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# Could Society’s willingness to reduce pesticide use be aligned with Farmers’ economic self-interest?

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## Abstract

In the context of the agreement of about 50% reduction in pesticide uses according to the accords du “Grenelle de l’environnement” in France, the central part of this study involves the assessment of agricultural intensification (*AI*) and agricultural extensification (*AE*) processes in crop activities.This is done with reference to pesticide uses per ha thereby helping to proffer a solution to the lingering questions of farmers as regards the use of inputs in an intensified manner or otherwise. With respect to this, a sample of 600 farms in the Meuse department was observed over a 12-year period. The analysis was essentially to assess cost efficiency dominance between the two technologies *AE* and *AI* using non parametric cost-functions which involves different characterizations of the reference set. This therefore helps to define the relative intensive and extensive technologies in terms of pesticide uses per ha, our empirical application therefore shows that *AE* process is a better option than *AI* not only for the society but also for the producers who could significantly reduce their global costs.

***Keywords:*** agricultural intensification (*AI*), agricultural extensification (*AE*), pesticide reduction, environmental performance, non parametric cost-functions

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## 1. Introduction

Use of chemical inputs such as pesticides has increased agricultural production and productivity. However, negative externalities from such use have increased too. These externalities include damage to agricultural land, fisheries, fauna and flora. Another major externality is the unintentional destruction of beneficial predators of pests thus increasing the virulence of many species of agricultural pests. The (agricultural, environmental and health) costs from these externalities are large and affect farmers' returns. However, despite these high costs, farmers continue to use pesticides in increasing quantities in a process known as intensification (Wilson, 2000). This could be partly due to the incentives given by pesticide industries thereby encouraging the farmers to use pesticide in an unsustainable manner.

In addition, it is not worthy to state that past increases in agricultural production have occurred as a result of both extensification and intensification but it is also important to state that there are common problems associated with crop intensification i.e. the excessive and inappropriate use of fertilizers and pesticides. This problem contributes to the deterioration of water quality, poses serious negative effects on human health and the environment, and it also leads to resistance of pests to pesticides. The crop intensification approach falls in line with the principles of Good Agricultural Practices (GAP). A GAP protocol can serve as a reference tool for deciding at each step in the production process (e.g. seed choice, soil preparation, weed control), on practices and/or outcomes that are environmentally sustainable and socially acceptable, in order to produce safe and high quality crops in an economically sustainable manner. The implementation of GAP can help in opting for less hazardous agricultural technologies. FAO's work on pesticide risk reduction include the promotion of Integrated Pest Management practices to reduce the overall use of pesticides and to encourage selection of less hazardous products when pesticide use remains needed. (FAO, 2004).

Special attention is therefore paid to the phasing out of highly toxic pesticides and the encouragement of using inputs in an efficiently sustainable manner. Based on the fact that it is generally believed that intensive use of pesticides and fertilizers can disrupt or erode biodiversity in natural habitats and ecosystem services that surround agricultural areas particularly when these inputs are used inappropriately, public authorities and businesses have multiplied the initiatives for sustainable development for several years in France. The most spectacular measure is the inscription of this sustainable development in the Charter of the environment since March 2005. This spurred the French government into action and it therefore recently established the National Council for Sustainable development (CNDD) and has invested a lot in the "Grenelle de l'environnement".

The purpose of the agreement is therefore to initiate a policy work that evaluates different scenarios in order to reduce the dependency culture systems to pesticide. This prompted the government to set a target of reducing pesticides used in French's Agriculture by 50% which should be achievable in the next ten years. Since 2008, several measures have already been taken by including the prohibition of 30 products considered most toxic, introducing a tax on plant health, increasing their level of toxicity, tax that should increase over time and the granting of tax credits for organic farming (Champeaux, 2006). All these are done due to the many advantages accompanied by pesticide reduction in crop activities.

The main advantages of pesticide reduction include: (1) Benefits for the farmer through (a) savings in production cost, savings in energy (b) User-friendliness, improvement in time and work management, applicator safety. (2) Benefits for the environment through (a) improved biodiversity, improved water quality, wildlife protection, protection of beneficial arthropods, reduced packaging waste (b) facilitating the adoption of conservation agriculture practices, representing an opportunity for more sustainable farming methods. (3) Benefits for the consumer through improved food quality: less mycotoxin (Wood et *al.*, 2000)

