Farmers' preferences for diversification crop attributes

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Abstract:

Crop acreage diversification is a major issue in the new CAP reform. In parallel, cash crop farmers with intensive short rotations face yield stagnancy and natural resources deterioration. Farmers have to move towards more diversified cropping systems.. This paper analyses how farmers' preferences for a diversification crop attributes can influence their adoption of this crop. A choice modelling approach is built and conducted among specialized cereal farms in Southwestern France. Fifteen virtual diversification crops differentiated by the level of their attributes are tested. Results show that non-monetary attributes, such as agronomic conditions, play a key-role in the adoption. Farmers' preferences for agronomic attributes are even stronger when they have already faced difficulties in their crop management. Farmers also display heterogeneous preferences across the crop attributes.

Keywords: stated preferences, adoption behavior, choice modelling, crop diversification

Code JEL: Q12, Q16, C35, C9

Introduction:

The global grain productivity has known a considerable increase in the past century due to technical improvement in chemistry, machinery and crop varieties. In favorable climate-soil areas, farm specialization in cereals with short rotations allows economies of scale and farmers are skilled in implementing the crop management to reach high levels of yield. The spread of specialized cropping systems in cereal production areas implies agronomic difficulties in the long run. No alternation of crops leads to a reduction of soil fertility and an intensive use of mineral fertilizers. Furthermore, pest and weed resistances increase due to a recurrent use of the same type of active molecule. In parallel, European regulation tends to limit the negative impact of farming activities on natural resources. A restrictive policy framework on pesticide use jointly with CAP-greening and cross-compliance incentives (notably, acreage should be composed of three crops at least) could lead farmers to move towards more diversified systems. In Southwestern France, farmers face agronomic and regulatory impasses due to a large implementation of the durum wheat on sunflower short rotation. Agronomists point out the current intensive cropping system reaching yield stagnancy. Farmers need to redesign the cropping system by introducing new crops to lengthen their rotation.

For specialized grain farmers, introducing a new crop in the rotation is considered as the adoption of a new agricultural technology. Lengthening the rotation implies uncertainties for farmers since they lack experience or information on the agronomic potential of the new crop in their own field. Based on their knowledge and production conditions, farmers also develop preferences. Farmers' characteristics, farm production context or farm structure have been widely studied as determinant of farm technology adoption (Baffoe-Asare et al. 2013; Feder et al. 1985; Knowler and Bradshaw 2007; Prokopy et al. 2008). By accounting for famer's risk preferences, it has been showed that a technology perceived as riskier might be rejected (Hellerstein et al. 2013; Reynaud and Couture 2012). In consumer theory, individuals have preferences for the products characteristics . Lancaster's theory assumes that the global utility of a product is the sum of the utilities of each attribute composing this product (Lancaster 1966). Farmers are considered as consumers of agricultural technology and develop preferences for the characteristics of the technology (Useche et al. 2013). Stated preferences methods enable evaluating the potential heterogeneity of the demand for a new technology and the weight of each attribute in the adoption decision. Conjoint analysis and the related choice-modelling approaches have been used for many years in marketing or environmental economics research to evaluate consumer's preferences for product attributes (Birol et al. 2006; Hanley et al. 2001). This method allows to jointly measure the monetary values of the attributes (Alriksson and Öberg 2008). In this paper, survey-based methods are built up to face farmers with the choice of a new crop that they still have not implemented on their field. Thus, a discrete choice modelling approach is employed to evaluate farmers' preferences for various attributes of a diversification crop and to evaluate their willingness to pay for the different crop attributes.

