The impact of farmers' risk preferences on the design of an individual yield crop insurance

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Working Paper SMART – LERECO N°16-03

March 2016

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Acknowledgments

This project is supported by the research programme "Assessing and reducing environmental risks from pesticides" funded by the French Ministries in charge of Ecology and Agriculture. The authors are grateful to the Centre de Gestion et d'Economie Rurale de la Meuse/CER France (ADHEO) for providing the data.

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Abstract

Kahneman and Tversky's Cumulative Prospect Theory (CPT) has proved to be better suited for representing risk preferences than von Neumann and Morgenstern's Expected Utility Theory (EUT). We argue that neglecting this may explain to some extent why farmers do not contract crop insurance as much as they are expected to. We model the decision to contract an individual yield crop insurance for a sample of 186 French farmers. We show that 21% of the farmers who would be expected to contract assuming that their preferences are EUT, would actually not do so if their true preferences were in fact CPT.

Keywords: yield, crop insurance, cumulative prospect theory, premium subsidy, France

JEL Classification: D81, Q10, Q12, Q18

L'impact des préférences des agriculteurs pour le risque sur le design d'une assurance récolte

Résumé

La théorie des perspectives cumulées (CPT) de Kahneman and Tversky représente mieux les préférences des agents pour le risque que la théorie de l'utilité espérée (EUT) de von Neumann and Morgenstern. Nous montrons que cela peut expliquer, dans une certaine mesure, pourquoi les agriculteurs tendent à moins s'assurer que prédit par la théorie. Nous proposons un modèle de décision de contractualiser une assurance rendement sur un échantillon de 186 agriculteurs français. Nous montrons que 21% des agriculteurs qui auraient été censés s'assurer sous l'hypothèse que leur préférences sont EUT ne s'assurent pas lorsque leurs préférences sont CPT.

Mots-clefs : rendement, assurance récolte, théorie des perspectives cumulées

Classification JEL : D81, Q10, Q12, Q18

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1 Introduction

The debate on why farmers do not contract crop insurance policies as much as they should when considering the risk they face, and on the ways to remedy the issue by optimal insurance contract design, has a long history in the agricultural economics research. From the insurer's point of view, *i.e.*, the supply side of the crop insurance market, authors have identified three main reasons why insurance companies are likely to set too high premiums: moral hazard and adverse selection *e.g.*, Skees *et al.* (1997), Nelson and Loehman (1987), Quiggin *et al.* (1993), Glauber (2004) and Smith and Glauber (2012), on the one hand and the systemic nature of the risk on the other hand (Miranda and Glauber, 1997). From the farmer's point of view, *i.e.*, the demand side of the crop insurance market, it has been noted that farmers are likely to prefer cheaper ways of coping with production risk than insurance (Smith and Glauber, 2012).
As far as moral hazard and adverse selection are concerned, authors mainly assumed that they originate from the propensity of farmers to adopt 'fraudulent' behaviors vis-à-vis the insurer in order to exploit information asymmetries (Miranda and Glauber, 1997). In this article, we argue that such a situation is also likely to derive, at least to some extent, from the modeling of preferences of farmers (*i.e.*, 'non fraudulent' attitudes) towards risk.
In fact, the von Neumann and Morgenstern (1947) Expected Utility Theory (EUT) has been the dominant theoretical framework invoked in most previous articles to model the decision of risk-averse farmers to get insured or not. However, since the pioneering work of Kahneman and Tversky (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992), many empirical studies have confirmed that the Cumulative Prospect Theory (CPT) is a more adequate framework to represent agents' attitudes towards risk *e.g.* Tanaka *et al.* (2010), farmers being no exception (Galarza, 2009; Bougherara *et al.*, 2011; Godinho Coelho *et al.*, 2012; Bougherara *et al.*, 2012). CPT extends EUT in three respects. Firstly, risk aversion is detailed for gains and losses, that is, the dis-utility of a loss may be larger than the utility of a gain of the same absolute amount. Secondly, losses and gains are defined with respect to a threshold, the 'reference point', which is commonly set to zero for convenience but which is in fact likely to depend on the situation. Thirdly, agents 'distort' the probabilities for events to occur in their utility computation, even when having an objective knowledge of these probabilities. Empirically, people generally have been found to overestimate small probabilities and to underestimate high probabilities.[1]

[1]For instance, this would explain why some people do not like to travel by plane though the probability of a crash is very low while, symmetrically, some others do not spontaneously fasten their security belt when driving though the probability of an accident is much higher.