In view of the above advantages, this paper attempts to know if extensification is a more economically competitive practice or not than intensification in crop activities for each observed farm or decision making unit (DMU). The reduction of pesticide use by the farmer is possible based on his interest to do so. In this paper we try to know if there is coherence between the economic interest of the farmer in terms of total cost decrease and the global benefit of the society in terms of pesticide reduction per hectare. Theoretically, it is important to give a brief definition of these two types of technologies. More significant use of agricultural land can take various forms. A first dimension would be extensification – increasing production by extending the area under cultivation while maintaining or reducing aggregate input levels per unit area while a second dimension would be intensification - increasing production per unit area through more intensive production practices. It thereby encompasses two distinct forms – land-use intensification (i.e., increasing the frequency of cropping per unit area) and technological intensification (i.e., increasing capital and/or input use per crop per unit area). The choice of agricultural strategy for land usage – extensification, and/or intensification– is probably a reflection of both biophysical (e.g., climate and water) and socio-economic (e.g., market pull and access) factors (Erenstein et *al.*, 2006). In the context of reducing pesticide uses, we will refer our definition of Agricultural Intensification (*AI*) or Agricultural Extensification (*AE*) technologies as technical practices with a relative high cost of pesticide per ha or relative low cost of pesticide per ha respectively.

Some estimations of cost functions are therefore done empirically to assess the comparisons between the respective technologies *AE* and *AI*. This can be achieved by developing an analytical framework based on non parametric cost function to assess the cost frontier comparisons between *AI* and *AE*. Non parametric cost functions requires neither a priori weights nor a functional form for input/output relationships and utilizes mathematical programming to construct an empirical production possibility set, thus providing a single efficiency score for that DMU by comparing it to a ‘‘virtual producer’’ on the efficient frontier. Last twenty years have seen a great variety of applications of non parametric approaches to estimate production or cost frontiers in a multiple output-input situation using in particular the well known Data Envelopment (DEA) or Free Disposal Hull (FDH) models. They have brought in possibilities for use in evaluating the efficiency performances of many different kinds of entities engaged in many different activities in many different contexts (e.g., Cooper et *al.*, 2000, Fried et *al.*, 2008).

One main feature of our approach is to consider various subsets of DMUs in the definition of the production possibility sets regarding the level of intensification of the evaluated producer that is defined as the level of pesticide cost per ha. Since the choice of an absolute and exogenous threshold of pesticide uses to characterize *AE* or *AI* could be difficult to justify, we have allowed for a relative and endogenous degree of extensification (intensification). Evaluated DMUs are compared to more or less intensive DMUs with regards to their own degree of intensification.

The study made use of a panel data located in a particular French department (la Meuse) which consists of 600 farms over a 12 year period (1992-2003) producing wheat, barley and rapeseed (including rapeseed for diester). The rest of the paper therefore unfolds as follows.

Following this introduction, the next section briefly provides some of the major effects of pesticide reduction. Section 3 presents the methodology to assess the cost frontier comparisons between the above two technologies *AE* and *AI* while section 4 is devoted to empirical analysis, results and comments which identifies the variables and provides the data information used in this study. The final section (5) concludes the paper.

## 2. Pesticide reduction effects and cost efficiency

Intensive forms of agriculture have been proven to cause severe environmental damages, such as soil erosion by water or wind (Deumlich et *al.*, 2006), pollution of ground and surface water by pesticide as well as contributing to the deterioration of natural habitats and losses in biodiversity (Firbank, 2005). Manifestly, any farmer or agricultural system with unlimited access to sufficient inputs, knowledge and skills can produce large amounts of food. The central questions, therefore, focus on: (i) To what extent can farmers increase food production by using low cost and inputs? (ii) What impacts do such methods have on environmental goods and services and the livelihoods of people who rely on them? The success of industrialised agriculture in recent decades has often masked significant environmental and health externalities (actions that affect the welfare of or opportunities available to an individual or group without direct payment or compensation). Environmental and health problems associated with industrialised agriculture have been well documented (Wood et *al.*, 2000), but it is only recently that the scale of cost has come to be appreciated through studies in China, Germany, UK, the Philippines and the USA (Pretty et *al.*, 2000).

What do we understand by agricultural sustainability? Systems high in sustainability are making the best use of nature’s goods and services whilst not damaging these assets (Li Wenhua, 2001; McNeely and Scherr, 2001; Uphoff, 2002). The aims are to: (i) integrate natural processes such as nutrient cycling, nitrogen fixation, soil regeneration and natural enemies of pests into food production processes; (ii) minimize the use of non-renewable inputs that damage the environment or harm the health of farmers and consumers.

As part of the conservation of a biological control approach, habitat management seeks to maximize one specific ecosystem service, i.e., pest regulation, by enhancing natural enemy impact through manipulating plant-based resources in the landscape. Typically, this is accomplished by selecting plants that provide a limiting resource such as pollen, nectar, alternative hosts, or shelter and establishing these plants or plant communities within the managed system (Landis et *al.*, 2000). Environmentally sound application of pesticides are central indicators for the sustainability assessment of agriculture, most especially since several studies have shown that the amount of fossil energy input is closely related to the release of carbon dioxide from a particular agricultural system (Dyer and Desjardin, 2003; Tzilivakis et *al.*, 2005). Energy efficiency can be seen as an integrative indicator as it is strongly correlated to other abiotic indicators (Hülsbergen et *al.*, 2001).