1. Literature on adoption behavior

1.1 Farmers' adoption behavior of agricultural technology

When farmers implement a new technology on the farm they face new uncertainties about yield potential, crop management strategies or the prices expected. The subjective expected utility (SEU) of Savage is a relevant conceptual framework to analyze the adoption behavior in agricultural economics (Savage 1972). This framework is based on the assumption that choices under uncertainty are guided by individuals' perceptions that subjectively distort the probabilities of risky events. Individuals choose the alternative that maximizes their perceived utility (Marra et al. 2003). Many studies analyze how farmer's heterogeneity affects the adoption behavior. The analysis of the determinants of agricultural technology adoption is a vast research topic and some recent surveys propose a focus on a country or a technology (Knowler and Bradshaw 2007; Mercer 2004; Prokopy et al. 2008). However, only a little number of determinants is admitted to consistently and unambiguously affect adoption behavior such as education, information, liquidity constraints or farm size (Feder and Umali 1993). Due to the specificity of farm context and of the technology studied, a large panel of socio-economic, institutional or agronomic determinants can play a role in the adoption choice (Prokopy et al. 2008).

Quantitative methods that allow a direct assessment of farmers' perceptions enable economists to directly integrate unobservable perceptions in the analysis (Machina and Schmeidler 1992; Norris and Kramer 1990). As farming activity is highly subject to risk, risk perceptions and farmers' subjective assessment of the technology are known as a major break in the adoption choice. Smale *et al.* show that when farmers perceive a high level of yield risk on their current production the adoption of high-yield-potential-varieties increases (Smale et al. 1994). A crop perceived as less risky is also more easily adopted than another crop with identical expected profit (Adesina and Baidu-Forson 1995). In addition to the risk linked to the implementation of a new technology on the farm, farmers also differently perceive the characteristics of the technology itself. Based on their perceptions and beliefs farmers develop individual preferences for the attributes of the innovation. Sociologists firstly underlie the role of perceptions in the adoption behavior (Kivlin and Fliegel 1967). Studies on agricultural technology adoption focus on the perceived relative advantage in terms of efficiency (Abdulai and Huffman 2014; Tosakana et al. 2010), profitability (Pandit et al. 2011; Paudel et al. 2008) and adaptability (Gillespie et al. 2007).

1.2 Farmers' preferences

Consumer theories have brought to light the significance of product characteristics in consumer demand. Thus, as consumers of agricultural technology, farmers develop preferences for the characteristics or attributes of the technology (Useche et al. 2013). Stated preferences methods enable studying the unobservable determinants of the technology adoption such as the preferences for the technology attributes. The underlying choice model is the random utility framework (Train 2009). The perceived utility of an individual for a product is the sum of two components: a determinist component and an unobservable one. The determinist and observable part of the utility function is defined as a function of the product attributes and of the individuals' characteristics. The stochastic and unobservable part contains the error term that captures unobservable factors influencing utility (Walker and Ben-Akiva 2002). Stated preferences and the related choice modelling methods have been used for many years in marketing research to evaluate consumer preferences for different products attributes. The number of applications in the field of environmental and agricultural economics has grown (Adamowicz et al. 1998; Alpizar et al. 2001; Birol et al. 2006; Hanley et al. 1998). The method measures how a respondent states that he will react in a given situation. Choice modelling methods mimic a choice situation and respondents choose, rate or rank the alternatives. By varying the levels of the attributes presented to the respondents, the preferences structure of the respondents is revealed (Alriksson and Öberg 2008). Attributes can be measured jointly. The willingness to pay or to accept corresponding to each attribute can be derived from the evaluation of respondents' preferences (Louviere et al. 2000).

Farmers are consumers of agricultural technology and their behavior can be approach using the Lancaster theory. Based on a choice modelling approach and the underlying random utility framework, farmers' preferences for the characteristics of a hypothetical diversification crop are revealed. Observed and unobserved heterogeneity in preferences is also analyzed within the sample. To evaluate farmers' sensitivity to the crop attributes, individual willingness to pay are calculated.