Here, we show that using the theoretical framework of CPT to model preferences towards risk may explain why at least some farmers do not contract insurance while they would be expected to do so under the assumption that their preferences follow the theoretical framework of EUT. To this end, we model the decision to contract an individual yield crop insurance for a sample of 186 farmers of the "Meuse" region located in the northeastern part of France, and investigate the policy implications of such an extended theoretical modeling framework.

The article is organized as follows. The first section presents the modeling framework. The second section describes the data used and the functional forms chosen while the fourth section reports the results. The last section concludes.

2 Modelling Framework

We consider N farmers who produce a unique and homogeneous good with an individual-specific yield $\tilde{y}_i$, where $i = 1, \ldots, N$. This yield is random because production is subject to exogenous shocks such as climatic events or pest attacks. In order to secure production against such risks, farmer i may decide to contract an individual yield crop insurance (IYCI) from a unique insurance company. The contract is defined as follows: if, at the end of the cropping season, the realized yield y_i is lower than a critical yield $y_i^* > 0$ defined in advance, he receives an indemnity $n(y_i)$, and nothing otherwise. Formally:

$$\tilde{n}(\tilde{y}_i) \equiv \max(y_i^* - \tilde{y}_i, 0) \tag{1}$$

where, following Miranda (1991) and the subsequent works by Smith *et al.* (1994), Skees *et al.* (1997) or Mahul (1999), $\tilde{n}(\tilde{y}_i)$, is a random variable expressed in the dimension of a yield, *i.e.*, in tons per hectare.

In order to be insured, farmer i has to pay a t/ha-equivalent premium ρ_i. We do not allow farmers to insure only a fraction of their area so that the decision to purchase the contract may be modeled through a set of binary variables d_i, where $d_i = 1$ when farmer i actually purchases the contract and $d_i = 0$ when he actually does not. We do not let the farmer elect the critical yield y_i^*. Each farmer therefore gets the random net yield:

$$\tilde{y}_i^{net} = \tilde{y}_i + \tilde{n}(\tilde{y}_i) - \rho_i. \tag{2}$$

Miranda (1991), Smith *et al.* (1994) and Skees *et al.* (1997) assumed that, through insurance, farmers seek to minimize the variance of their net yield or, equivalently, to maximize their yield risk reduction, as measured by the difference between the variance of the yield and the variance of the net yield. Mahul (1999) and Bourgeon and Chambers (2003) considered rather that the objective of farmers is to maximize the expected utility stemming from their net yield. We adopt a third approach which is also based on the (expected) utility maximization but consists in viewing the maximization program of the farmer as a lottery choice. Actually, each farmer faces the following two lotteries:

- *'Insurance lottery'*: if the farmer contracts, he faces the following outcomes:
  - if $y_i < y_i^*$, the net yield he expects is $y_i^* - \rho_i$
  - if $y_i \geq y_i^*$, the net yield he expects is $\overline{y}_i - \rho_i$
- *'Non-insurance lottery'*: if the farmer does not contract, he faces the following outcomes:
  - if $y_i < y_i^*$, the net yield he expects is $\underline{y}_i$
  - if $y_i \geq y_i^*$, the net yield he expects is $\overline{y}_i$

where $\underline{y}_i \equiv \mathrm{E}(\tilde{y}_i | y_i < y_i^*)$ and $\overline{y}_i \equiv \mathrm{E}(\tilde{y}_i | y_i \geq y_i^*)$. In both lotteries, the 'unfavorable' outcome, *i.e.*, $y_i < y_i^*$, happens with the probability q and the 'favorable' outcome, *i.e.*, $y_i \geq y_i^*$, happens with the probability $1 - q$.

