, reducing the total number of valid questionnaires to 195.

3.2. Econometric approach

To analyze farmers' preferences towards the proposed hydrological drought insurance, a mixed logit model in WTP space was used. The main advantage of these models is that they allow the direct estimation of the WTP of each attribute, instead of deriving it from the distribution of utility coefficients, which can be difficult or impossible with some choice of parameter distribution (Daly et al., 2012). In addition, they provide more reasonable distributions of the WTP (Train and Weeks, 2005).

The model starts from a conventional specification of the utility function, with n individuals, t choice cards, and j alternatives:

$$U_{njt} = -\alpha_n p_{njt} + \beta_n \chi_{njt} + \varepsilon \quad [1]$$

where p_{njt} is the insurance premium, χ_{njt} is a vector with the rest of the attributes and levels in the choice cards, α_n and β_n are the utility coefficients for the premium and the other attributes, respectively (including a set of alternative specific constants, ASC), which vary randomly over people, and ε is a random term representing all unobserved components of the utility function, which is assumed to be i.i.d. type-one extreme value and follows a Gumbel distribution.

Individuals' WTP for the attributes is calculated as the ratio between the utility coefficients of the attribute (β_n) and the premium coefficient (α_n). Therefore, expression [1] can be reordered as follows:

$$U_{njt} = -\alpha_n p_{njt} + \alpha_n w_n \chi_{njt} + \varepsilon \quad [2]$$

where w_n is the WTP associated with these attributes. As in expression [1], α_n and w_n are randomly distributed over people. w_n can be further decomposed in $w_n = w + w_z Z_n$, where w is a vector of individual willingness to pay, randomly distributed across the population following a

[5] This attribute involves two opposite effects, which combined could positively or negatively influence the utility function. On the one hand, the higher the amount of insured capital, the higher the indemnities received by the farmer (higher utility); on the other hand, a larger amount of capital also implies an increase in the premium to be paid (lower utility). Since there is not enough information to indicate which effect would prevail, we took the conservative approach of not imposing any sign.

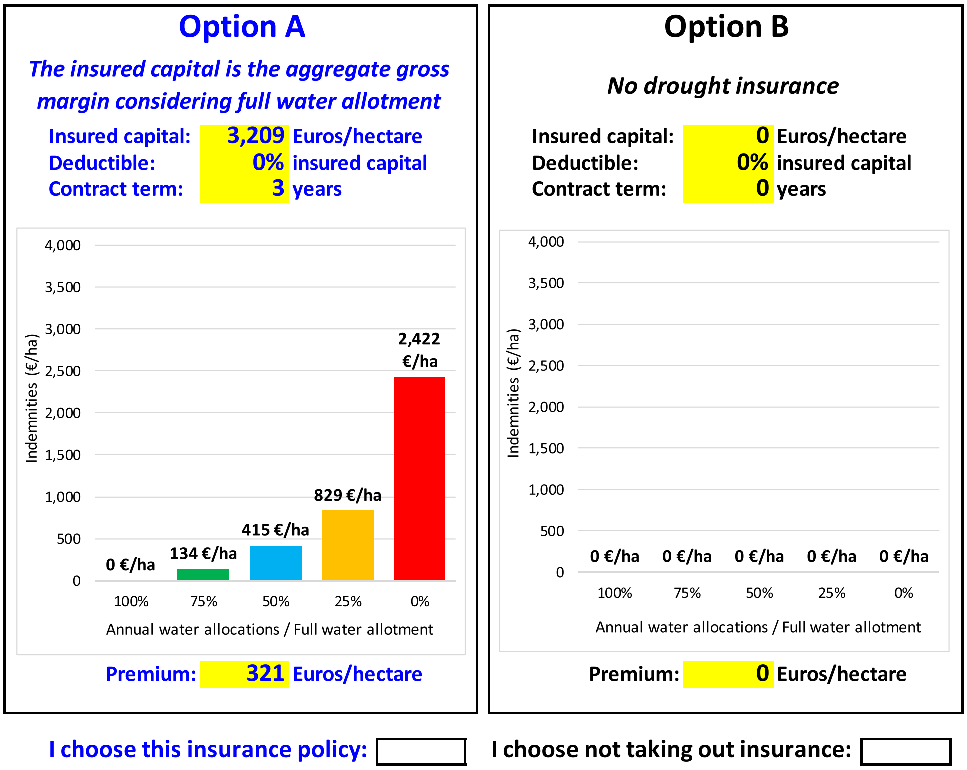

Fig. 2. Example of a choice card.

density function $f(w|\theta)$ (with θ representing the parameters of the distribution), and $w_z Z_n$ represents the heterogeneity in the mean of the WTP associated with the attributes and levels, with w_z being the coefficients to be estimated and Z_n a vector of individual characteristics.