2 Design of a choice modelling approach

1.1 Design and presentation of the questionnaire

A questionnaire is built in two parts. The first part collects data on farmers' characteristics, farm structure and economic variables (gross margins, income, debt ratio). Also, farmers' perceptions and difficulties concerning their current management practices are collected. Farmers' subjective probability distributions of sunflower and durum wheat yield and price are collected using the visual impact method (Hardaker et al. 2004). The second part of the questionnaire is the choice modelling experiment. It aims at assessing farmers' preferences for the attributes of a diversification crop. Farmers face repeated crop acreage choices considering fifteen virtual diversification crops.

1.2 Choice modelling design: attributes, levels

In this questionnaire the Choice Modelling (CM) has a twofold objective i) hierarchize farmer's preferences for the crop attributes and, ii) analyze the observed and unobserved heterogeneity of preferences within the sample. Based on these results farmers' willingness to pay is quoted to quantify the weight of each attribute in the adoption decision and their variability between farmers.

Thus, the CM design consists in defining a set of attributes and their levels to characterize in a credible and consistent way a diversification crop. Several focus groups and interviews have been organized in order to select consistent attributes. Eight farmers, four public researchers from INRA[1], six experts from Arvalis[2] and seven cooperative experts have been consulted. This exploratory step resulted in the selection of five relevant attributes divided in two categories. The "crop intrinsic" attributes: gross margin, cropping season and technicality of the crop management and the "crop rotational effects" attributes: nitrogen restitution and effect on pesticide use for the next crop. Since durum wheat is the main interest crop in this rotation, due to the high level of gross margin, the diversification crop is assumed to be a previous crop of wheat. Table 1 presents the attributes and their associated levels. To limit the hypothetical bias, farmers are put in a common situation they face every year: the acreage choice. Individuals are given fifteen hypothetical diversification crops, chosen based on an experimental plan, and then asked to choose whether they wish to insert this crop in the rotation. Each crop is described by five attributes that take on different levels (Table 1).

Table 1: Attributes of the choice modelling

Attribute	Description	Levels
Nitrogen restitution (*Nitro*)	Number of nitrogen units available for the durum wheat (UN)	0 / 25 / 50
Rotational effect on pesticide use (*Pest*)	Number of additional pesticide treatments comparatively to the sunflower (treatment)	-1 / 0 / +1
Gross margin (*Margin*)	Gross margin per hectare (€/ha)	325 / 400 / 475 / 525 / 600
Cropping season (*Season*)	Cropping season of the crop	Summer / Winter
Level of technicality of the cropping management (*Tech*)	Technicality of the crop management including the monitoring requirement and the number of technical operation	Low technicality (ex: sunflower) Medium technicality (ex: wheat) High technicality (ex: rapeseed)

3. Choice models

The adoption choice for a diversification crop is reduced to choose between alternatives. Alternatives are defined by several attributes. Relying to the random utility framework, the unobserved utility of an individual *i* is composed of two components (Equation 1):

$$V_{ij} = U_{ij} + \varepsilon_{ij}$$

(Equation 1)

[1] French National Institute of Agronomic Research
[2] Technical Institute specialized in plants

$V_{ij}$is the unobserved utility of a *j* good for individual *i*. U_{ij} is the determinist and observable part of the utility function and defined as a function of the *j* attributes of the good and the characteristics of the individual. The stochastic part ε_{ij} describes the error term that captures factors that influence utility but are not observable. Individual are assumed to choose the alternative that maximize their utility.

3.1 Logit model for binary responses

The observed outcome of the choice modelling is a binary answer of adoption or reject. The logit model allows evaluating the adoption probability of the good *j* in each choice situation. The determinist part of the indirect utility is specified as a linear index of the attributes and the individual characteristics express in Equation 2.

$$V_{ij} = U_{ij} + \varepsilon_{ij} = \beta X_{ij} + \varepsilon_{ij}$$

(Equation 2)

Where X_{ij}denotes a vector of explanatory variables describing the good *j* and the respondent *i* and β is the corresponding vector of coefficients. The probability for an individual *i* of choosing the good *j* rather than the current situation *h* is in Equation 3.

