Effects of direct payments on technical catching-up and structural convergence processes in a selection of French crop farms

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Abstract

We investigate the relationship between the type of direct payments (coupled or decoupled) granted to a selection of crop farms in the French department of Meuse between 1992 and 2012. We analyze the occurrence of both a technical catching-up process and a structural convergence process defined as the homogenization of the input-output mixes among farms. Using a robust nonparametric efficiency frontier, we first derive a distribution of technical and structural inefficiency estimates. Second, through a series of pooled-data samples, we regress these estimates on other exogenous, farm-specific variables, such as the subsidies granted and the financial situation. We show that only technical catching-up occurred for the farms studied. Furthermore, the presence of decoupled payments during the final period has slowed down this process. Finally, farms' long-term debts also have a negative impact on the technical catching-up.

Keywords: technical catching-up, structural convergence, directional distance function, CAP reform, direct payments, single farm payments

1. Introduction

Since its creation in 1962, the Common Agricultural Policy (CAP) has undergone several reforms. Although the CAP was, at its origins, oriented towards insuring constant

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increases in the production level, starting with the MacSharry reform in 1992, a major change of direction occurred. Thus, the final objectives targeted by the successive reforms (Agenda 2000, 2003 Mid-Term Review, "the CAP Health check" in 2008, CAP Reform 2014-2020) were to align producers' practices with the agricultural market expectations and to reduce misallocation of farms' resources. The MacSharry reform (1992) introduced for the first time a set of reductions in administered support prices. Particularly targeted by this reform were the cereals crops with a 30% of reduction over three years. In return, *coupled direct payments* and a set of accompanying measures were introduced in order to compensate farmers for the expected loss in revenue. The Agenda 2000 reform pursued in the same direction by introducing a new reduction in the cereals intervention price (by 15% in two equal steps of 7.5% in two marketing years). These cuts were expected to lead to support prices for wheat falling below world prices during the planning period, although not for barley. In return, area payments increased so as to compensate for half of this reduction. The 2003 Mid-term Review (MTR) of the Agenda 2000 (through the Luxembourg Agreement in June 2003) introduced an innovation by imposing the *decoupling of direct payments* to farmer[1].

Although these payments were supposed to be paid irrespective of production, they are still linked to land[2]. In return, famers had to comply with a set of requirements related the environmental protection, food safety, animal health and welfare and occupational safety (cross-compliance criteria). In practice, Single Farm Payments (SFP) were calculated as the mean of the subsidies the farmer received during three base years (2000, 2002 and 2003).

In France, decoupled payments were partially introduced in 2006 (e.g. for cereals, protein crops and oilseeds while 25% of the subsidies remain linked to the crop surfaces). In 2012, after the regular decoupling phases, most of vegetal and animal subsidies were decoupled. At the European level, this proportion reached 94% of the direct payments in 2013.

Finally, the 2014 reform aims to better target direct payments by limiting support to active farmers. Moreover, Member States must introduce on top of basic payment, the green direct payment (30% of total direct payments) and a specific compensation for young farmers entering the sector, with the possibility to attribute natural constraint support

1 Intervention price cuts were pursued, but this time with a focus on rice and dairy.

2 Moreover, farmers' entitlements on the land can be leased or bought and sold under certain conditions.

(up to 5%), redistributive payment (up to 30%) for the first hectares in order to support small and medium-sized farms. Moreover, the Member States may grant limited coupled subsidies (up to 10% or 15%) to secure potentially vulnerable sectors. The historic-based approach, used to calculate the level of direct payments, will be progressively adjusted with the introduction of a minimum national average direct payment per hectare for all Member States by 2020.