The choices are modeled following a panel structure so that the probability integral is composed of a product of logistic formulae. This integral does not have a closed form, so its solution requires an iterative process (Train, 2003). The model has been estimated using 1000 Modified Latin Hypercube Sampling (MLHS) draws (Hess et al., 2006), assuming a normal distribution in all the parameters.

For modeling purposes, all the attributes except for the premium have been treated as categorical variables. Thus, the econometric model requires fixing one of the levels in each attribute as the base category, with the coefficient values of the other levels representing the additional WTP associated with these levels over the base category. In our case, the lowest level in each attribute has been fixed as the base category, that is, the sum of variable costs until May 1st for the insured capital, 0% for the deductible, and one year for the contract term.

For a more in-depth analysis of the heterogeneity of farmers' preferences for the proposed hydrological drought insurance, interactions of farm and farmers' socio-economic characteristics with the ASC were included. The modeling procedure was to include each of the selected variables (those shown in Table 2) in a single interaction WTP space model to check their significance. In a second step, all interactions found to be significant were included in a multiple interaction model. From this model, the least significant interactions were excluded one by one, until a fully significant model was obtained.

All models were estimated with R, using the Apollo package, version 0.2.7 (Hess and Palma, 2019, 2022).

4. Results and discussion

4.1. WTP space model

The results of the WTP space model are shown in Table 5. The model

Table 5
WTP Space model.

	Mean		Standard deviation	
	Coef.	*St. Err.*	*Coef.*	*St. Err.*
ASC	10.358***	0.988	1.635***	0.225
Insured capital: aggregate gross margin	-4.388***	0.576	0.399	1.046
Insured capital: variable costs May 1st + aggregate gross margin	-4.405***	0.466	1.154*	0.646
Deductible: 10%	-2.140***	0.428	-0.433	1.309
Deductible: 20%	-4.975***	0.544	1.507**	0.566
Deductible: 30%	-6.117***	0.670	2.376**	0.809
Contract term: 3 years	-3.061***	0.424	2.340***	0.453
Contract term: 5 years	-4.588***	0.425	1.506**	0.558
Premium (%)	1.077***	0.205	-0.357***	0.112
Heterogeneity in the mean				
ASC x Full time farmer (1 =Yes)	-1.294*	0.585		
ASC x % Cotton	5.922***	1.161		
ASC x CRRA	0.177*	0.099		
Model fit statistics				
LL		-516.22		
Adjusted Pseudo-R^2		0.503		
AIC		1074.43		
Observations (individuals)		1560 (195)		

Note: Base categories: variable costs until May 1st (insured capital), 0% (deductible) and 1 year (contract term). ***; **; * denote significance at 0.1%, 1%, and 5% level, respectively.

presents a very high goodness-of-fit (adjusted pseudo-$R^2 = 0.503$). In order to interpret these results, it is worth clarifying that in a WTP space model, all coefficients, except those associated with the monetary attribute (i.e., the premium in our case study), represent the parameters of the distribution of the marginal WTP for the different attributes.

The results of the model show that all mean coefficients are highly significant. The ASC has a positive sign, accounting for the average WTP (i.e., a premium equal to 10.36% of the insured capital) for the insurance designed with the fixed levels (i.e., base categories) mentioned above. The premium coefficient also has a positive sign, which implies a reduction in utility associated with the increase of the premium to be paid.[6] In contrast, the rest of the attributes have a negative sign, which indicates a reduction in the utility (i.e., WTP) attached to the insurance when the insured capital, the deductible, and the contract term are increased.

It should be recalled that the insurance premium is measured as a percentage of the insured capital. Therefore, an increase in the insured capital implies the same proportional increase in the actual amount of money to be paid by the farmer for taking out the insurance. However, the higher the insured capital, the higher the indemnity in the event of a water allotment shortage. In this sense, the negative sign obtained for the attribute insured capital indicates that the effect on the amount to be paid prevails over the effect on the indemnities. This means that farmers are willing to pay a higher percentage for a lower level of insured capital because this entails a smaller payment, although it also implies lower potential indemnities.

