Economic incentives to the adoption of low input cropping systems: The case of multi-resistant wheat cultivars in France

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Abstract

Our main objective is to analyze the effects of policy instruments that could provide agricultural producers economic incentives to the adoption of innovative cropping practices which allow a reduction of pesticide use. To do so, we combine economic data, reflecting the intensive cropping practices currently used in France, and experimental agronomic data, on a low input technology, to conduct econometric estimations. The estimated economic models are then used to conduct policy simulations. Our results show that without public incentives producers would not adopt the new technology and that a tax on pesticides generates larger effects when these low input practices are available.

JEL codes: Q12 Q55 Q58

Keywords: multi-crop ecometric model, low input technology, pesticide taxation, agronomic data

Introduction

Traditional intensive cropping systems involve a heavy use of pesticides, plant growth regulators and chemical fertilizers in order to maximize crop yields. Yet, this intensive use of chemical inputs, notably pesticides, is associated to numerous health and environmental risks. More and more attention is being paid to this issue, and governments in developed countries are setting objectives to control the use of pesticides. This is the case in the European Union, globally (European Commission, 2006) and at country levels: in France for instance one of the objectives of the 2008 *"Grenelle de l'environnement"* is a 50% reduction of pesticides use by 2018. There is thus a need for new policy instruments to reach these goals. In this respect, the taxation of pesticides has often been advocated in the economic literature (Lichtenberg, 2004, Sexton et al., 2007). This policy instrument actually exhibits several advantages: it is flexible enough, can be progressively implemented letting time to farmers to adjust their production decisions, does not impose any particular practice and involves less management costs than other instruments like contracts (Aubertot et al., 2005). However, as mentioned by Skevas et al (2013) in their literature review on the design of an optimal European policy, the pesticides demand elasticity is very low (estimates found in the literature range between -0.7 and -0.02); there is thus a risk to get very few impacts on farmers' pesticides consumption if the tax rate is too low. This raises the question of their political acceptance (Falconer and Hodge, 2000). Yet, this assertion holds under the assumption of a constant production technology and does not account for a potential change in cropping practices induced by the taxation. Indeed, another way to lower the use of pesticides would be to provide incentives to agricultural producers to adopt new production technologies involving less use of pesticides. Actually, over the last few years, several agronomic studies have focused on low-input crop management systems which allow a significant reduction of fungicide and excess fertilizer use (Bouchard et al., 2008; Félix *et al.* 2002, 2003; Loyce et al., 2012; Meynard et al., 2009; Rolland *et al*,. 2003 and 2006). To avoid the risk of disease linked to the fungicide reduction, these cropping systems are associated to specific cultivars, more resistant to diseases. The yields obtained with the combination of resistant cultivars and low input crop management are slightly lower than the yields obtained with traditional cropping systems. However, the reduction in input expenditures induced by the adoption of such innovative systems can compensate the yield losses and lead to gross margins comparable to those of intensive cropping systems, depending on the output price (Rolland et al, 2003, Bouchard et al., 2008, Loyce et al., 2008; Meynard et al., 2009, Loyce et al., 2012). Despite this apparent attractiveness, low-input farming systems are still rarely used in Europe. A number of reasons can explain this low adoption rate: Vanloqueren and Baret (2008) focus on factors related to policy regulations, farmers' information or the influence of seed companies. Our view point is that it could in fact be attributed to a lack of economic incentive in the current context of high crop prices. This raises the question of the need for a public intervention to incent farmers to adopt these practices. Yet several studies have focused on innovative technology adoption but few have attempted to analyze the impacts of public interventions on the adoption of low-input farming systems from econometric models deriving from the optimization problem faced by agricultural producers when they take their production decisions. The results of the above mentioned agronomic studies rely on gross margins computation based on experimental data: there is no representation of farmers' economic decisions. Some economic papers, like Jacquet et al. (2011) or Falconer and Hodges (2000), study the issue of economic incentives to the adoption of new crop management techniques. However their studies rely on Mathematical Programming (MP) models which are calibrated at one point and not estimated on a range of data: contrary to an econometric approach this does not allow any statistical inference for the model validation. The lack of econometric studies dealing with the adoption of innovative cropping technologies can be explained by the fact that the economic models usually used to model farmers' behavior are based on dual approaches using reduced form profit functions where the production technology is not explicitly represented. Yet, since low input farming systems are rarely applied, no economic data are available to estimate this kind of economic models. The only information available to economists is based on experimental agronomic data reflecting the characteristics of the new production technology. There is thus a need to rely on primal forms of economic models to be able to account for this information.