From a theoretical point of view, several studies have looked into the way in which (de)coupled subsidies are expected to affect technical and allocative efficiencies[3]. Thus, one direction of research is to see whether the way in which these subsidies are granted produce or not an effect on farmers' production decision. In this sense, we remind the papers of Oude Lansink and Peerlings (1996), Serra et al (2005) and finally Bezlepkina et al (2005) who show that the subsidies introduced in 1992 (thus linked to the land) affect the relative prices of inputs or outputs. Moreover, the latter show that if subsidies are entirely decoupled, then they produce a wealth effect, without altering input-output decisions[4]. Basically, subsidies linked to the aggregate land use may have, through the income effect, a positive effect on farms' technical efficiency if they are used in order to increase agricultural investments. They may also increase farm efficiencies by increasing their land-size (Kleinhanβ et al., 2007). Moreover, farmers can use these subsidies as collaterals to obtain either higher loans or better loan conditions which may, indirectly, affect positively agricultural production (Young and Westcott, 2000). Finally, these subsidies may play the role of an insurance effect, giving farmers the possibility to adopt more risky (and higher revenue) crops in the future (Hennessy, 1998). On the other hand, it is expected that, in presence of subsidies, farmers may continue to produce below the efficiency frontier which may harm efficient farmers overseas (Zhu and Oude Lansink, 2010; Latruffe and Sauer, 2010).

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3 The term "*decoupling*" has two different meanings in the literature (Swinbank and Tranter, 2005). The first one is related to the policy design, or the policy-makers approach, whereby, a payment is said to be decoupled if it is not connected to the quantity produced by the farm receiving it. The second interpretation is purely economic and a payment is "decoupled" if it does not modify farmer's profit maximizing decision-making. In what follows, we use this term in its institutional sense.

4 Other ways through which subsidies may affect production decisions are either the wealth effect (Young and Westcott, 2000), the insurance effect (Hennessy, 1998) or the exit decision (Ahearn et al, 2005).

This paper deals with the impacts of the MTR 2003 change of subsidies on two forms of farm inefficiency, namely technical and structural inefficiencies. While the technical inefficiency is mainly due to differences among farms (producers' management skills, social environment, climatic conditions, …), structural inefficiency stems from a misallocation of farms' resources according to the market orientations. Thus, we can remind a rich body of literature dealing with technical efficiency in EU farms which seeks to put forward a decomposition of its determinants (Zhu, Oude Lansink 2010; Brumer et all. 2002; Hadley 2006; Moro and Sckokai, 1999). Some other studies focused on the impact of subsidies (and the direct payments introduced in 1992) on technical efficiency. Several papers showed that these payments affect up to some extent farmers' efficiency (Ridier and Jacquet, 2002; Moro and Skokai, 1999; Guyomard et al, 1996; Serra et al, 2005). The study of the different impacts that the MTR in 2003 had on farmers' efficiency has been less studied. Kleinhanβ et al. (2007) analyzed the relationship between efficiency, environment friendliness and subsidies, but their data was livestock holdings in Spain and Germany over the 1999-2000 period and the effects of the MTR 2003 are only simulated in this study. Boussemart et al. (2011) studied the effects of the Single Payment Scheme on a selection of crop farms in Eure-et-Loir (French department) over the period 2005-2008.

In our study of a selection of crop farms in the Meuse department[5], we aim at giving some evidence on the impacts that the MTR 2003 policy had on the technical efficiency catching up, which is illustrated by the fact that inefficient farms progressively reach the productive leaders located on the frontier. Moreover, we are interested to check whether an input/output mix convergence (structural efficiency convergence) occurred in accordance with market signals. In 2005, the average agricultural acreage of this department was of 144 ha which ranked it 2nd amongst the French departments (cf. Ecoscopie de la Meuse, INSEE). Moreover, the same year, 9% of the employed population of this department was in agriculture, which is three times higher than the French average the same year. Agriculture in the Meuse department is mainly based on crops and animal husbandry. However, this activity was heavily subsidized the same year. Thus, CAP subsidies (both coupled and decoupled) counted for 44% of the agricultural added value of the department and for 74% of the net results. In comparison with the rest of France, a farmer in the Meuse department produced 710€/ha, which ranked him 73rd/101. Therefore, given the