This effect is not appreciable when comparing the two higher levels of insured capital, as no significant differences are found between the means of the two coefficients.[7] This result indicates that farmers would be willing to pay, on average, the same percentage of their insured capital as an insurance premium if the variable costs on May 1st are added to the aggregate gross margin, even though it would increase the payment in euros per hectare.

In the case of the deductible, the higher the deductible, the lower the WTP for the insurance. This result is to be expected, as the increase in the deductible would imply a lower probability of receiving an indemnity in the event of a water shortage (i.e., the water shortage needed to receive an indemnity would be more acute) and lower indemnities in every case (see also Pérez-Blanco et al., 2016, for similar results). However, it is worth noting that the relationship between farmers' WTP and the deductible is not linear: the decline in WTP is less between the 30% deductible and the 20% deductible than between 20% and 10% and between 10% and 0%.

Finally, regarding the contract term, the results show that increasing contract duration represents a disutility for farmers (i.e., lower WTP for the insurance), as a longer contract term means they are committed to paying the insurance and reduces their capacity to implement other alternative risk management instruments (e.g., precautionary savings as a self-insurance alternative). As in the case of the deductible, the relation between the contract term and the WTP is not linear: the decline is greater for an increase in the contract term from one to three years than from three to five.

Three significant interactions were found between socio-economic variables and the ASC (see Table 5). First, the interaction between full-time farmers and the ASC turns out to be negative, indicating those farmers have a lower WTP to insure their farms against hydrological droughts. This result could be due to these farmers perceiving that they have a higher degree of control over their farm, allowing them to better adapt their crop mix and irrigation strategies in cases of water shortage (Goodwin, 1993). Another potential explanation is that full-time farmers are more likely to implement other alternative risk management instruments to make them less vulnerable to drought events, such as diversification (Mishra et al., 2004).

On the other hand, the interaction with the percentage of cotton on the farm yields a positive result, indicating that the higher the presence of this crop on the farm, the stronger the farmers' preference for the insurance. In this regard, it should be noted that in the case study area, cotton represents a relatively low-profit option compared to other alternative crops such as vegetables; therefore, the insured capital would similarly be lower. As a result, the actual insurance premium would be lower as the percentage of cotton increases.

Finally, the interaction with the coefficient of Constant Relative Risk Aversion (CRRA) also has a positive coefficient, indicating that more risk-averse farmers would be more willing to insure their farms. This finding is aligned with those reported by Jin et al. (2016) or Zhang et al. (2021), although it contrasts with the evidence found by Giné et al. (2008) or Cole et al. (2013).

In any case, the standard deviation coefficients turn out to be significant for most attributes and the ASC (see Table 5), indicating the existence of heterogeneity among farmers' preferences with regard to these attributes which has not been captured by the interactions with the mean included in the model. The only exceptions are the insured capital, when it accounts for the aggregate gross margin of the farm, and the 10% deductible. Therefore, further research is needed to explore other sources of heterogeneity in irrigators' WTP for the proposed insurance.

4.2. WTP for different drought insurance designs

Table 6 shows the mean WTP for different hydrological drought insurance designs, both as the percentage of the insured capital and in euros per hectare, considering the case of the average farm in the SBXII (shown in Table 3). In this table, only the designs with significant positive WTP are reported. However, it is worth noting that there are also alternative mixes with negative mean WTP; more specifically, those including a high deductible and/or an extended contract term (e.g., the alternative combining an insured capital "Var. costs May 1st + Gross margin", a deductible of 30%, and a contract term of 5 years). They can thus be ruled out as promising policy designs.

Mean WTP for the different hydrological drought insurance considered ranges between 12.77% (Var. costs May 1st; 0% deductible; 1 year) and 2.24% (Var. costs May 1st + Gross margin; 30% deductible; 1 year) of the insured capital. According to the results explained in the previous section, it can be seen that the WTP decreases as the insured capital, the deductible, and the contract term increase.