Environmental effects of arable farming are affected by numerous influencing factors. Even though site conditions and regional pedo-climatic factors considerably impact the environmental performance of farming (Pacini et *al.*, 2003), the implementation of management practices directly modifiable by the farmer, such as farming system, crop rotation, tillage intensity, or fertilizer and pesticide application, has significant influence on the use efficiency of limited resources and, accordingly, on the potential of environmental endangerments. Thus, sustainable farming systems must obtain high yields while minimizing environmental influence. In this context, maintenance of the agricultural production capacity of land resources is a fundamental element in the discussion on sustainable land use (Bindraban et *al.*, 2000). This falls in line with the multiplication of initiatives for sustainable development by businesses and public authorities for several years in France.

In fact, the existence of cost inefficiencies offers an opportunity to reduce input expenses without reducing outputs. This concept is of particular interest when related to possibilities of input reductions or substitutions that may cause environmental impacts, such as pesticide uses per ha of land. The farmers can be stimulated to adopt agricultural practices which are the most efficient in terms of costs. These practices are not necessarily the more ecological technologies using less pesticide per ha, the choice will depend on the relative input prices and the possibilities of input substitutions. In view of this, this paper will therefore assess the cost frontier comparisons with respect to both intensive and extensive technologies practicing farms. If the latter dominates the former in terms of cost, then *AE* process has always attracted ecological interest because of its environmental arguments to reduce pollution; but because of its financial benefits, it is now an even more attractive option. Therefore, information on the input reducing capabilities of polluting inputs as pesticides is useful to elucidate the possibilities of improving environmental performance while maintaining output levels and decreasing production cost (De Koeijer et *al.*, 2002).

The question most paramount now is: *is pesticide reduction economically feasible in French's agriculture?* It is very obvious that an incorrect manner of pesticide application will definitely hold negative effects on human health and the environment and that is why the main objective of this research paper seeks to assess if a less pesticide use per ha is a cost competitive practice or not in crop activities by comparing cost frontiers between *AE* and *AI*.

## 3. Cost efficiency assessment with the use of non parametric cost functions

Firm's performance has been estimated using a number of efficiency concepts including production and cost. Productive efficiency is derived as the distance an individual firm has from the 'optimal' or 'best practice' firm existing on the production frontier. Cost efficiency estimates how far the production cost of an individual firm differs from the production cost of a best practice firm operating under the similar conditions and producing the same output. Cost efficiency is evaluated with reference to a cost function constructed from the observations of all firms considered within the sample set. The cost function which assumes the production cost of individual firm is dependent on price of inputs, the quantity or value of outputs produced, and any other additional variables accounting for the environment or particular circumstances.

This hypothesized 'best practice' firm is defined with reference to all firms retained in the sample set. Farrell (1957) originally introduced a simple method of measuring firm's specific productive efficiency that employs the actual data of the evaluated firms to generate the production frontier. Thus this method assumes that the performance of the most efficient farmers can be used to assess the benchmark. Transposing this in the cost function context, if a farm lies on the cost frontier, then it is perfectly cost-efficient but if it lies above the benchmark then it is inefficient with the ratio of the actual to potential minimal cost defining the level of cost inefficiency of the individual firm. This approach yields a relative measure as it assesses the cost efficiency of a farm relative to all other farms in the sample. Farrell argued that this is more appropriate as it compares a farm’s performance with the best performance actually achieved rather than with some unattainable ideal.

Cost frontiers can be modelled, thanks to a Non Parametric Frontier Approach (NPFA) that can be evaluated with an Activity Analysis Framework (AAF) originally developed by Koopmans (1951) and Baumol (1958). AAF is a linear programming based technique for measuring relative efficiency where the presence of multiple inputs and outputs makes comparisons difficult. NPFA has both advantages and disadvantages relative to parametric frontier techniques such as the Stochastic Frontier Approach (SFA). The main advantage is that NPFA allows cost efficiency estimations without specifying any functional form between inputs and outputs. On the other hand, it is important to state that the disadvantage of the NPFA technique is that it does not allow for deviations from the efficient frontier to be a function of random error. As such, NPFA can produce results that are sensitive to outliers, model specification and data errors.

The basic standpoint of relative efficiency, as applied in NPFA, is to individually compare a set of DMUs. NPFA constructs the frontier and simultaneously calculates the distance to that frontier for the (inefficient) farms above the cost-frontier. The frontier is piecewise linear and is formed by tightly enveloping the data points of the observed ‘best practice’ activities in the observations, that is the most efficient farms in the sample in terms of cost. NPFA uses the distance to the frontier as a measure of inefficiency. The measure provides a ratio-score for each farm from 0% (best performance) to x% meaning that the evaluated DMU would reduce its cost of x% to reach the cost frontier. For a review of the NPFA techniques see Färe et *al.* (1994) or Thanasoullis et *al.* (2008).