5 An administrative area located in the North-East of France.

initial differences in the productivity levels and input/output mixes of the holdings in the Meuse department, the question of knowing whether the MTR brought about technical efficiency catching-up and structural convergence processes seems of high interest to us. The period covered by our study is 1992-2012. Through a nonparametric activity analysis framework, we begin by estimating farm technical and structural inefficiencies. We then use these inefficiency scores in extended catching-up or convergence models. Our regression models distinguish two periods: before and after the MTR 2003. In order to test the hypothesis of conditional catching-up and convergence processes to the CAP reforms, we introduce specific indicators concerning direct payments received by farmers such as the ratio of subsidies to output and the weight of single farm payments (SFP) to total subsidies. Farm short and long term debts complete the list of explanatory variables to take into account producers' financial capabilities of improving technical and/or structural efficiencies[6]. In that perspective, we expect that our two step analysis is able to bring light on the issues at stake for the MTR 2003:

i) Do direct payments impact or not the technical catching-up and structural convergence processes?
ii) Does the substitution of coupled subsidies by decoupled SFP accelerate or not the two above processes according to market orientations?
iii) After the MTR 2003, do the SFP substitute for financial loans taken out by farmers?

The rest of this article is organized as follows. Section 2 states the concepts of technical catching-up and structural convergence processes, develops some methodological issues concerning the directional distance framework and finally specifies our algorithm estimating sub-sampling inefficiency scores. Section 3 is devoted to the empirical analysis. Thus, after presenting the data in this study, we identify the variables of interest and comment on our main results. Section 4 concludes our findings.

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6 Ciaian and Swinnen (2009) showed that in a model with fixed supply of land, the imperfections in the credit market can have an incidence on the expected effects of area payments.

2. Analyzing technical catching-up and structural convergence processes through directional distance functions

This section develops a nonparametric activity analysis framework to determine both a technical catching-up effect and a structural convergence process between farms. Over time, a potential technical catching-up effect is revealed through a regular decrease of distances between observed farms and their respective optimal benchmarks located on the production frontier. This decrease indicates that farms are progressively reaching their own maximal feasible productivity levels. A structural convergence process highlights a time-trend of input/output mix homogenization among farms. Although the former depends on producers' capabilities to implement available best technical practices, the latter covers the heterogeneity in farm level input intensity and output specialization. This can be viewed as a proxy for an input/output deepening or expanding effect linked to opportunities of resource reallocation over time.

2.1. Concepts and measures

2.1.1. Definition of a technical catching up process.

A technical catching-up process is defined by the tendency of the least efficient farms (Decision Making Units, DMUs) to catch up with the most efficient ones. Two cases can be observed in this context. First, the inefficient farms are catching-up with the leaders which maintained their positions on the benchmark. Here, one can conclude that there is a convergence process to the technical frontier. Second, a more subtle technical catching up process arises when initially more efficient farms increase their inefficiency levels while the followers decrease or increase their inefficiency scores at a lower rate. This means that there is a convergence process away from the technical benchmark.

In both cases, a negative relationship between the initial level of technical inefficiency and its variation over two periods t_1 and t_0 should be detected.

$$\Delta TI_a = TI_{a,t_1} - TI_{a,t_0}$$
$$\frac{\Delta TI_a}{TI_{a,t_0}} = \beta Ln(TI_{a,t_0}) + \alpha + \mu_a \quad (1)$$

with TI_{a,t_0} = technical inefficiency of DMU a at the initial period t_0

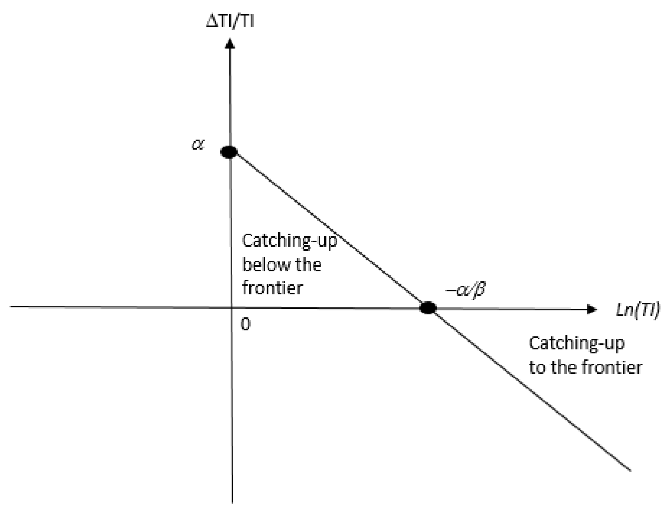
$\frac{\Delta TI_a}{TI_{a,t_0}}$ = technical inefficiency growth rate of DMU a between t_0 and t_1