Mean WTP for the proposed insurance in euros per hectare ranges between 72.58 and 360.80 €/ha. Since the expected indemnities increase with the insured capital, the premium per hectare that farmers are willing to pay to purchase the insurance is higher for options with higher levels of insured capital (i.e., aggregate expected gross margin and aggregate expected gross margin plus the sum of all variable costs by May 1st). However, the percentage of the insured capital that farmers are willing to pay for these options is lower than for the lowest level of the insured capital (sum of all variable costs by May 1st). The only exception is for the option of a deductible of 30%, where the estimated mean WTP in euros per hectare for the first level of insured capital (variable costs by May 1st) is slightly higher than for the second level (aggregate expected gross margin), although the difference between them is not significant.[8]

On the other hand, the premiums farmers are willing to pay are lower when the contract term or the deductible increase. This reduction is

[6] As can be seen in expressions [1] and [2], the premium attribute is multiplied by − 1. Therefore, the positive sign implies a negative effect in the utility function.

[7] The delta method has been used on the difference between the mean coefficients of both levels of insured capital, showing that the difference between them is not different from zero.

[8] Tested using the delta method for the difference between the two estimates of mean WTP.

Table 6
Total willingness to pay (WTP) for different hydrological drought insurance policies considering the insured capital of an average farm in the SBXII.

	% Insured capital		Euros per hectare	
	Mean	*Conf. int. (95%)*	*Mean*	*Conf. int. (95%)*
Var. costs May 1st; 0% deductible; 1 year	12.77	(11.69–13.84)	141.20	(129.29–153.11)
Gross margin; 0% deductible; 1 year	8.38	(7.65–9.11)	268.87	(245.53–292.21)
Var. costs May 1st + Gross margin; 0% deductible; 1 year	8.36	(7.65–9.08)	360.80	(329.93–391.68)
Var. costs May 1st; 0% deductible; 3 years	9.71	(8.68–10.73)	107.35	(96.01–118.69)
Gross margin; 0% deductible; 3 years	5.32	(4.19–6.45)	170.65	(134.41–206.90)
Var. costs May 1st + Gross margin; 0% deductible; 3 years	5.30	(4.27–6.33)	228.74	(184.30–273.18)
Var. costs May 1st; 0% deductible; 5 years	8.18	(7.13–9.22)	90.45	(78.90–102.00)
Gross margin; 0% deductible; 5 years	3.79	(2.79–4.79)	121.63	(89.64–153.62)
Var. costs May 1st + Gross margin; 0% deductible; 5 years	3.77	(3.00–4.55)	162.82	(129.50–196.13)
Var. costs May 1st; 10% deductible; 1 year	10.63	(9.59–11.67)	117.53	(106.04–129.02)
Gross margin; 10% deductible; 1 year	6.24	(5.28–7.19)	200.20	(169.58–230.81)
Var. costs May 1st + Gross margin; 10% deductible; 1 year	6.22	(5.53–6.91)	268.47	(238.68–298.25)
Var. costs May 1st; 20% deductible; 1 year	7.79	(7.03–8.56)	86.18	(77.70–94.65)
Gross margin; 20% deductible; 1 year	3.40	(2.25–4.55)	109.22	(72.30–146.14)
Var. costs May 1st + Gross margin; 20% deductible; 1 year	3.39	(2.36–4.41)	146.13	(101.82–190.44)
Var. costs May 1st; 30% deductible; 1 year	6.65	(5.16–8.14)	73.55	(57.06–90.03)
Gross margin; 30% deductible; 1 year	2.26	(0.96–3.56)	72.58	(30.81–114.35)
Var. costs May 1st + Gross margin; 30% deductible; 1 year	2.24	(0.93–3.56)	96.86	(40.03–153.69)

Note: All the estimates of total mean WTP are significant at 0.1%. Estimates were obtained using the delta method.

greater for higher levels of insured capital. For example, for the variable costs by May 1st option, increasing the contract term from one to three years yields a reduction in the payment of €33.85/ha, while for the aggregate gross margin plus variable costs by May 1st option, this reduction is €132.06/ha. Likewise, increasing the deductible from 0% to 30% reduces the WTP by €67.65/ha for the first level of insured capital, with a reduction of €263.94/ha for the highest level of insured capital.