$$p_{ij} = P[V_{ij} > V_{ih}]$$

(Equation 3)

In the logit model , the probability of adoption of the good *j* by individual *i* follows a logistic distribution (Equation 4). In addition, the error term is supposed independent and identically distributed (iid).

$$p_{ij} = \frac{e^{\beta X_{ij}}}{1 + e^{\beta X_{ij}}}$$

(Equation 4)

3.2 Random parameter logit

The random parameter logit (RPL) or mixed effects logit is a more flexible model which accounts for unobserved and unconditional heterogeneity within individuals. The utility function is the same as the logit model (Equation 2) but the coefficient vector β_i varies over the respondents (Equation 5):

$$V_{ij} = \beta_i X_{ij} + \varepsilon_{ij}$$

(Equation 5)

Both β_i and ε_{ij} are unobservable in the latter formulation. The random component ε_{ij} is assumed to be a type I extreme value distribution and independent of β_i and X_{ij}. The coefficient vector β_i is a random variable of density function $f(\beta_i|\theta^*)$ with θ^* the true parameters of this distribution (Train 2009). The conditional probability on β_i follows a logistic distribution (Equation 6).

$$P\left[V_{ij} > V_{ih} | \beta_i\right] = \frac{e^{\beta_i X_{ij}}}{1+e^{\beta_i X_{ij}}}.$$

(Equation 6)

The probability p_{ij} that individual *i* adopt the good *j* can be expressed by (Equation 7):

$$p_{ij} = \int P\left[V_{ij} > V_{ih} | \beta_i\right] f(\beta_i | \theta^*) d\,\beta_i$$

(Equation 7)

3.3 Marginal willingness to pay (WTP)

The marginal willingness to pay (WTP) is equivalent to the individual's surplus for a change in the level of an attribute. It can be derived from the two types of models presented (logit and RPL) (Adamowicz et al. 1994). It represents the marginal monetary value of an attribute. The marginal WTP is defined as the negative ratio of the marginal utility of each attribute over the marginal utility of the monetary attribute (Equation 8):

$$WTP = -\frac{\beta_{attribute}}{\beta_{monetary}}$$

(Equation 8)

4. Empirical analysis

4.1 Farmers selection and survey procedure

The questionnaire was beforehand reviewed by agricultural scientists, cooperative stakeholders and farmers. The final version was tested thought a sample of 8 farmers to check respondents' understanding of the survey. The list of farmers finally surveyed was provided by cooperatives. Farmers were randomly selected considering two selection criteria. Firstly, the farm is located in a traditional area of production of durum wheat on sunflower rotation. Secondly, at least 50% of their cropping area is occupied by this rotation. This sampling procedure insures that farmers are principally grain farmers but also allows farm diversity within the sample. The survey was carried out with 100 farmers from January to July 2014 using face to face interviews or meetings without interactions between individuals. Both type of interviews are conducted following the same sequences. In introduction, the objective and progress of the survey is presented. It is specified that the data are anonymous and not available for the cooperative, but only for the research team. Thus, farmers individually answer directly on the paper. Finally the survey is concluded with an oral debriefing open to farmers' questions about the survey. The average duration of the whole interview is about 2 hours.

Table 2 reports descriptive statistics of the sample. Concerning the farmers' characteristics the mean age of farmers is 50 years old, which is the same as the regional mean. Respondents are farmers for more than 20 years and most of them do not have a secondary school-leaving degree (Baccalaureate). More than one third of the farmers has an off-farm employment[3]. The mean total agricultural area is over 150 ha while it is about 100 ha in the region. Concerning the production context, data show that half of the farms have sloping plots. Farmers face on average 1.5 recurrent difficulties on their farm within the following list: soil fertility, soil structure, weed pressure, crop pest and disease, water management (drought or excess), labor management, crop management technicality. The current level of durum wheat gross margin is in line with the regional average (770€/ha while 777€/ha in the Midi-Pyrenees region) even if the standard deviation is high (230€/ha) showing a high heterogeneity within the sample. Finally, most of the farmers are cooperative members. Concerning the experimentation, 60% of farmers have already done experimentation on their field in the past. This variable gathers any type of experimentation (pesticide, crops, practices *etc.*) supervised by the cooperative or researchers.