In order to set up a general enough framework to encompass both the EUT and the CPT, we assume that: i) there exists an individual-specific value function $\nu_i(y) : \mathbb{R} \rightarrow \mathbb{R}$ which maps net yields into the utility space, and; ii) farmers, when evaluating their utility, distort the cumulative probability of yields through an individual specific weighting function $\psi_i(q) : [0, 1] \rightarrow [0, 1]$. Then, the expected utilities of the above lotteries are given by:

- *'Insurance lottery'*: $\mathrm{E}\big(U_i^I(\rho)\big) = \psi_i(q)\nu_i(y_i^* - \rho_i) + \psi_i(1 - q)\nu_i(\overline{y}_i - \rho_i)$
- *'Non-insurance lottery'*: $\mathrm{E}\big(U_i^N\big) = \psi_i(q)\nu_i(\underline{y}_i) + \psi_i(1 - q)\nu_i(\overline{y}_i)$

Under this setting, farmer i will decide to purchase the insurance as long as the 'insurance lottery' will provide him with an expected utility greater than or at least equal to the 'non-insurance lottery':

$$d_i = 1 \quad \Leftrightarrow \quad \mathrm{E}\big(U_i^I(\rho_i)\big) \geq \mathrm{E}\big(U_i^N\big) \tag{3}$$

For each farmer, we can then find the threshold premium $\hat{\rho}_i$ which leaves him indifferent between both lotteries, *i.e.*, $U_i^I(\hat{\rho}_i) = U_i^N$. This represents his willingness-to-pay (WTP) for transferring his risk to the insurer. Equation (3) can then be rewritten as:

$$d_i \times \Big(\mathrm{E}\big(U_i^I(\rho_i)\big) - \mathrm{E}\big(U_i^I(\hat{\rho}_i)\big)\Big) \geq 0 \tag{4}$$

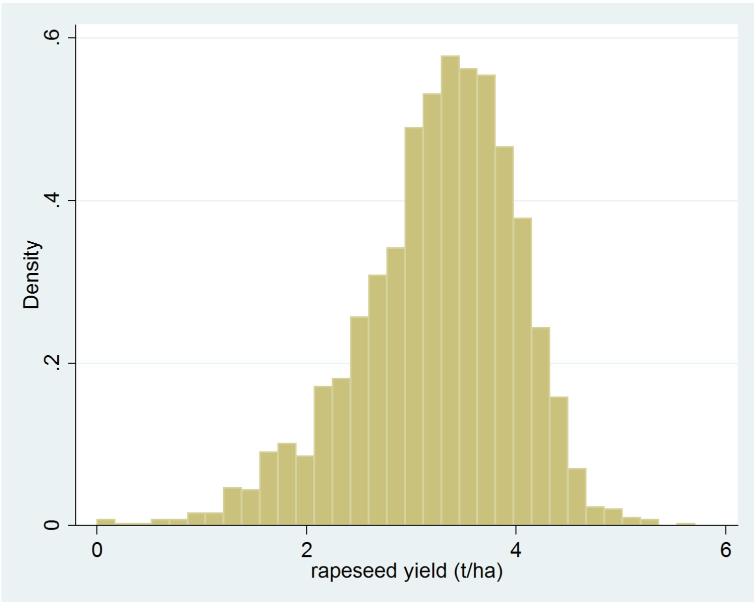
3 Empirical Study

In this section, we describe and provide summary statistics for the data used in the article. We also present the functional forms chosen so that the specification can encompass both the CPT and EUT framework.