## Methodology

### *The Cost model*

Let us consider that $K$ DMUs are observed and we denote the associated index set by $\mathfrak{K} = \{1, \ldots, K\}$ . We also assume that DMUs face a production process with *M* outputs and *N* inputs and we define the respective index sets of outputs and inputs as

$\mathfrak{M} = \{1,\dots,M\}$ and $\aleph = \{1,\dots,N\}$ where $y = \left(y_1,\dots,y_M\right) \in R_+^M$ $x = \left(x_1,\dots,x_N\right) \in R_+^N$ and $w = \left(w_1,\dots,w_N\right) \in R_+^N$ are respectively the vector of output quantities, input quantities and input prices. We begin by introducing the assumptions on the production possibility set (*PPS*) of all feasible input and output vectors which is defined as follows:

$$PPS = \left\{(x, y) \in \mathbb{R}_+^{N+M} : x \text{ can produce } y\right\} \text{ (1)}$$

Now, we suppose that the technology obeys the following axioms:

*A1*: $(0,0) \in PPS, (0, y) \in PPS \Rightarrow y = 0$, that is, no free lunch;

*A2*: the set $A(x) = \left\{(u, y) \in PPS : u \le x\right\}$ of dominating observations is bounded $\forall x \in \mathbb{R}_+^{N+M}$, that is infinite outputs cannot be obtained from a finite input vector;

*A3*: *PPS* is closed;

*A4*: for all $(x, y) \in PPS$, and all $(u,v) \in \mathbb{R}_+^{N+M}$, we have $(x,-y) \le (u,-v) \Rightarrow (u,v) \in PPS$ (free disposability of inputs and outputs);

*A5*: *PPS* is convex.

With these axioms, *PPS* is therefore defined as:

$$PPS = \left\{(x, y) : \sum_{k\in \mathfrak{K}} \lambda^k y_m^k \ge y_m \;\; \forall m \in \mathfrak{M}, \sum_{k\in \mathfrak{K}} \lambda^k x_n^k \le x_n \;\; \forall n \in \aleph, \;\; \lambda^k \ge 0 \;\forall k \in \mathfrak{K}, \sum_{k\in \mathfrak{K}} \lambda^k = 1\right\} \text{ (2)}$$

The production cost is equal to $C = wx^T$ where the superscript $T$ denotes a transposed vector. Usually for a DMU *o* with a production plan $(x^0, y^0)$ and a production cost $C^o$, the calculation of cost inefficiency involves solving the following minimum cost model

$$\begin{aligned}
&\underset{\lambda,\tilde{x}}{Min}\, C = \sum_n w_n \tilde{x}_n \\
&\sum_{k\in\mathfrak{K}} \lambda^k y_m^k \ge y_m^o, \forall m \in \mathfrak{M} \\
&\sum_{k\in\mathfrak{K}} \lambda^k x_n^k \le \tilde{x}_n, \forall n \in \aleph \qquad\qquad (3) \\
&\sum_{k\in\mathfrak{K}} \lambda^k = 1 \\
&\lambda^k \ge 0, \forall k \in \mathfrak{K}
\end{aligned}$$

The solution of this model results in minimum cost *C* for the evaluated DMU *o*. Therefore its cost inefficiency is *1-(C/C$^o$) and* reflects the potential decrease in % of *C$^o$*. For each $\lambda^k \neq 0$, DMU k forms a part of the optimal linear combination which minimizes cost of farm *o* and can be considered as a benchmark referent. The linear program is therefore solved once for each observation in order to compute its cost inefficiency.

*AI versus AE dominated technologies*

Furthermore, we also considered varying the types of DMUs entering into the production possibility set of the evaluated farm *o* (all DMUs or some subset of more or less intensive DMUs than DMU *o*). By denoting $AE = \text{more or equally agricultural extensive}$ and $AI = \text{more or equally agricultural intensive}$, their production possibility sets $PPS^o(AE)$ and $PPS^o(AI)$ are respectively defined by:

$$PPS^o(AE) = \left\{ (x,y): \sum_{k\in\mathfrak{K}(AE)} \lambda^k y_m^k \geq y_m, \forall m \in \mathfrak{M}, \sum_{k\in\mathfrak{K}(AE)} \lambda^k x_n^k \leq x_n, \forall n \in \aleph, \lambda^k \geq 0\ \forall k \in \mathfrak{K}(AE), \sum_{k\in\mathfrak{K}(AE)} \lambda^k = 1 \right\} \quad (4)$$

$$PPS^o(AI) = \left\{ (x,y): \sum_{k\in\mathfrak{K}(AI)} \lambda^k y_m^k \geq y_m, \forall m \in \mathfrak{M}, \sum_{k\in\mathfrak{K}(AI)} \lambda^k x_n^k \leq x_n, \forall n \in \aleph, \lambda^k \geq 0\ \forall k \in \mathfrak{K}(AI), \sum_{k\in\mathfrak{K}(AI)} \lambda^k = 1 \right\} \quad (5)$$