μ_a = random error

$\beta < 0$, catching-up parameter

A convergence process to the technical frontier is verified by a negative growth rate of farms' inefficiencies ($\frac{\Delta TI}{TI_{t_0}} < 0$) which according to equation (1) implies that $Ln(TI_{t_0}) > -\frac{\alpha}{\beta}$. Conversely, for $Ln(TI_{t_0}) \leq -\frac{\alpha}{\beta}$, the concerned DMUs converge to a common inefficiency level below the frontier. Figure 1 illustrates these two cases.

Figure 1: Catching-up to versus catching-up below the frontier



2.1.2 Measuring technical inefficiencies

Formally, let $\mathbf{x}_t \in R_+^I$ denote the vector of inputs and $\mathbf{y}_t \in R_+^O$ the vector of outputs for a farm observed at time *t*. As we compare DMUs which have similar types of farming (crop productions) and located in the same geographical area within the same year *t* (Meuse), producers are assumed to face the same technology represented by the production set T_t:

$$T_t = \{(\mathbf{x}_t, \mathbf{y}_t) : \mathbf{x}_t \text{ can produce } \mathbf{y}_t\} \qquad (2)$$

Distances between observed production plans and the boundary of the technology are measured through the following directional distance function: $D_{T_t} : (R_+^I \times R_+^O) \times R_+^I \times R_+^O \to R_+$ defined by:

$$\vec{D}_{T_t}(\mathbf{x}_t, \mathbf{y}_t; \mathbf{g_x}, \mathbf{g_y}) = \sup_{\theta_t} \left\{ \theta_t \in \Re_+ : (\mathbf{x}_t - \theta_t \mathbf{g_x}, \mathbf{y}_t + \theta_t \mathbf{g_y}) \in T_t \right\} \qquad (3)$$

where $(\mathbf{g_x}, \mathbf{g_y})$ is a positive nonzero vector fixing the direction in which $\vec{D}_{T_t}(\cdot)$ is defined. Properties of directional distance functions can be found in Chambers et al. (1996). The production set T_t can be characterized by the directional distance function since $(\mathbf{x}_t, \mathbf{y}_t) \in T_t \Leftrightarrow \vec{D}_{T_t}(\mathbf{x}_t, \mathbf{y}_t; \mathbf{g_x}, \mathbf{g_y}) \geq 0$.

Based on the non-parametric literature on activity analysis, an operational definition of T_t in (2) is specified given a set of observed DMUs and a list of axioms. Thus, the two main assumptions which structure T_t for estimation purposes are free disposability of inputs and outputs and convexity. Under variable returns to scale (VRS), $T_{t,VRS}$ is defined as:

$$\begin{aligned} T_{t,VRS} = \Big\{ & (\mathbf{x}_t, \mathbf{y}_t) : \mathbf{x}_t \in R_+^I, \mathbf{y}_t \in R_+^O, \sum_{n=1}^{N} z_n y_{n,t}^o \geq y_t^o, o = 1,\dots,O, \\ & \sum_{n=1}^{N} z_n x_{n,t}^i \leq x_t^i, i = 1,\dots,I, \sum_{n=1}^{N} z_n = 1, z_n \geq 0, n = 1,\dots,N \Big\} \end{aligned} \qquad (4)$$