Our objectives in this article are first to analyze the effects of the adoption of a low input technology on the farmers' production decisions (input uses, acreage choices …); and then to study the impacts of pesticide taxation on their choice to adopt the innovative practice, and on their use of pesticides given that the innovative practice is available. We focus on the case of multi-resistant winter wheat cultivars on which agronomic experiments have been conducted in France since 1999. To conduct our study we use the model originally proposed by Carpentier and Letort (2012 and 2013) which was applied by Kamininski et al. (2013) in a study on the adaptation of agricultural technology to climate change. Therefore we use a primal form multi-crop econometric model. This model includes yield, input demand and land use equations. Its main originality lays in the specification of the yield functions. The functional form chosen is a re-parameterization of the standard quadratic production function. The yields only depend on variable inputs and thus mostly represent the biological crop production process. The main benefit of this framework is that the yield functions are similar to the ones considered by agricultural scientists. The acreage model relies on the specification of a cost function which defines the motive for crop diversification. It can be interpreted as the effects of binding constraints on acreage choices, that is to say constraints associated to limiting quantities of quasi-fixed inputs such as labor and machinery. The complete model is estimated on economic data from a French territorial division, *la Meuse*, where traditional intensive cropping is prevalent. In a second step we use the agronomic data on both traditional cropping practices, associated to a standard wheat variety, and low input cropping practices, associated to a resistant wheat cultivar, in order to estimate the changes in the yield function parameters induced by the adoption of the new cultivar. This allows us to define a new economic model, corresponding to the low input technology, and to run our simulations on the two types of cropping practices.

We first simulate the impact of change in technology on agricultural producers' decisions and wheat production outcomes. Our results show that, in the current context of high wheat prices, the low input technology is less profitable to farmers than the standard intensive practice. An economic incentive is thus needed to encourage them to adopt the new technology. In a second step, we simulate the effects of a tax on pesticide and find that the impacts of this type of policy on input uses are larger when agricultural producers can change their practices and use the low input technology. This result derives from a lower price elasticity of input demand with the new technology which generates higher effects of the taxation.

The first part of the paper is devoted to the presentation of the economic model and the results of the econometric estimations conducted on data representing the behaviors of farmers using traditional intensive cropping. In a second part, we present the agronomic data and the results of the estimations, based on these data, of the change in yield functions implied by a switch from intensive to low input cropping practices. This allows us to build a new economic model. The third part is devoted to the presentation of the simulations results. Finally we conclude.

1. Economic model

1.1 Description of the model

We use the model developed by Carpentier and Letort (2012), which is particularly adapted to our study since its parameters are easily interpretable in agronomic terms. Its main features are as follow.

The yield y_k of each crop is assumed to be a quadratic function of variable inputs quantities $\mathrm{x_k}$:

$$\boldsymbol{y_k} = \boldsymbol{\alpha_k} - \frac{\mathbf{1}}{\mathbf{2}}(\beta_k - \mathrm{x_k})^{\boldsymbol{T}} \boldsymbol{\Gamma_k}^{-\mathbf{1}}(\beta_k - \mathrm{x_k}) \qquad (1)$$

The α_k parameter can be interpreted as the highest potential achievable yield of crop k and the β_k parameters as the quantity of inputs necessary to reach this yield. $\boldsymbol{\Gamma_k}$ is a symmetric matrix of parameters determining the curvature of the yield function. These parameters thus characterize the production technology and will be impacted by the switch to the new cropping systems.

The agricultural producer seeks to maximize his expected profit Π, which is equal to the weighted sum of the expected gross margins of each crop $\bar{\pi}_k$ minus the acreage management costs, subject to the production technology constraint:

$$\max \Pi(\mathrm{s}, \bar{p}, \mathrm{w}) = \sum_k s_k \bar{\pi}_k(\bar{p}_k, \mathrm{w}) - \mathrm{C}(\mathbf{s}) \qquad (2)$$
$$\text{s. t. } y_k = \boldsymbol{\alpha_k} - \frac{1}{2}(\beta_k - \mathrm{x_k})^T \boldsymbol{\Gamma_k}^{-\mathbf{1}}(\beta_k - \mathrm{x_k})$$

Where the expected gross margins $\bar{\pi}_k$ are defined as $\bar{\pi}_k = \bar{p}_k y_k - w^{\mathrm{T}}\mathrm{x_k}$, with $\bar{p}_k$ the expected selling price of crop k (we assume here naïve expectations: the expected price is equal to the past year price) and w the vector of input prices.