The results pertaining to the deductible are comparable to those reported by Liesivaara and Myyrä (2014, 2017), who also found that increasing the deductible reduces farmers' WTP for insurance policies. In the case of the contract term, Doherty et al. (2021) found that farmers who had already insured their farms showed higher WTP for longer contract terms, while farmers not currently insuring their farms presented lower WTP in such cases. Given that the proposed hydrological drought insurance is not yet available, and farmers have no previous experience with this risk management instrument, our finding is aligned with that reported by these authors. In any case, further research is needed in order to clarify farmers' preferences toward longer or shorter contract terms.

4.3. *Probability of taking out the insurance*

Gómez-Limón (2020) implemented an actuarial analysis aimed at calculating the commercial premiums for the same hydrological drought insurance and irrigated district considered in this paper. These premiums are the prices that insurance companies would request to underwrite the different policies of the proposed drought insurance. The results found in that study can be seen in the third column of Table 7. It should be noted that in the previous study, only differences in the insured capital and the deductible were analyzed, considering a one-year contract term in every case. Thus, only the premium based on one-year term policies can be included in the WTP comparison in this paper.

It is worth noting that while the commercial premium is a deterministic value (i.e., it is the same for all potentially insured farmers), the WTP for taking out the insurance is a probabilistic value (i.e., it is distributed among the population of targeted farmers). This is shown graphically in Fig. 3, where the probability of taking out the insurance (measured on the horizontal axis) is charted for the case of the average farm in the SBXII considering an insurance policy designed with a 10% deductible and one-year contract term. As can be observed, the commercial premiums are represented by horizontal lines, depending only on the insured capital, while the WTP values are represented by downward sloping lines, meaning that the lower the premium, the higher the uptake of insurance. This chart actually represents the insurance supply (i.e., commercial premium) and demand (WTP), which reach the market equilibrium at their intersection, pointing to the probability of taking out the insurance. In the example shown in Fig. 3, these probabilities are 65.5% for the insured capital accounting for variable costs May 1st, 1.6% for the insured capital accounting for the gross margin, and 3.4% for the insured capital accounting for the variable costs May 1st plus the gross margin.

Table 7
Willingness to pay (WTP) vs. actuarial commercial premium to be paid by the average farm in the SBXII.

	WTP Mean (St. Dev.)		Comm. premium	Comm. premium-mean WTP gap		Prob. of taking out
	€/ha		*€/ha*	*€/ha*	*%*	*%*
Var. costs May 1st; 10% deductible; 1 year	117.53	(18.71)	110.07	7.46	6.8%	65.5%
Gross margin; 10% deductible; 1 year	200.20	(55.78)	319.35	-119.15	-37.3%	1.6%
Var. costs May 1st + Gross margin; 10% deductible; 1 year	268.47	(88.36)	429.42	-160.95	-37.5%	3.4%
Var. costs May 1st; 20% deductible; 1 year	86.18	(24.59)	71.21	14.97	21.0%	72.9%
Gross margin; 20% deductible; 1 year	109.22	(72.49)	206.60	-97.38	-47.1%	9.0%
Var. costs May 1st + Gross margin; 20% deductible; 1 year	146.13	(108.10)	277.81	-131.68	-47.4%	11.2%
Var. costs May 1st; 30% deductible; 1 year	73.55	(31.90)	43.00	30.55	71.1%	83.1%
Gross margin; 30% deductible; 1 year	72.58	(93.43)	124.75	-52.17	-41.8%	28.8%
Var. costs May 1st + Gross margin; 30% deductible; 1 year	96.86	(134.03)	167.75	-70.89	-42.3%	29.8%

Note: Commercial premium from Gómez-Limón (2020). All the WTP estimates (means and standard deviations) are significant at 0.1%. Estimates were obtained using the delta method.