The aggregated output vector of the total group of N farms determines the direction of translation; i.e. $(\mathbf{g_x}, \mathbf{g_y}) = \left(0, \sum_{n=1}^{N} \mathrm{y}_{n,t} \right)$. As a result, for any specific farm, a non-radial technical inefficiency score is computed as a ratio of its output increment to the aggregate output of all observed DMUs (Dervaux et al., 2004). Thus, for any evaluated DMU "*a*", its non-radial technical inefficiency score at period t $NRTI_{a,t} = \theta_{a,t}$ is defined by the distance function $\vec{D}_{T_{t,VRS}}(\mathbf{x}_{a,t}, \mathbf{y}_{a,t}; 0, \sum_{n=1}^{N} \mathbf{y}_{n,t})$ and is estimated by the following linear program (*LP*):

$$\vec{D}_{T_{t,VRS}}(\mathbf{x}_{a,t},\mathbf{y}_{a,t};0;\sum_{\mathbf{n=1}}^{\mathbf{N}}\mathbf{y}_{n,t}) = \max_{\mathbf{z},\theta_{a,t}} \ \theta_{a,t}$$

$$\begin{aligned} s.t. \ & \sum_{n=1}^{N} z_n y_{n,t}^o \geq y_{a,t}^o + \theta_{a,t}\sum_{n=1}^{N} y_{n,t}^o \quad \forall o = 1,\cdots,O \\ & \sum_{n=1}^{N} z_n x_{n,t}^i \leq x_{a,t}^i \quad \forall i = 1,\cdots,I \\ & \sum_{n=1}^{N} z_n = 1 \\ & z_n \geq 0 \quad \forall n = 1,\dots,N \end{aligned} \qquad (LP1)$$

As a result, $NRTI_{a,t} = \theta_{a,t}$ depends on the relative size of the evaluated DMU. Comparatively to the smaller farms, large big inefficient farms will get higher inefficiency scores due to their bigger level of outputs and contribute to the inefficiency of the total group more significantly. For the single-output case, this size effect can be neutralized by retrieving the radial inefficiency score from the non-radial one through the formula:

$$TI_{a,t} = NRTI_{a,t}\left(\frac{\sum_{n=1}^{N} y_{n,t}}{y_{a,t}}\right) \quad (5)$$

2.1.3 Definition of a structural convergence process

In the case of a multi outputs-inputs technology, structural inefficiency highlights a subtle source of inefficiency due to heterogeneity in input and output endowments among DMUs (Ferrier et al, 2010). As shown in Figure 2.A in the input space $\left(x^1, x^2\right)$, two technically efficient DMUs (A and B) producing a same level of output $y_A = y_B$ with two different input mixes $\frac{x_A^2}{x_A^1} < \frac{x_B^2}{x_B^1}$ generate inefficiency at the aggregate level. Figures 2.B and 2.C illustrate similar effects in the output and the input-output spaces respectively. In fact, these structural inefficiencies are due to differences in relative input and output allocations between the two DMUs.