By defining $I(k)$ and *I(o)* as the respective degrees of intensification of DMUs *k* and *o* which are equal to their ratios of pesticides per ha:

In (4), $\mathfrak{K}(AE) = \{k \in \mathfrak{K} : I(k) \leq I(o)\}$

And in (5), $\mathfrak{K}(AI) = \{k \in \mathfrak{K} : I(k) \geq I(o)\}$

The meanings of “more or equally agricultural extensive” and “more or equally agricultural intensive” are now clear. $\mathfrak{K}(AE)$ contains observed DMUs in the data set using less pesticide per ha than the current evaluated farm while $\mathfrak{K}(AI)$ contains only the observed DMUs that has an equal or higher ratio of pesticides per ha than the evaluated DMU.

Given the definition of the technologies in (3) and in (4), we now estimate the two cost functions for all farms *o* using the following programs:

$$\begin{aligned}&\underset{\lambda,\tilde{x}}{Min}\ C_{AE}=\sum_{n} w_n \tilde{x}_n\\&\sum_{k\in\Re(AE)}\lambda^k y_m^k \geq y_m^o, \forall m\in\mathfrak{M}\\&\sum_{k\in\Re(AE)}\lambda^k x_n^k \leq \tilde{x}_n, \forall n\in\aleph\\&\sum_{k\in\Re(AE)}\lambda^k=1\\&\lambda^k\geq 0, \forall k\in\Re(AE)\end{aligned}\qquad(6)$$

$$\begin{aligned}&\underset{\lambda,\tilde{x}}{Min}\ C_{AI}=\sum_{n} w_n \tilde{x}_n\\&\sum_{k\in\Re(AI)}\lambda^k y_m^k \geq y_m^o, \forall m\in\mathfrak{M}\\&\sum_{k\in\Re(AI)}\lambda^k x_n^k \leq \tilde{x}_n, \forall n\in\aleph\\&\sum_{k\in\Re(AI)}\lambda^k=1\\&\lambda^k\geq 0, \forall k\in\Re(AI)\end{aligned}\qquad(7)$$

Comparing the two minimal costs $C_{AE}$ and $C_{AI}$ based on their respective programs (6) and (7), one can evaluate the gap between the two technologies in order to know if *AE* is a more cost-competitive practice than *AI* for the current evaluated farm *o*. The originality of our approach is to consider the various subsets of DMUs used in the definition of the production possibility sets as regards the evaluated producer’s level of intensification. An exogenous choice of the threshold of pesticide use practices could be difficult to justify and that is why we use a relative and endogenous degree of extensification (intensification). With respect to their own degree of intensification, the evaluated DMUs are compared to more or less intensive DMUs.

## 4. Empirical application: data, results and comments

### *Data for Efficiency Analysis*

A total of 600 farms were observed in the Meuse department between 1992 and 2003 forming an unbalanced panel. Three outputs and four inputs were used to specify the technology of the farms for a total of 7135 observations. The outputs include: Wheat, Barley and Rapeseed (including rapeseed diester) while the inputs comprises Surface (land), Fertilizer, Seeds and Pesticides. The outputs are measured in quintals and the land surface which is the weighted surface by the land quality is measured in acres (other inputs are measured in Constant Euros).

The total cost of production in Euros is composed of the costs of fertilizer, seed, and pesticide as well as the cost of land for only these three outputs. The unit price of land was estimated by the hired cost that the farmer paid to the owner when the land was rented. As regards owned land, a fictitious price equal to the hired cost of his rented land was applied. The yearly average land price over the sample was applied uniformly to all the observations.