Table 2: Descriptive statistics of the sample

	Description	**Sample Mean (std dev)**
Farmer characteristics		
Age	Farmer's age in years	50.1 (11.8)
Education	= 1 if the farmer has baccalaureate and 0 other wise	0.3 (0.4)
Experience	Farming experience of the farmer in years	22.1 (11.9)
Household size	Number of household dependent members	2.6 (0.8)
Off farm work	= 1 if the farmer works off-farm and 0 other wise	0.4 (0.5)
Farm characteristics		
Total land (hectares)	Total land size of the farmer	151.4 (81.2)
Working unit	Number of workers on the farm (farmer included)	1.8 (1.7)
Agronomic difficulties	Number of recurrent agronomic difficulties	1.5 (1.9)
Slope	= 1 if sloping plot 0 other wise	0.5 (0.5)
Wheat gross margin	Farmer current gross margin in durum wheat	769.7 (237.9)
Information		
Coop member	= 1 if the farmer is a coop member 0 other wise	0.9 (0.1)
Experiments	= 1 if the farmer do or have done experiment on the farm	0.6 (0.5)

4.2 Farmers' preferences for the crop attributes

The logit regression enables analyzing dichotomous choices. As a starting point, the indirect utility V_{ij} derived from the adoption of crop *j* by farmer *i* is assumed to be a linear function of all attributes. The basic specification of the indirect utility becomes (Equation 9):

$$U_{ij} = \alpha Margin + \gamma Nitro + \delta Tech + \zeta Pest + \eta Season$$

(Equation 9)

[3] Data from extension services report about 26% of off-farm employment in the region

Where *Tech*, *Pest* are variables for the technicality and the effect on pesticide use respectively. *Tech* and *Pest* have three levels describe in the Table 1. The reference crop is sunflower with attributes levels: *0 effect* on the *Pest* and *medium technicality* of the crop management (*Tech*). Based on these reference levels, for the analysis, two dummy variables are constructed for each variable. The *Season* attribute is a dummy variable equal to 1 for summer and 0 for winter. Margin and Nitro are quantitative variables. Margin is the annual gross margin expressed in hundred euros per hectare and Nitro is the level of nitrogen restitution for the next crop expressed in units of nitrogen per hectare.

The estimates of the logit model with the basic specification of the indirect utility function are presented in the first column of Table 3. The overall fit of the model measured by the MacFadden's r^2 is 0.19 and the model correctly predicts 72% of choices. The hypothesis of all coefficients equal to zero is rejected at 1%. Most of the coefficients are significant and all the signs are as expected. The cropping season (*Season*) is the only not significant attribute estimate. The gross margin (*Margin*) and the pest management (*Pest*) attributes estimates are highly significant (p-values $<10^{-4}$). Thus, in the same line as the recent literature, farmers' preferences for the agronomic attribute have the same level of significance as for the monetary attribute. As expected, the monetary attribute estimate, the gross margin, is positive. At the opposite, the requirement of an additional treatment negatively affects the adoption. Farmers with short rotation are exposed to weed and pest resistances due to recurrent treatments in the field which entail yield stagnation. Thus, farmers avoid crops that conduct to increase the number of treatments.

The technicality of the cropping management (*Tech*) appears as highly significant in farmer adoption behavior (p-value of 0.004). High technicality in the crop management implies more workload and many technical operations, but also a higher yield risk. Therefore, farmers probably prefer crops with a lower level of technicality. Results also show that the nitrogen restitution (*Nitro*) positively affects the adoption of a diversification crop. Indeed, nitrogen is a limiting factor for grain production especially for durum wheat in short rotation. An increase in nitrogen restitution can reduce fertilization costs for farmers This is consistent with the previous result about the gross margin attribute showing that farmers prefer more profitable crops.