The acreage management costs $\mathrm{C}(\mathbf{s})$, that correspond to the costs associated to labor, machinery and other quasi fixed factors, are introduced in the model through a quadratic function:

$$C(\mathrm{s}) = \frac{1}{2}(\mathrm{r}-\mathrm{s})'\mathrm{M}(\mathrm{r}-\mathrm{s}) \qquad (3)$$

This cost function can be interpreted as a distance, between the actual acreage s (vector of acreage shares s_k) and an acreage for which the management costs are minimal: r (vector of acreage shares r_k). The distance is measured by a metric M which depends on the farm characteristics, notably machinery and labor endowment[1].

Solving for this optimization program leads to the following econometric model:

$$y_k = \alpha_k - \frac{1}{2\bar{p}_k{}^2} w^{\mathrm{T}}\mathbf{\Gamma_k}\mathrm{w} + u_k^y \qquad (4)$$
$$\mathrm{x}_k = \beta_k - \frac{1}{\bar{p}_k}\mathbf{\Gamma_k}\mathrm{w} + u_k^x \qquad (5)$$
$$\bar{\pi}_k = \bar{p}_k\alpha_k - w^{\mathrm{T}}\beta_{\mathrm{k}} + \frac{1}{2\bar{p}_k{}^2} w^{\mathrm{T}}\mathbf{\Gamma_k}\mathrm{w} \qquad (6)$$
$$s_k = g_k + S\sum_l \delta_{kl}\,(\bar{\pi}_k - \bar{\pi}_K) + u_k^s, \text{ for } k = 1, \dots, K-1 \quad (7)$$
$$s_K = S - \sum_{k=1}^{K} s_k \qquad (8)$$

K is a crop chosen as “reference crop” in order to account for the land use constraint: $\sum_k s_k = S$. Here S denotes the total quantity of available land. The g_k and δ_{kl} parameters are respectively functions the elements of r and M and thus depend on the cost structure of the farm (on the flexibility of acreage adjustments).

u_k^y, u_k^x and u_k^s are random terms accounting both for the heterogeneity among farmers and for stochastic events that impact the production once the decisions are taken. This economic model allows a full representation of farmers’ production decisions based on market conditions, which is not the case in agronomic studies (*e.g.* Loyce et al., 2012). We can notably notice from Equations (4)-(7) that the yields, input demands and acreage all depend on input/output prices ratios.

1.2 Estimation results

[1] see Carpentier and Letort, 2012, for a detailed description of the cost function

Estimations are conducted on a sample of 2509 farms located in a French territorial division, *la Meuse*, for which we have acreages, yields, output prices and input expenditures from 1996 to 2008. We consider two inputs: fertilizers and pesticides. The three crops mainly grown in the region are considered: standard wheat, barley and rapeseed. Rapeseed is chosen as the reference crop.

The estimated parameters are reported in Table 1 below.

Almost all parameters of the production and cost functions are significant at 1% level and lie in their expected ranges (in regards of the empirical distributions of yields and input uses).

	Wheat		Barley		Rapeseed	
α	618.13	***	553.87	***	637.80	***
$\beta_{fertilizer}$	170.13	***	148.49	***	235.80	***
$\beta_{pesticide}$	157.39	***	125.65	***	178.12	***
$\gamma_{fertilize.ferlizer}$	38.66	***	28.33	***	58.77	***
$\gamma_{pesticide.pesticide}$	27.61	***	22.64	***	7.00	
$\gamma_{pesticide.ferlizer}$	-32.96	***	-30.96	***	-24.98	***
δ_{kk}	0.019	***	0.017	***	-	
δ_{kl}	0.014	***	0.014	***	-	
g_k	43.20	***	33.87	***	-	