Finally, despite the fact that the price evolution over time is known, the sample does not contain any prices at the farm level for seed, fertilizer and pesticides, but only costs per input category. If we assume that all farms face identical input unit-prices each year (most inputs are procured within the same regional markets where prices between farms differ little), it can be shown that the two previous minimum cost models (6) and (7) can be rewritten as the followings programs (Färe et *al.*,1990):

$$\begin{aligned} &\underset{\lambda, C_{AE}}{Min}\ C_{AE} \\ &\sum_{k \in \Re(AE)} \lambda^k y_m^k \geq y_m^o, \forall m \in \mathfrak{M} \\ &\sum_{k \in \Re(AE)} \lambda^k C^k \leq C_{AE} \\ &\sum_{k \in \Re(AE)} \lambda^k = 1 \\ &\lambda^k \geq 0, \forall k \in \Re(AE) \end{aligned} \tag{8}$$

$$\begin{aligned} &\underset{\lambda, C_{AI}}{Min}\ C_{AI} \\ &\sum_{k \in \Re(AI)} \lambda^k y_m^k \geq y_m^o, \forall m \in \mathfrak{M} \\ &\sum_{k \in \Re(AI)} \lambda^k C^k \leq C_{AI} \\ &\sum_{k \in \Re(AI)} \lambda^k = 1 \\ &\lambda^k \geq 0, \forall k \in \Re(AI) \end{aligned} \tag{9}$$

The descriptive statistics showing the different scenarios of inputs and output vectors used in the efficiency analysis are presented in the table below.

Table 1: Brief descriptive statistics of the data (period 1992-2003):

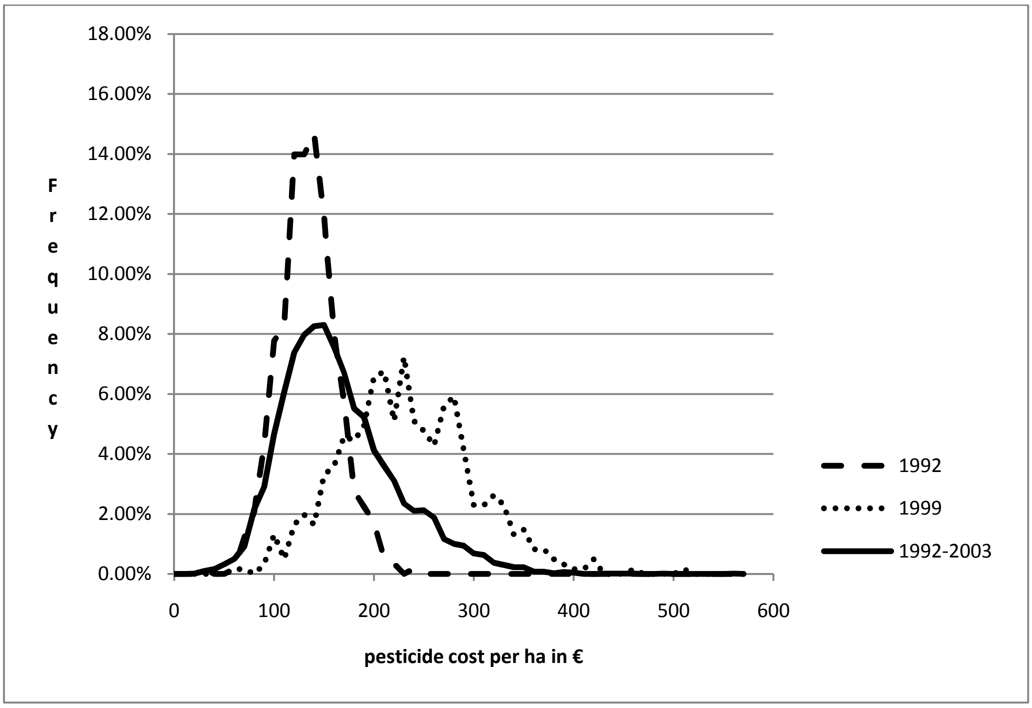
| | Mean | CV | ROG (%) |
|---|---|---|---|
| Barley (quintals) | 1114 | 1.014 | 3.60 |
| Wheat (quintals) | 2891 | 0.783 | 1.43 |
| Rapeseed & diester (quintals) | 999 | 1.064 | 3.64 |
| Surface (acres) | 8991 | 0.769 | 2.40 |
| Total Cost 2(€) | 42872 | 0.862 | 1.89 |
| Pesticide per ha (€) | 157 | 0.375 | 1.12 |

ROG: tendency rate of growth, CV: coefficient of Variation

The descriptive statistics detailed in Table 1 above shows a rather low and stable spread for the inputs (the coefficients of variation are less than one as well as the total cost, land and pesticide per ha). In addition, barley and rapeseed outputs increase faster than wheat production. It can be noticed that the rate of growth of total cost is lower than the surface hence, the ratio of total cost per ha is decreasing.

From figure 1, even though the standard deviation of pesticide per ha is rather small over the all period, one can check that the sampling distribution can vary quite significantly according to the different years of the period. This reveals some heterogeneity of pesticide uses among farmers who can individually adopt some different practices in order to respond to climatic or other random effects. In such a context, it is preferable to estimate cost function year-by-year in order to impose minimal assumptions with respect to the nature of annual technological shifts. Therefore, thanks to the panel nature of the sample, it is possible to define the previous different possibility sets (4) and (5) for each year separately from 1992 to 2003.