Figure 2 : Different cases of structural inefficiency

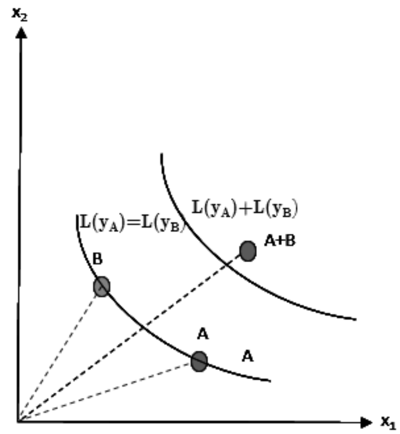


Figure 2.A

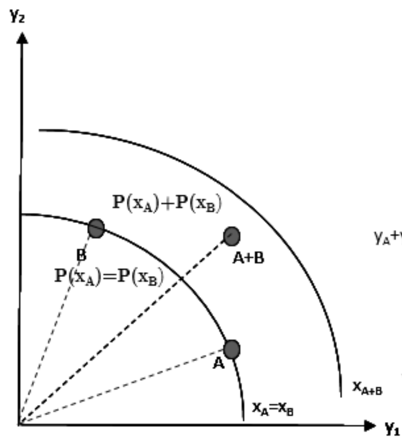


Figure 2.B

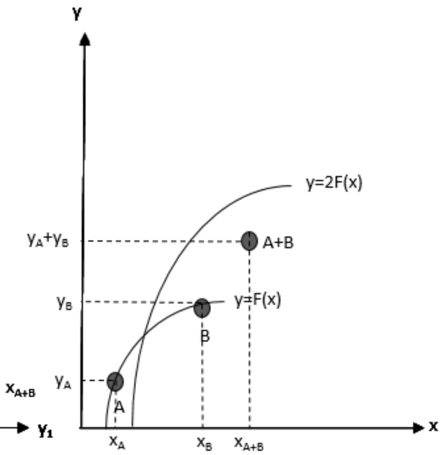


Figure 2.C

It is well known that in a perfectly competitive market, any single input-output price vector should lead DMUs to choose similar input-output mixes. As a result, structural inefficiencies measure an inefficient market allocation of resources (misallocation) in the spirit of the Debreu (1951) coefficient of resource utilization. Thus, their decrease over time reveals a structural convergence process since farms homogenize their input-output endowments progressively, which exerts a positive impact on aggregate productivity at the group level. Therefore a sufficient condition is that the growth rate of structural inefficiency is negative ($\frac{\Delta SI_a}{SI_{a,t_0}} < 0$). Consequently in case of input-output mix homogenization, the negative linear relationship between the initial level of structural inefficiency and its variation over periods t_1 and t_0 is given by equation (6):

$$\Delta SI_a = SI_{a,t_1} - SI_{a,t_0}$$

$$\frac{\Delta SI_a}{SI_{a,t_0}} = \varphi Ln(SI_{a,t_0}) + \lambda + \mu_a$$

with $SI_{a,t}$ = structural inefficiency of DMU a at period t *(6)*

μ_a = random error

$\varphi < 0,$ convergence parameter

and has to verify $Ln(SI_{a,t_0}) > -\frac{\lambda}{\varphi}$

2.1 4 Measuring structural inefficiencies

First of all, structural efficiency is measured at the group level. The total group of farms (G) is composed of N farms $(n = 1,...,N)$ and the group technology T_t^G is simply defined as the sum of the individual farm technologies at period t:

$$T_t^G = \sum_{n=1}^{N} T_t \qquad (7)$$

Under the convexity of the individual technology, Li (1995) demonstrated that the VRS aggregate technology is equal to N times the individual technology:

$$T_{t,VRS}^G = \sum_{n=1}^{N} T_{t,VRS} = N \times T_{t,VRS} \quad (8)$$

Next we can define the directional distance function under the VRS aggregate technology:

$$\vec{D}_{T_{t,VRS}^G}\left(\sum_{n=1}^{N} \mathbf{x}_{n,t}, \sum_{n=1}^{N} \mathbf{y}_{n,t}; \mathbf{0}; \sum_{n=1}^{N} \mathbf{y}_{n,t}\right) \quad (9)$$

Equation (8) evaluates the technical inefficiency of the aggregate production plan also called the overall inefficiency $OI_t^G = \theta_t^G$ and is estimated by the following LP:

$$\begin{aligned}
&\vec{D}_{T_{t,VRS}^G}\left(\sum_{n=1}^{N} \mathbf{x}_{n,t}, \sum_{n=1}^{N} \mathbf{y}_{n,t}; \mathbf{0}, \sum_{n=1}^{N} \mathbf{y}_{n,t}\right) = \max_{z,\theta_t^G} \ \theta_t^G \\
&s.t. \ N\sum_{n=1}^{N} z_n y_{n,t}^o \geq (1+\theta_t^G)\sum_{n=1}^{N} y_{n,t}^o \quad \forall o = 1,\cdots,O \\
&N\sum_{n=1}^{N} z_n x_{n,t}^i \leq \sum_{n=1}^{N} x_{n,t}^i \quad \forall i = 1,\cdots,\mathrm{I} \qquad\qquad (LP2) \\
&N\sum_{n=1}^{N} z_n = N \\
&z_n \geq 0 \quad \forall n = 1,...,N
\end{aligned}$$

Finally, the structural inefficiency of the total group (G) is the gap between the overall inefficiency evaluated at the aggregated level and the sum of individual technical inefficiencies:

$$\vec{D}_{T_{t,VRS}^G}\left(\sum_{n=1}^{N} \mathbf{x}_{n,t}, \sum_{n=1}^{N} \mathbf{y}_{n,t}; \mathbf{0}, \sum_{n=1}^{N} \mathbf{y}_{n,t}\right) - \sum_{n=1}^{N} \vec{D}_{T_{t,VRS}}\left(\mathbf{x}_{n,t}, \mathbf{y}_{n,t}; \mathbf{0}, \sum_{n=1}^{N} \mathbf{y}_{n,t}\right) \quad (10)$$

One can note that technical efficiency is farm-specific while structural efficiency is computed for the whole group. However, the overall inefficiency of the group can be shared across individual farms through the shadow prices derived in ($LP2$) (Briec and al., 2003).