3.1 Data

We used individual-level data for a sample of French farmers originating from the NUTS3 region Meuse.[2] It was a balanced panel of 186 farmers observed over $T = 12$ years for the period 1992-2003 ($186 \times 12 = 2232$ observations). Though the database included 10 crops, we focused on rapeseed because, according to planted area, it was one of the major crops cultivated by farmers in our sample, and because it was produced every year by all of them.
Summary statistics for our sample show that the average acreage of rapeseed was fairly stable from year to year, amounting to a little more than 30 ha, or around 15% of the total utilized area of farms (Table 1). There was no clear trend in rapeseed yield, neither at the individual nor at the average level, so it was not necessary to detrend those yields. As shown in Figure 1, the distribution of yields for rapeseed over the whole sample and the whole period was negatively skewed, which is consistent with evidence found by other authors, *e.g.*, Skees *et al.* (1997). A detailed review of the yield data showed that it was zero in three cases only, corresponding to three different farmers, two of them appearing in 1996 and one in 2002.

Figure 1: Distribution of yields in the sample (all years)



Note: Source ADHEO, 1992-2003 - authors' calculation

[2]The Nomenclature of Territorial Units for Statistics (NUTS) is a hierarchical breakdown system for the European Union territory (see http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:NUTS). France consists of 101 NUTS3 units which correspond to the administrative areas 'départements', five of them being overseas.

Table 1: Summary Statistics

Year	Obs.	Total area (ha)				Rapeseed area (ha)				Rapeseed yield (t/ha)			
		Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
1992	186	185.94	92.92	60.80	733.00	30.35	22.63	2.00	160.00	2.33	0.68	0.27	3.86
1993	186	198.19	96.61	77.11	720.38	28.15	21.23	1.00	127.50	3.42	0.55	1.30	4.70
1994	186	202.73	97.67	77.56	717.83	29.93	24.94	4.67	214.80	2.77	0.67	0.98	4.38
1995	186	205.34	97.76	77.56	718.10	27.44	22.92	0.93	156.30	3.67	0.58	0.78	5.71
1996	186	207.82	98.21	77.56	717.97	30.66	23.82	0.80	190.44	3.51	0.61	0.00	4.91
1997	186	210.25	99.81	77.56	717.96	34.04	23.81	4.40	162.55	4.02	0.41	2.12	4.85
1998	186	211.08	101.10	77.54	717.30	36.89	25.21	5.86	186.69	3.62	0.44	2.00	4.58
1999	186	211.71	101.68	77.54	716.71	35.39	27.31	2.91	232.80	3.70	0.52	2.54	5.20
2000	186	214.71	102.92	77.54	716.24	32.01	24.05	2.36	190.74	3.26	0.56	1.21	5.30
2001	186	216.04	102.26	77.54	707.92	31.10	22.32	3.52	157.90	2.46	0.63	0.74	4.40
2002	186	215.92	101.82	77.53	707.92	29.20	22.70	0.90	156.09	2.94	0.60	0.00	4.26
2003	186	217.52	103.83	76.34	707.92	27.32	18.83	0.69	113.90	3.34	0.54	1.40	5.22
all years	2232	208.10	99.90	60.80	733.00	31.04	23.53	0.69	232.80	3.25	0.76	0.00	5.71

Note: Source ADHEO, 1992-2003 - authors' calculation

3.2 Functional forms

We used the CPT specification proposed by Tversky and Kahneman (1992) both for $\nu_i(y)$ and $\psi_i(q)$, for any yield y and probability q:

$$\begin{aligned} \nu_i(y) &= \begin{cases} \left(y - y_i^0\right)^{\alpha_i} & \text{if} \quad y \geq y_i^0 \\ -\lambda_i\left(-y + y_i^0\right)^{\alpha_i} & \text{if} \quad y < y_i^0 \end{cases} \\ \psi_i(q) &= \frac{q^{\gamma_i}}{\left(q^{\gamma_i} + (1-q)^{\gamma_i}\right)^{\frac{1}{\gamma_i}}} \end{aligned} \tag{5}$$

where y_i^0 is an individual-specific reference yield which defines the gain ($y \geq y_i^0$) and loss ($y < y_i^0$) domains for each farmer i, and α_i, λ_i and γ_i are individual-specific parameters characterizing the attitude of farmer i towards risk: α_i is the risk aversion coefficient, λ_i is the loss aversion coefficient and γ_i is the probability distortion coefficient.