Figure 1: Sampling distribution of pesticide cost per ha[1]



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[1] Sampling distributions of pesticide cost per ha are drawn for the whole sample as well for years 1992 and 2003 which present the annual lower and higher standard deviations respectively.

### *Results and comments*

Consequently the linear programming problems given in the methodology section of this paper are solved for each of the observations connoting that all farms observed at year *t* are evaluated against two different annual technologies. One is composed of less extensive DMUs *(AE)* relative to the evaluated farm and the other is composed of more intensive DMUs *(AI)* also relative to the current evaluated farm. Then for each year, the two minimum costs are compared in order to select the best cost-practice for the evaluated farm. Annual cost analyses are presented in table 2 below.

Table 2: Percentage of cases where *AE* dominates *AI*

| Year | %*AE* |
|---|---|
| 1992 | 80.83 |
| 1993 | 72.52 |
| 1994 | 79.08 |
| 1995 | 87.58 |
| 1996 | 83.44 |
| 1997 | 86.27 |
| 1998 | 84.35 |
| 1999 | 90.30 |
| 2000 | 84.31 |
| 2001 | 66.84 |
| 2002 | 78.57 |
| 2003 | 79.03 |
| Total | 81.23 |

*AE* = Agricultural Extensification ; *AI* = Agricultural Intensification

The table above clearly shows that extensification dominates intensification in terms of cost irrespective of the annual context. Depending on the year, between 67% and 90% of farmers should operate under a more relatively extensive technology than a more intensive one. The mean average of the total sample is around 81% of cost dominance in favour of the *AE* practices. The minimized costs of production under the two technologies and their gaps are shown in the columns of table 3 below. Over the whole period, there is a positive gap between the two minimum costs in favour of *AE* practices which varies from 2% to 27%, the mean average of the gap is around 17%. Therefore from their actual practices, the cost reductions would be 24.3% if the farmers adopt *AE* technology against 11.5% for *AI*.

Table 3: Observed and minimum costs between *AE* and *AI*

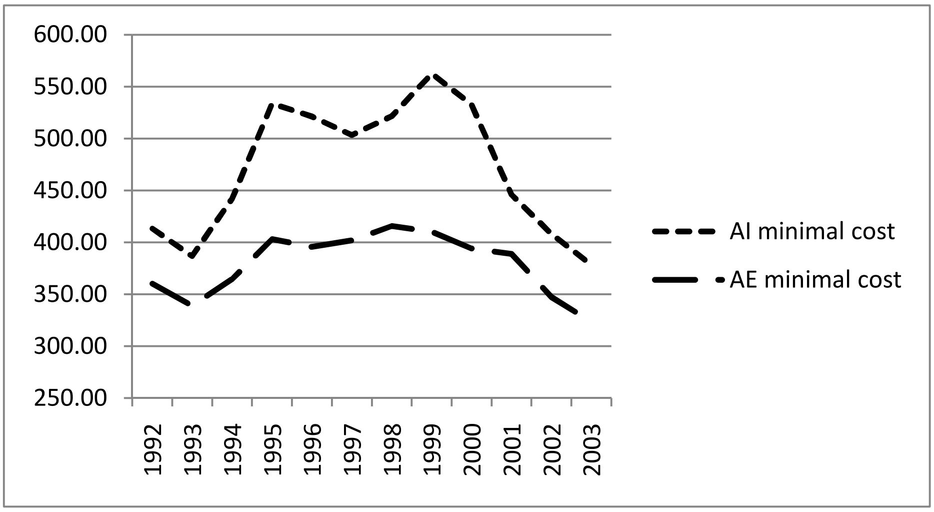
| Year | Observed Cost in € | Minimum cost in € for *AE* | Minimum cost in € for *AI* | Gap between *AI* and *AE* in % |
|---|---|---|---|---|
| 1992 | 30 982 | 26 097 | 27 528 | 5.48 |
| 1993 | 26 761 | 21 251 | 23 544 | 10.79 |
| 1994 | 35 263 | 26 757 | 31 148 | 16.41 |
| 1995 | 49 683 | 35 161 | 43 903 | 24.86 |
| 1996 | 48 282 | 34 336 | 43 362 | 26.29 |
| 1997 | 47 829 | 36 755 | 42 694 | 16.16 |
| 1998 | 51 220 | 39 830 | 46 373 | 16.43 |
| 1999 | 58 321 | 40 584 | 51 627 | 27.21 |
| 2000 | 54 803 | 37 242 | 47 408 | 27.30 |
| 2001 | 39 660 | 33 138 | 33 765 | 1.89 |
| 2002 | 37 282 | 31 252 | 33 602 | 7.52 |
| 2003 | 33 148 | 26 793 | 29 510 | 10.14 |
| Total | 43 002 | 32 538 | 38 079 | 17.03 |

*AE* = Agricultural Extensification ; *AI* = Agricultural Intensification

Where the results are presented in terms of cost per ha instead of total cost, the *AE* dominance is more spectacular. At the sample mean, an amount of 483 Euros is spent per ha. To reach the frontier of the *AI* Technology, the farmer can produce at 478 Euros/ha while the farmer produces at 382 Euros per hectare to reach the frontier identified by *AE* Technology. Hence, between the two technologies, the gap is higher than 96 Euros (25%). This confirms that the cost frontier under an extensive scenario is below that of intensive scenario.