In order to capture the observed heterogeneity in the sample a logit model is estimated where several farm-specific characteristics interact with the attributes of the diversification crop. The indirect utility function becomes (Equation 10):

$$\begin{aligned} U_{ij} = {} & Margin\,(\alpha_1 + \alpha_2 * Z_i) + Nitro\,(\gamma_1 + \gamma_2 * Z_i) + Tech\,(\,\delta_1 + \,\delta_2 * Z_i) \\ & + \,Pest\,(\zeta_1 + \zeta_2 * Z_i) + Season\,(\,\eta_1 + \,\eta_2 * Z_i) \end{aligned}$$

(Equation 10)

Z_i is a vector of farm characteristics. After testing several possible interactions, seven interactions have been selected based on their significance. The final model is presented in the second column of the Table 3. The interaction logit model exhibits a rather high fitness with a Mac Fadden r^2 of 0.23 (Hensher and Johnson 1981). The model correctly explains 75% of the choices. Concerning the preferences for the attributes, the gross margin, the additional treatment and the high technicality significantly affect the adoption in the same way as the basic specification model.

The interactions reveal that individual characteristics affect farmers' sensitivity to the diversification crop attributes. Firstly, the gross margin attribute interacts with two farm characteristics. The effect of the gross margin significantly decreases with the farmer's current level of durum wheat gross margin (*Margin X Wheat GM*). Thus, farmers with a high level of current wheat gross margin probably can afford adopting less profitable crops. Furthermore, farmers who partially insure their income with production contracts less value the gross margin of the diversification crop (*Margin X Contract*).

Not surprisingly, crops requiring a low level of technicality are preferred by farmers that express a higher number of difficulties in their farm (*Low Tech X Agro. Diff*). In the same line, farmers that already have disease problems on the sunflower prefer crops with a lower number of treatments (Pest -1 X Sunflow. Disease).

The *Nitro* attribute estimate is no longer significant. Indeed, the nitrogen restitution attribute positively interacts with two soil-climate characteristics that mostly explain farmers' preferences. Calcareous soils (*Calc. soil*) and sloping plots on the farm positively affects farmers' preference. This is coherent with the fact that fertilizers efficiency is strongly dependent on soil-climate conditions. Nitrogen is less mineralized in calcareous soils and nitrogen leaks are considerable in sloping plots. To reduce production costs farmers prefer high levels of nitrogen restitution. Finally, the *Season* attribute estimate appears significant only for farmers with labor constraint (*Peaks*). Farmers with a high number of labor peaks favor a winter crop to alternate the cropping season to smooth the workload in the year.

The two logit models show that, in addition to the monetary attribute, agronomic attributes can strongly affect farmers' choice for a diversification crop. Furthermore, the diversity of the production contexts and strategies affect farmers' preferences for both monetary and agronomic attributes.

Table 3: Results of the basic specification and the interaction logit estimates

Attributes	Basic Specification Model			Interaction Model		
	Coef.	Std. Err.	P>|z|	Coef.	Std. Err.	P>|z|
Margin	0.948	0.072	0.000***	1.395	0.120	0.000***
Nitro	0.011	0.004	0.005**	-0.009	0.007	0.218
Tech = High technicality	-0.542	0.188	0.004**	-0.543	0.195	0.005**
Tech = Low technicality	0.395	0.178	0.027*	0.196	0.209	0.418
Pest = +1 Treatment	-0.839	0.195	0.000***	-0.886	0.202	0.000***
Pest = -1 Treatment	0.089	0.189	0.637	-0.551	0.347	0.112
Season = Summer	-0.053	0.152	0.726	-0.607	0.342	0.076
Nitro X Calc. Soil	-	-	-	0.018	0.006	0.008**
Nitro X Slope	-	-	-	0.013	0.005	0.011*
Margin X Contract	-	-	-	-0.001	0.000	0.002***
Margin X Wheat GM	-	-	-	-0.055	0.011	0.000***
Low Tech X Agro. Diff	-	-	-	0.198	0.067	0.003**
Pest -1 X Sunflow. Disease	-	-	-	0.308	0.134	0.022*
Summer X Peaks	-	-	-	-0.096	0.044	0.030*
Constant	-4.289	0.396	0.000***	-4.602	0.394	0.000***
N		1065			1065	
LL		-592			-557	
R²		0.19			0.23	