This specification is general enough to encompass both CPT and EUT since, if we set $y_i^0 = 0$, $\lambda_i = 1$ and $\gamma_i = 1$, it reduces to the standard von Neumann and Morgenstern (1947) formulation of EUT.

4 Results

The individual-specific critical yield was set for each farmer to the average yield, *i.e.*, $y_i^* \equiv \frac{1}{T}\sum_{t=1}^{T}\tilde{y}_i(t)$. From this definition and the observed yields, we deduced the empirical individual-specific conditional yields $\underline{y}_i$ and $\overline{y}_i$, and the probability q of an unfavorable outcome as the empirical average probability of experiencing a yield loss:

- $\underline{y}_i = \frac{\sum_{i=1}^{T}\tilde{y}_i^-(t)}{\sum_{i=1}^{T}t^-}$, with $\tilde{y}_i^-(t) = \tilde{y}_i(t)$ and $t^- = 1$ if $\tilde{y}_i(t) < y_i^*$ and zero otherwise;
- $\overline{y}_i = \frac{\sum_{i=1}^{T}\tilde{y}_i^+(t)}{\sum_{i=1}^{T}t^+}$, with $\tilde{y}_i^+(t) = \tilde{y}_i(t)$ and $t^+ = 1$ if $\tilde{y}_i(t) \geq y_{i^*}$ and zero otherwise.

In turn, the probability q of an unfavorable outcome was computed at the sample level as the empirical average probability of experiencing a yield loss:

- $q = \frac{1}{N}\frac{1}{T}\sum_{i=1}^{N}\sum_{t=1}^{T}p_i^-(t)$, with $p_i^-(t) = 1$ if $\tilde{y}_i(t) < y_i^*$ and zero otherwise.

We then used Equation (1) to compute the indemnities each farmer would have received over the studied period conditional on the definition of y_i^*.

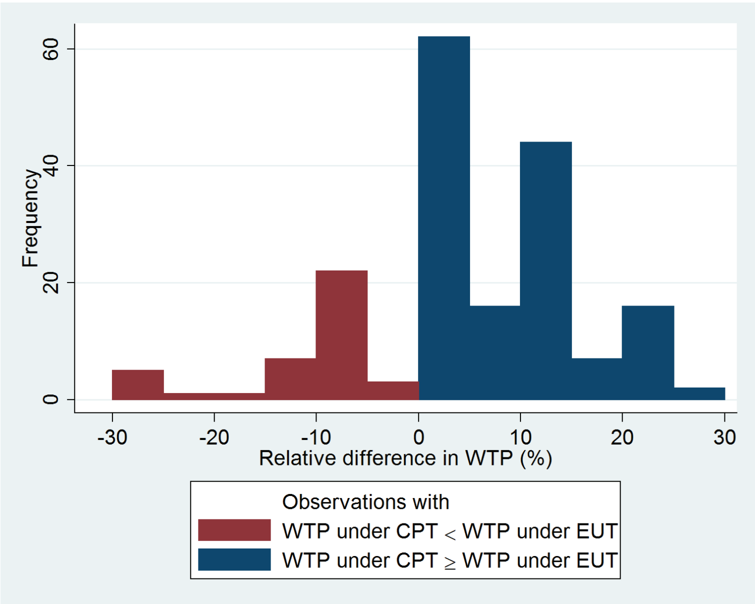
Table 2 reports descriptive statistics for the resulting reference yields, conditional yields and expected indemnities. The probability of unfavorable outcome q was found to be 0.442. In order to compute the WTP, $\hat{\rho}_i$, for each farmer under both theoretical frameworks for risk preferences, EUT and CPT, values for the parameters in Equation (5) had to be set. We assumed that farmers are homogeneous, *i.e.*, $\alpha_i = \alpha$, $\lambda_i = \lambda$ and $\gamma_i = \gamma$ for all i, and took the values from Gassmann (2014), who experimentally estimated them on a different sample of 197 French farmers located near the NUTS3 region Meuse. He concluded that, for this sample, CPT is a more likely assumption than EUT to model preferences, *e.g.*, Bougherara *et al.* (2012).