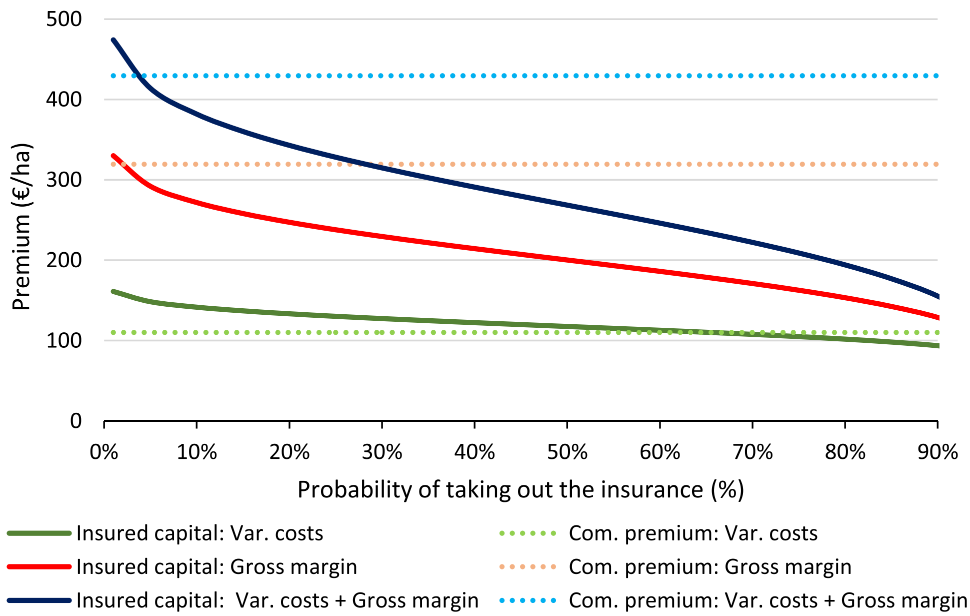

Fig. 3. Probability of taking out the drought insurance by the average farm in the SBXII considering a 10% deductible and one-year contract term.

According to the probabilities of taking out the insurance shown in the last column of Table 7 for every policy design, it can be seen that only policy designs considering the variable costs May 1st as insured capital would be commercially successful. In all these cases, the share of farmers contracting the drought insurance would be above 65%, reaching 83.1% when this insured capital is combined with a deductible of 30%.

Other policy designs based on a deductible of 30% could also have commercial potential, although with a much more limited potential market (share of farmers taking out the drought insurance slightly below 30%). The rest of the designs have very low contracting rates, and thus insurance firms would have no interest in bringing them to market.

5. Conclusions

The results provide evidence that farmers would be willing to pay for index-based hydrological drought insurance, showing a higher preference for policy designs with a smaller amount of insured capital (i.e., variable costs until May 1st), lower deductible (i.e., 0%), and shorter contract term (i.e., one year). The novelty of the proposed insurance could explain these results; it is plausible that once farmers get used to the insurance, they would be more willing to purchase other options involving a larger amount of insured capital, higher deductible, and longer contract term.

The results also show the existence of heterogeneity among farmers' preferences, depending on their socio-economic characteristics. Full-time farmers would be more reluctant to purchase the proposed insurance, while those with a higher percentage of the farm devoted to cotton (the most important crop in the study area) and who are more risk-averse would pay a higher premium for contracting the insurance.

Furthermore, we compared the distribution of farmers' WTP for different policy design options of the proposed drought insurance with the commercial premium estimated using actuarial analysis. The results show that the options with the insured capital based on variable costs until May 1st are the only ones with a mean WTP lower than the commercial premium (i.e., probability of taking out the insurance above 50%). The rest of the policy design options would have to be subsidized, as other agricultural insurance schemes are (i.e., a share of the premium would be paid by the public sector), to make them attractive to most farmers.

The evidence above suggests it would be advisable to start implementing the proposed hydrological drought insurance, initially only marketing policies in which the insured capital accounts for variable costs incurred until May 1st. Moreover, it is expected that once the farmers have gained some experience with this risk management instrument, all the other different policy design options would become more attractive (i.e., the WTP would increase), thus reducing the need for public subsidies to make policies with higher levels of insured capital and longer contract terms more appealing.

Finally, it is worth noting that this work is not free of methodological limitations. The most relevant one affects all valuation exercises based on stated preferences, since the Lucas critique applies in this case. In fact, the results reported should be considered simply a 'snapshot' of the case study analyzed at the time the survey was carried out. Notwithstanding, market prices (inputs and outputs), agricultural policy instruments implemented, and water allocation criteria in effect at this time in the SBXII cannot be considered structural characteristics of this irrigation district but are policy variants. This means any estimation of farmers' WTP for the proposed insurance policies is context-specific, and does not account for the actual dynamics of farmers' preferences depending on changes in the circumstances. This limitation calls for new empirical evidence on farmers' WTP for hydrological drought insurance in different market, agricultural policy, or water management frameworks to check the reliability and stability of the results.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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