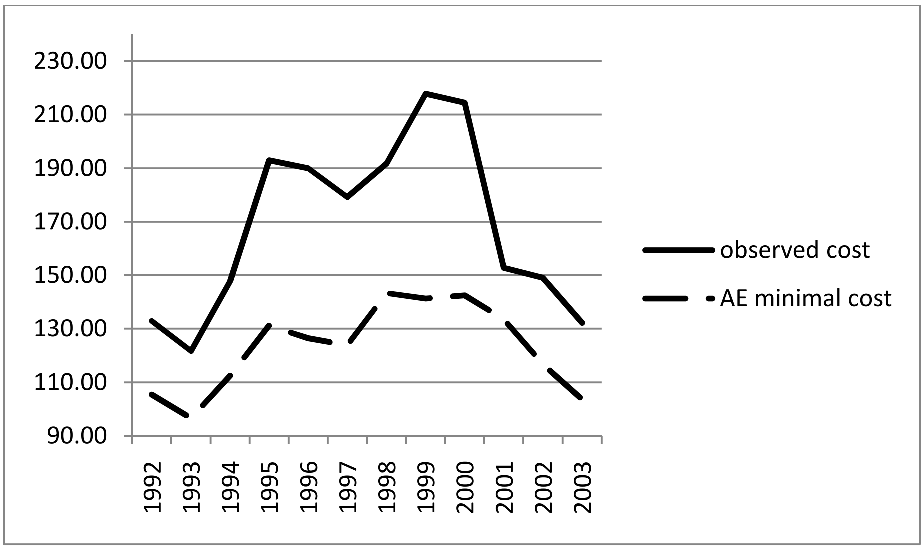
As reflected in Figure 2, the technology-gap varies in terms of Euros per ha between 48 Euros (14%) and 152.6 Euros (37%) always in favour of *AE* according to the different years. Therefore, in order to improve the cost of production, it is better and very preferable to reduce the amount of pesticides use per hectare.

Figure 2: Cost per ha in €



Now focusing our attention on the pesticide uses per ha, it can be noted that the potential reductions of pesticide from the actual situations could reach 27% (sample mean) if the farmers adopt the best extensive practices. This is reflected by Figure 3 where the gaps between the observed pesticide cost per ha and the *AE* minimal cost vary between 12% and 35% over the whole period, thus resulting to a huge pesticide saving.

Figure 3: Cost of pesticide per ha in €



Of course the results gotten here depends on the sample, hence it is not easy to generalize it in conformity with all French's agriculture, therefore more applications needs to be run in different regions. These conclusions can also rightly be improved for future researches by taking climatic effects into account with a consideration of the fact that some micro climatic problems could exist. More importantly, crop rotations issues and the previous crop planted should also be put into consideration. Lastly, questions about risk, which include agronomical risk, climatic risk, and economical risk, are also needed to be taken into account.

## 5. Conclusion

This paper gave some estimations of production costs for cereals and rapeseed with the use of NPFA to assess the comparisons between lower and higher pesticides uses namely *(AE)* and *(AI)* respectively. This helps in achieving the objective of this paper that seeks to check if the minimized cost of production which is the individual interest of the farmer is in convergence with the pesticide reduction per hectare thereby helping to know if extensification is a cost-competitive practice or not.

This was achieved by developing an activity analysis framework to assess the cost frontier comparisons between extensive and intensive technologies. It is therefore worthwhile to note that the methodological originality of this paper is the cost dominance analysis between *AI* and *AE* which is done by a definition of dynamic reference sets relative to the evaluated farm.

Our results show that in 81% of cases, a more extensive technology cost dominates a more intensive one. In addition, the results clearly reveal that the interests of farmers and the policy makers could converge. Indeed, the benefit for the individual producer to reduce his total costs around 24% by adopting less intensive practices leads to a reduction of pesticide per ha of about 27% which is in coherence with the ecological wishes of the society. Moreover it is important to state that the results gotten in this paper are derived from the current technology of farms which ensures its feasibility. These final two conclusions affirm that in 10 years time, the aim of 50% rate of reduction in French’s agriculture seems really reachable.

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