Table 2: Summary Statistics for the Reference Yield, Conditional Yields, and Expected Indemnity

	obs.	mean	std. dev.	min	max
Reference yield y_i^* (t/ha)	186	3.25	0.31	2.36	4.07
Unfavorable conditional yield $\underline{y}_i$ (t/ha)	186	2.61	0.42	1.09	3.45
Favorable conditional yield $\overline{y}_i$ (t/ha)	186	3.74	0.31	2.91	4.56
Expected indemnity ρ_i (t/ha)	186	0.27	0.07	0.14	0.50

Note: Source ADHEO, 1992-2003 - authors' calculation

Figure 2: Distribution of farmers' WTP under EUT *vs.* CPT



Note: Source ADHEO, 1992-2003 - authors' calculation

Table 3 shows that, according to Gassmann's (2014) findings, farmers in this region are risk averse ($\alpha < 1$ under both theoretical frameworks) and that, under CPT, they are loss averse ($\lambda > 1$), overweight lower probabilities and underweight higher probabilities ($\gamma < 1$). It appears that due to the particular value of γ, on the one hand, the unfavorable-outcome probability q is only slightly (downside) distorted, since $\psi_i^{\gamma=0.818}(q = 0.442) = 0.440$ (-0.5%), while, on the other hand, the favorable-outcome probability $1 - q$ is a bit more (downside) distorted, since $\psi_i^{\gamma=0.818}(1 - q = 0.558) = 0.532$ (-4.7%). Finally, under CPT, we set the reference net yield y_i^0

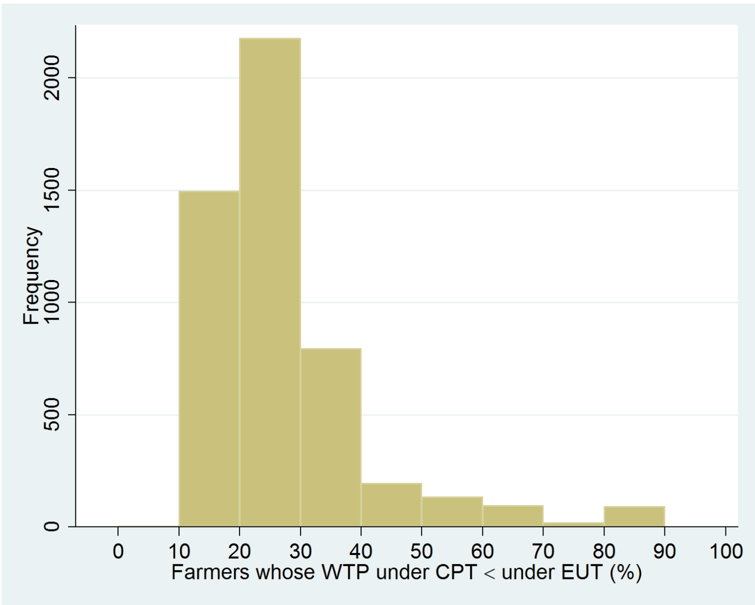
to the average yield y_i^*, assuming that, for each farmer, a net yield below (respectively above) the average yield defines a loss (gain).