Significance levels: *** 1%; ** 5%; *10%

Table 1: Parameter estimates of the economic model – the standard cropping case

2. Re parameterization of the economic model based on agronomic data

2.1Description of the data

In this section, we use agronomic data on resistant wheat cultivars to estimate a yield function similar to Equation (1). These data have been collected by a French trial network from 1999 to 2005. This network has compared four cropping systems, from the more intensive to the more extensive system involving an important reduction of input uses. These cropping systems are combined with productive wheat cultivars and with less productive but more resistant wheat cultivars. The intensive system combined to the productive wheat cultivars corresponds to the practice the most widely used in France in general and in *La Meuse* in particular. A database was built based on these wheat cultivar trials. To expand the possibilities of cropping systems, an agronomic model was used to simulate, from the experimental data, a larger number of observations. This model is the Betha system built by Loyce et al. (2002a and 2002b) initially to generate feasible crop management plans from an agronomic model.

The yields and input uses corresponding to the intensive cropping system associated to the standard wheat cultivars on the one hand, and to the low input cropping system associated to the resistant wheat cultivars on the other hand, are extracted from this database to conduct our estimations. Table 2 below summarizes the main characteristics of these two practices.

	Intensive cropping practice	Low input cropping practices
Wheat cultivar	Standard	Resistant
Seeding rate (seeds/m²)	260	156
Use of plant gross regulator	Yes	No
Average fertilizer use (€/ha)	372	258

Table 2: Main characteristics of the two cropping systems

2.2 Estimation of the production function on agronomic data

Since the combination of low input cropping and resistant cultivar we consider in this study has been developed so as to minimize the number of interventions, we consider that the structure of the acreage management costs does not change with the adoption of the new cropping system: the parameters of this cost function (δ, g) will not be impacted. Thereby, we focus on the impacts of the change in cropping practice on the parameters representing the production technology (α, β,): the production function (Equation 1) is first estimated on the experimental data corresponding to the standard practice and then on the data corresponding to the low input cropping practice. The estimation results are presented in Table 4 below.

	Intensive practice		Low input practice		%age variation
α	108.75	***	93.00		-15%
$\beta_{fertilizer}$	696.01	***	537.19	***	-23%
$\beta_{pesticide}$	221.62	***	193.07	***	-13%
$\gamma_{fertilize.ferlizer}$	2589.09	***	1938.10	***	-25%
$\gamma_{pesticide.pesticide}$	1089.71	***	2538.57	*	+133%
$\gamma_{pesticide.ferlizer}$	300.42	**	195.27		-35%

Significance levels: *** 1%; ** 5%; *10%

Table 4: Parameter estimates of the production function using agronomic data

We can first notice that here again almost all the estimated parameters are significant. The differences in order of magnitude between these parameters and the estimates reported in Table 1 are due to unit differences (in price indexes notably) between the economic and agronomic databases. The relevant information here lays in percentage differences in parameters between the two cropping practices. As could be expected, the potential wheat yield (α) decreases by about 15% and the quantities of inputs needed to achieve this yield (β) decreases by about respectively 23% and 13% for fertilizers and pesticides and when the low input practice is used in place of the intensive practice.

These changes in parameters are then applied to the coefficient of the economic model previously estimated on the “standard intensive practice” data (Table 1) to obtain a new economic model corresponding to the low input cropping practice.

The next section presents the results of simulation conducted with these two models.

Simulations results

2.3 Impacts of the adoption of the resistant cultivar

Table 6 reports the changes in wheat production induced by a switch from standard to low input cropping practices for a wheat price of 180€/ton which corresponds to the lower bound of wheat prices observed in 2013.

The yield decreases by 16% and the input use by 30%, for both fertilizers and pesticides. This is in accordance with the conclusion of agronomic studies: the use of the resistant variety allows a reduction of input use for a moderate yield decrease. The decrease in input expenditures is not sufficient to compensate for the loss of income generated by the yield drop: the gross margin decreases by 7.8%. A lack of economic incentive can thus solely explain the non adoption of the new cropping practice, independently of other factors related to the information available to farmers or the behaviors of seed companies. The decrease in wheat production is higher than the yield decrease (-19%) because part of the land devoted to wheat in the standard practice in reallocated to other cropping activities (3.2%).