4.3 Unobserved heterogeneity in preferences: random parameters logit estimation

The interaction model shows that observable farm characteristics affect farmers' preferences for the crop attributes. The recent literature on adoption behavior underlies the importance of heterogeneity in preferences due to individuals' unobservable characteristics. The logit model assumed fixed effects of preferences between individuals. Thus, a random parameter logit is estimated to analyze unobserved heterogeneity. To make the implementation of the model easier[4], all attributes are assumed to be independent and normally distributed with the exception of the monetary attribute (*Margin*) (Ruud 1996). As for the logit model, a basic specification is tested with crops attributes (Equation 11).

$$U_{ij} = \alpha_i Margin + \gamma_i Nitro + \delta_i Tech + \zeta_i Pest + \eta_i Season$$

(Equation 11)

Results are reported in Table 4. The introduction of random parameters improves the model overall fit with an increase in the log likelihood ratio compared with the two

[4] Models with all coefficients varying did not converge in any reasonable number of iterations, as expected by Ruud's observation

fixed effects logit models. For the mean parameters estimates, the results are close to the logit models. The standard deviation estimates exhibit heterogeneity in taste for the nitrogen attribute (*Nitro*). The standard deviation estimate is greater than the mean estimate. Thus, within the sample, farmers' valuation for the nitrogen restitution attribute is highly heterogeneous. This variability of preference is partially explained by observable characteristics. The interaction model shows that soil condition (slope and soil type) affect farmers' sensitivity to this attribute.

Table 4: Results of the random parameter logit estimates

Attributes	**Coef.**	**Std. Err**	**P>|z|**
Margin	1.26	0.110	0.000***
Nitro	0.015	0.006	0.006**
Tech = High technicality	-0.662	0.240	0.008**
Tech = Low technicality	0.598	0.223	0.008**
Pest = +1 Treatment	-1.182	0.241	0.000***
Pest = -1 Treatment	0.157	0.259	0.545
Season = Summer	-0.028	0.216	0.895
Constant	-6.051	0.568	0.000***
Standard deviation	Coef.	Std. Err	
Nitro	0.022***	0.007	-
Tech = High technicality	0.316	0.679	-
Tech = Low technicality	$6.18\ 10^{-7}$	0.666	-
Pest = +1 Treatment	0.041	4.316	-
Pest = -1 Treatment	1.030	0.309	-
Season = Summer	0.971	0.2555	-
Constant	1.059	0.198	-
N		1065	
LL		-540	

The marginal willingness to pay (WTP) defined in Equation 8 is computed from the results of the random parameter logit (Table 5). The results show that the mean marginal WTP for nitrogen is 1.21€/unit. It is comparable to the market value of a nitrogen unit. The market price of nitrogen varies from 0.80 to 1.50€/unit. In the same line, in the experiment, an additional pest treatment is valued 93€ by farmers. Considering the global cost of a pest treatment (product, fuel and machinery) this WTP is close to the current market cost of an herbicide treatment in Southwestern France (about 80€/ha based on the extension services data). Both results give robustness to our experiment since estimates are close to the market price. The estimation of the WTP also assigns monetary value to non-market attributes. The effort to implement a crop with a high level of technicality of the crop management is valued 52€ by farmers. At the opposite, farmers will accept to pay 47€ to reduce the level of technicality for medium to low level of technicality.