Table 3: Preference Parameters under EUT and CPT

	EUT		CPT	
	Coef.	Std. Err.	Coef.	Std. Err.
Risk aversion (α_i)	0.574	0.023	0.619	0.025
Loss aversion (λ_i)	1.000	n/a	1.385	0.090
Probability distortion (γ_i)	1.000	n/a	0.818	0.016

Note: 'n/a' means 'not applicable'. Source: Gassmann (2014, 51, Table 2.4) for EUT and Gassmann (2014, 53, Table 2.5, model 1a) for CPT

Figure 3: Sensitivity analysis with respect to preferences parameters (5,000 replications – see text)



Note: Source ADHEO, 1992-2003 - authors' calculation

Table 4 reports some descriptive statistics for the WTP obtained under both risk preferences frameworks. It shows that the average WTP under EUT is 0.305 while it is 0.310 under CPT. That is, on average, if we consider that preferences follow the CPT framework, our sample of farmers is ready to contract at a higher premium than they are expected to if one assumes that preferences are EUT-like. However, as is visible from the maximum values in Table 4 and is confirmed by Figure 2, this is only true on average: for 39 out of the 186 farmers in the sample, the WTP under CPT is actually lower than that under EUT. This means that, neglecting that risk preferences should be modeled through the CPT, 21% of our farmers would actually not contract insurance if they were proposed a premium consistent with EUT preferences. This supports our case that ignoring the superiority of the CPT with respect to the EUT may explain why some farmers contract less than expected.

Table 4: Summary Statistics for the WTP (in t/ha) under EUT and CPT

	obs.	mean	std. dev.	min	max
EUT	186	0.305	0.115	0.113	0.771
CPT	186	0.310	0.089	0.140	0.642

Note: Source ADHEO, 1992-2003 - authors' calculation

Yet this result could have been contingent to the particular combination of parameters we chose. We therefore performed a Monte-Carlo analysis to test its robustness. WTP computations were thus replicated 5,000 times by drawing the parameters in the normal distributions deriving from their estimators as reported in Table 3 (Figure 3). It appeared that for one half of the replications, the percentage of farmers whose WTP under CPT was actually lower than that under EUT lies between 20% (first quartile) and 30% (third quartile), with the median being at 22%. While our above conclusion thus appears quite robust to the combination of parameters, it is worth noticing that, as Figure 3 shows: (i) this percentage was never under 8% for any replication, and (ii) it could even reach quite high values, with 7% of the replications leading to a percentage above 50%.

When considering again the central values chosen for the parameters, the largest absolute WTP difference for those whose WTP under CPT is lower than their WTP under EUT amounts to 0.166 (for an WTP under EUT at 0.604 and a WTP under CPT at 0.438). From a policy perspective, this leads to conclude that the EUT-premium would have to be subsidized at a 27.5% rate if all farmers were to be encouraged to contract.

5 Conclusion

Kahneman and Tversky's Cumulative Prospect Theory (CPT) is better suited for representing preferences towards risk in place of the traditional von Neumann and Morgenstern's Expected Utility Theory (EUT). In this article, we have shown that neglecting such demand characteritics may explain why some farmers do not contract crop insurance policies as much as they are expected to do.

Though we are confident that this general qualitative conclusion would remain valid, the model and empirical analysis presented here could be extended in three respects. Firstly, we have assumed that all farmers in the sample are homogeneous with respect to their preferences towards risk, *i.e.*, that they share the same parameter values. It would certainly be more relevant to introduce individual heterogeneity in these preferences; the extension of the structural estimation proposed by Bougherara *et al.* (2012) towards this direction, as proposed by Gassmann (2014), is a first step to do so. Secondly, we have followed the modeling framework proposed by Miranda (1991) and extended by Mahul (1999) which bases farmers decisions on the expected net yield. It would theoretically be more sound to express the model in terms of expected profit, which would imply, as Chambers and Quiggin (2002) note, to explicitly introduce the production function in the model. Thirdly, we have modeled the choice of an individual yield crop insurance contract. It would be desirable to turn to the modeling of an area yield crop insurance, which, as several authors like Miranda (1991) show, is less sensitive to adverse selection and moral hazard issues.

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