	Standard intensive practice	Low input practice	%age change
Yield (€/ha)	1111.9	931.6	-16%
Fertilier expenditure (€/ha)	143.5	97.8	-30%
Pesticide expenditure (€/ha)	155.5	107.8	-30%
Gross margin (€/ha)	1108.5	1021.7	-7.8%
Production (tons)	317.0	256.5	-19%
Acreage (ha)	51.3	49.6	-3.2%

Table 6: Impacts of a change from standard to low input practice in the wheat sector (wheat price: 180€/ton)

The own price elasticity of pesticides increases in absolute term from -0.10 for the standard intensive practice to -0.32 for the low input practice. This reflects the fact that farmers using the low input technology are less dependent on the use of input, notably pesticides, and can just adjust more easily their input consumption to changes in input prices. This increase of price elasticity also implies larger potential effects of a tax on pesticides. This will be discussed in the next section.

We have seen that a change in cropping practices toward the use of a low input technology would not be profitable to agricultural producers for a 180€/ton wheat price. However, since a few years wheat prices have been, and will certainly be in the future, highly volatile. To study the implications of price changes on farmers' economic incentives to adopt the low input technology, we have reported on Figure 1 the evolution of wheat gross margins, with respect to price, for the two cropping practices: the standard practice in plain line and the low input practice in dashed line.

The two curves intersect at a price of 98€/ton: under this price the adoption of the new technology is profitable to farmers, above it is not. Actually, at 98€/ton 35% of the producers in our sample switch from standard to multi-resistant cultivars. This price, way below the recent observed wheat prices, must be considered with caution. Indeed the current version of our model does consider energy in the inputs. Yet, as pointed out by Loyce et al. (2012), oil prices, which are highly volatile, can have a large impact on the price equalizing the gross margins of standard and multi resistant wheat: their results show a 40% difference in "equilibrium price" between the low (29$/barrel) and high (144$ /barrel) oil price situations. The low input technology actually also allows a lower dependency on fossil energy. Nevertheless, even if this price was 50% higher, it would still not be profitable for agricultural producers to adopt the low input technology in the current wheat market context. Apart from anything else, a lack of economic incentives thus seems explain the low adoption rate of low input cropping practices, which advocates for the implementation of policy instruments to provide agricultural producers these economic incentives. In the next part we focus on one particular instrument: the taxation of pesticides and study its impacts on the adoption of the low input farming practices and on the use of inputs.

Figure 1: Evolution of the wheat gross margin with respect to the price of wheat

2.4 Policy simulations

We first focus on the adoption of the low input cropping technology and run simulation to find the tax rate that would provide farmers enough economic incentive to change their practices. The tax is implemented on the part of the aggregate input price index corresponding to pesticides.

Here again the results depend on the price of wheat. For a price of 180€/ton, a 130% tax is needed to equalize the standard and low input practices gross margins. In this case, the adoption of the low input technology by 23% of the farmers induces a 36% decrease of total pesticide use. The same tax implemented in the case of standard cropping practices would generate a decrease of pesticide use of 19% only. To achieve a 50% decrease of input use, which is close to the goal of the French *"Grenelle de l'environnement"*, a 200% tax is necessary, in that case all the farmers of the sample adopt the new technology. However, in a situation where the low input technology would not be available to farmers, the tax needed to reach the same level of reduction would be 25% higher. These figures illustrate an interesting outcome of the new technology adoption: the agricultural producers adopting the low input practices become more responsive to a taxation of pesticides. This is due to the increase of the price elasticity of pesticide demand induced by the adoption: the demand of inputs adjusts faster to changes in input price and thus to input tax. Pesticide taxation would thus be more efficient if alternative cropping practices are available. Figure 2 illustrates this point: it reports the decrease of pesticide use, with respect to the taxation rate, for the standard (associated to standard wheat) and low input (associated to resistant wheat) cropping practices.