Table 3: Marginal willingness to pay (in €) for crop traits (Krinsky and Robb procedure)

Attribute	**Estimate**	**95% Confidence interval**	
		Lower bound	**Upper bound**
Nitro	1.21(€/U)	0.32	2.11
Tech = Highly technical	-52.2 (€/ha)	-89.4	-15.1
Tech = Slightly Technical	47.2 (€/ha)	12.2	82.1
Pest = +1 IFT	-93.3(€/ha)	-131.2	-55.4
Pest = -1 IFT	12.4(€/ha)	-27.6	52.4
Season = Summer	-2.2(€/ha)	-35.7	31.2

Heterogeneity in farmers' preferences is due to observed and unobserved heterogeneity. The observed heterogeneity is captured in the interaction logit and show that farm characteristics such as soil conditions affect farmers' sensitivity to the nitrogen attribute. The random parameters logit model also reveals unobserved heterogeneity in preferences for the nitrogen restitution attribute (*Nitro*). To evaluate both observed and unobserved heterogeneity, the WTP for the nitrogen restitution attribute (*Nitro*) is estimated according to both main farm characteristics that affect preferences: soil type and plot slope. As expected, farmers with calcareous soil more value the nitrogen restitution than farmers with clay soil respectively 1.24 and 0.74 €/unit. However, the coefficient of variation indicates heterogeneity of the WTP. More precisely, within the subsample of farmers with clay soil, the valuation of the nitrogen restitution is highly heterogeneous with a coefficient of variation of 180% (Annex1). In parallel, the field slope partially explains the heterogeneity in preferences. The mean willingness to pay for farmers with sloping plots is 1.5€ per nitrogen unit whereas for farmers in the plain it is 0.9€. Furthermore, preferences are highly heterogeneous within the plain subsample compare to the hillside (Annex 1).

Farm characteristics strongly affect farmers' preferences for the diversification crop attributes. However, a share of the farmers' heterogeneity in preferences is still not directly observable. The farmers' preferences are affected by a large range of factors endogenous or exogenous to the farmers that the experience do not capture.

Discussion and conclusion

Crop diversification is a major concern in specialized crop farms in Europe. Environmental regulation combined with an increase in agronomic difficulties drive farmers to redesign their cropping systems by introducing a new crop to lengthen the rotations. In this paper, Lancaster's consumer theory is transposed to the analysis of farmers' preferences. Farmers' preferences for a diversification crop attributes are measured with a choice experiment. In agricultural economics literature, the key role played by monetary determinants in the adoption behavior is widely accepted. However, this is a restrictive view of farmers' adoption behavior. This paper brings to light the role played by non-monetary attributes in farmers' adoption of a crop diversification. We show that agronomic attributes such as the level of nitrogen restitution and the pest management are highly valued by farmers. This is even stronger when farmers are already facing difficulties in their current cropping system or have restrictive soil-climate conditions. Results show that farmers' preferences are linked to their production context that can restrain their adoption choice. Before promoting crop diversification, the assessment of the current management practices is useful to understand farmers' expectations. To design effective support policies it seems necessary to assess the adoption of innovations at a homogeneous small agricultural region scale. Furthermore, we show that farmers reject high technicality of the crop management. The increase in risk exposure due to yield variation and the additional working time probably lead farmers to prefer crops with a low level of technicality. Extension services and researchers can improve the adoption of highly technical crops by relaying objective information on crop agronomic performance to farmers. However, even if farmers' characteristics enhance understanding in farmers' adoption behavior, a share of the farmers' heterogeneity in preferences is still not identified. Farmers' preferences are affected by a large range of farm characteristics but also by farmers' knowledge, experience and perceptions that are difficult to capture.

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Annex 1: Farmers' marginal WTP distribution depending on farm characteristics