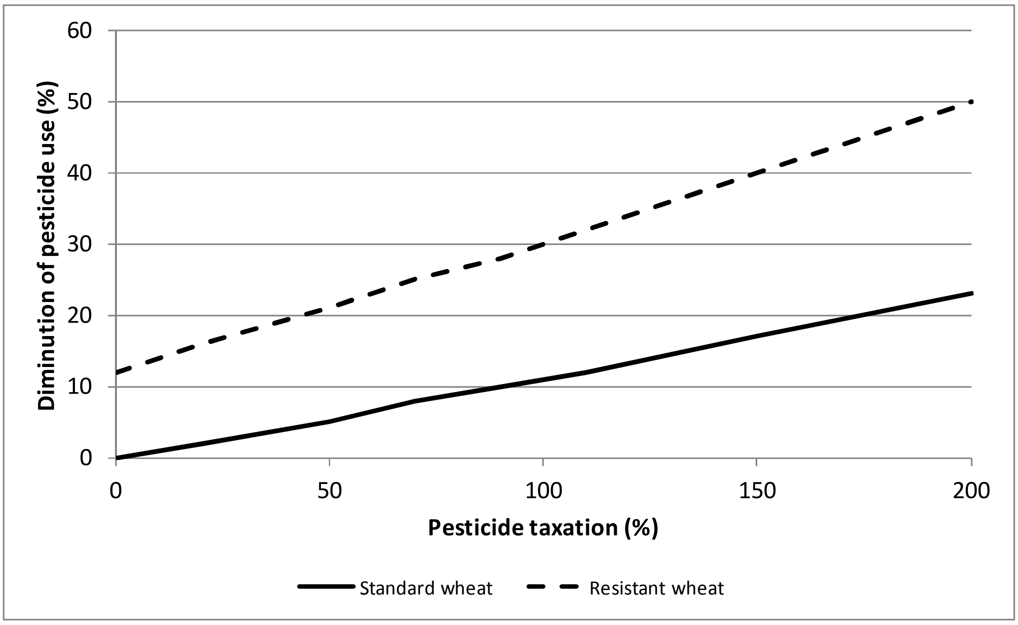

Figure 2: Decrease of pesticide use induced by a pesticide taxation.

We can notice here that the decrease in pesticide use is always higher for the low input cropping practice.

Conclusion

In this paper we use an original approach to study the economic incentive to the adoption of a low input cropping practice associated to a multi-resistant wheat cultivar. Indeed, we rely on a primal form econometric model of acreage and crop production decisions which allows to integrate the agronomic characteristics of a new production technology. To our knowledge this is the first attempt to estimate a yield function using experimental agronomic data.

In first set of simulations, this approach allows us to study the impacts of a switch from intensive to low input cropping practices on farmers' market based production decisions and on the outcomes of these production decisions. We show that the decrease in input consumption following the adoption of the resistant wheat variety will not compensate the income loss due to the yield decrease, unless wheat prices are unrealistically low, implying a decrease of farmers' gross margin. A lack of economic incentives can thus explain the current low rate of adoption of this type of technology. In a second set of simulations we focus on the effects of pesticide taxation on the adoption of low input cropping practices and on the use of inputs. We find that, on the one hand, this policy can lead agricultural producers to change their cropping practices;

and that, on the other hand, the pesticide taxation has larger effects on input use when alternative technologies are available to farmers. Indeed, the low price elasticity of input demand increases with the technological change and the same objective in input reduction can be reached with a lower tax. This can improve the political acceptance of this policy instrument. Other results, not reported here, show that the pesticide taxation leads agricultural producers to reallocate part of their land from the highest input consuming crop, rapeseed, to wheat; this is all the more true when low input cropping are used for wheat.

The results presented here are based on econometric estimations conducted with two inputs: pesticides and fertilizers. In the next version of the paper the costs of oil will be introduced. So that we will account for the fact that the new cropping system allows a reduction in the costs of energy which increases its profitability compared to the standard system.

References

Aubertot, J.N., Barbier, J.M., Carpentier, A., Gril, J.J., Guichard, L.,Lucas, P., Savary, S., Savini, I. and Voltz, M. (2005). Pesticides,agriculture et environnement. Réduire l'utilisation des pesticides et limiter leurs impacts environnementaux. *Expertise scientifique collective INRA et Cemagref.*
http:// www.international.inra.fr/research/pesticides_agriculture_and_the_environment2005

Bouchard, C., Bernicot, M.H., Félix, I., Guérin, O., Loyce, C., Omon, B. and Rolland B. (2008). Associer des itinéraires techniques de niveau d'Intrants variés à des variétés rustiques de blé tendre : Evaluation Economique, Environnementale et Energétique. *Courrier de l'environnement de l'INRA* 55: 53-77.

Carpentier A. and Letort E. (2012). Accounting for heterogeneity in multicrop micro-econometric models: Implications for variable input demand modeling. *American Journal of Agricultural Economics* 94(1): 209-224.

Carpentier A. and Letort E. (2013). Multicrop production models with multinomial logit acreage sares. *Environmental and Resource Economics*. Published onlin. doi: 10.1007/s10640-013-9748-6.

European Comission (2006). Thematic strategy on sustainable use of pesticides. Europa website. http://europa.eu/legislation_summaries/other/l28178_en.htm. Accessed January 2013.

Falconer K. and Hodges I. (2000). Using economic incentives for pesticide usage reductions: responsiveness to input taxation and agricultural systems. *Agricultural Systems* 63 175-194.

Félix, I., Loyce, C., Bouchard, C., Meynard, J.M., Bernicot, M.H., Rolland, B. and Haslé H. (2002). Associer des variétés rustiques à des niveaux d'intrants réduits : Intérêts Economiques et Perspectives Agronomiques. *Perspectives Agricoles* 79:30-35.

Félix, I., Loyce, C., Bouchard, C., Meynard, J.M., Rolland, B., Bernicot, M.H. and Haslé H. (2003). Une des voies pour s'adapter aux baisses de prix du blé : Des variétés rustiques conduites à faible coût. *Perspectives Agricoles* 290:22-29.

Jacquet F., Butault J.P. and Guichard L. (2011). An economic analysis of the possibility of reducing pesticides in French field crops. *Ecological Economics* 70(9):1638-1648.

Kamininski J., Kan I. and Fleischer A. (2013). A structural land-use analysis of agricultural adaptation to climate change: A proactive approach. *American Journal of Agricultural Economics* 95(1):70-93.

Lichtenberg, E. (2004). Some hard truths about agriculture and the environment. *Agricultural and Resource Economics Review* 33(1): 24-33.

Loyce C., Bouchard C., Meynard J.M., Rolland B., Doussinault G., Bernicot M.H. and Haslé, H. (2001). Les variétés tolérantes aux maladies : une innovation majeure à valoriser par des itinéraires techniques économes. *Perspectives Agricoles* 2001:50-56.

Loyce, C., Rellier, J.P. and Meynard J.M. (2002a). “Management Planning for Winter with Multiple Objectives (1) : The BETHA System.” *Agricultural Systems* 72:9-31.

Loyce, C., Rellier, J.P. and Meynard J.M. (2002b). “Management Planning for Winter with Multiple Objectives (2) : Ethanol-Wheat Production.” *Agricultural Systems* 72:33-57.

Loyce C., Meynard J.M., Bouchard C., Rolland B., Lonnet P., Bataillon P., Bernicot M.H., Bonnefoy M., Charrier X., Debote B., Demarquet T., Duperrier B., Félix I., Heddadj D., Leblanc O., Leleu M., Mangin P., Méausoone M. and Doussinault G. (2012). Growing winter wheat cultivars under different management intensities in France: A multicriteria assessment based on economic, energetic and environmental indicators. *Field Crops Research* 125:167-178.

Meynard J.M., Rolland B., Loyce C., Félix I. and Lonnet P. (2009) Quelles combinaisons varieties/conduits pour améliorer les performances économiques et envoronnementales de la culture de blé tendre? *Innovations Agronomiques* 7:29-47.

Rolland, B., Bouchard, C., Loyce, C., Meynard, J.M., Guyomard, H., Lonnet, P. and Doussinault G. (2003). Des Itinéraires Techniques à Bas Niveaux d’Intrants pour des Variétés Rustiques de Blé Tendre : Une Alternative pour Concilier Economie et Environnement. *Courrier de l’environnement de l’INRA* 49:53-77.

Rolland, B., Oury, F.X., Bouchard, C. and Loyce C. (2006). Vers une Evolution de la Création Variétale pour Répondre aux Besoins de l’Agriculture Durable? L’Exemple du Blé Tendre. *Dossier de l’environnement de l’INRA* 30:79-90.

Sexton, S. E., Lei Z. and Zilberman, D. (2007). The economics of pesticides and pest control. *International Review of Environmental and Resource Economics* 1:271-326.

Skevas T., Oude Lansink A.G.J.M. and Stefanou S.E. (2013). Designing the emerging EU pesticide policy: A literature review. *Wageningen Journal of Life Science* 64-65:95-103.

Vanloqueren G. and P.V. Baret. (2008). Why are ecological, low-input, multi-resistant wheat cultivars slow to develop commercially? A Belgian agricultural 'lock-in' case study. *Ecological Economics* 66:436-446.