Based on these concepts and their operational measures, we are now able to highlight their implications concerning the technical-catching up and structural convergence processes among farms. First, running (*LP1*) for all observed production plans "*a*" belonging to the group of N farms at period t, we estimate the contemporaneous levels of individual non radial technical inefficiencies $NRTI_{a,t} = \theta_{a,t}$. Second, running (*LP2*) for the aggregate production plan at period t, we measure the group of farms' contemporaneous technical inefficiency $OI_t^G = \theta_t^G$ also called overall inefficiency (OI). Third, this overall inefficiency for the whole group is shared among the N different farms $OI_t^G = \sum_{n=1}^{N} OI_{n,T}$. Fourth, structural inefficiency for the whole group and non-radial structural inefficiency for each farm are simply estimated by the difference of their respective overall and technical inefficiencies

$$\begin{aligned} & SI_t^G = OI_t^G - TI_t^G \\ & \text{with } TI_t^G = \sum_{n=1}^{N} NRTI_{n,t} \\ & NRSI_{n,t} = OI_{n,t} - NRTI_{n,t}, \forall n \in \{1, 2, ..., N\} \\ & \text{with: } SI_t^G = \sum_{n=1}^{N} NRSI_{n,t} \end{aligned} \quad (11)$$

Similarly to the technical component, we retrieve the individual radial structural inefficiency score by the following calculation:

$$SI_{a,t} = NRSI_{a,t} \left(\frac{\sum_{n=1}^{N} y_{n,t}}{y_{a,t}} \right) \quad (12)$$

2.2. A robust sub-sampling DEA approach of technical and structural inefficiencies

The production set, as well as the distance functions defined in (3) and (8) remain major concerns in empirical efficiency analysis as inefficiency scores compare observed and optimal performances positioned on the relevant production frontier. In fact, this true frontier is unknown, therefore an empirical benchmark must be estimated. The DEA model, developed by Charnes et al. (1978) is usually considered to be one of the appropriate models for gauging such distance functions in a general multi-output, multi-input framework. Thanks to its non-parametric nature, this linear programming method allows one to circumvent any confusion between the inefficiency components and the misspecification effects due to an arbitrary choice of functional forms of the technology required by econometric techniques. However, as DEA is fundamentally an enveloping technique, its main practical difficulty is to include a statistical error term as in usual econometric methods. Consequently, extreme observations of the reference production set (outliers) can impact estimated results significantly. To overcome this drawback, one may prefer to apply the notion of sub-sampling frontiers by estimating successive partial frontiers rather than the usual full frontier approach. Thus, despite the fact that a well-defined technology frontier was always defined in our theoretical models, the following empirical analysis will consider the presence of potential outlier observations by applying a variant of the estimation strategy formulated by Kneip et al. (2008), who showed the consistency of inefficiency estimators.

Estimators $\hat{\theta}_{a,t}$ and $\hat{\theta}_t^G$ from (*LP1*) and (*LP2*) can be biased if outliers exist and are used to estimate the production set and the associated frontier. To bypass this problem, a large number of sub-samples of a predetermined size are selected from the initial observed DMUs. This enables to build an empirical distribution of inefficiency scores across the different sub-samples. Since the estimated production set varies over the sub-samples, the potential outliers are not always included in the referent technology. As a result, the evaluated DMU is not always compared with extreme observations while the outlier is not completely ignored either. This leads to more robust estimations of inefficiencies.

The computational algorithm is now presented. For all evaluated DMUs, B Monte-Carlo replications compute a distribution of sub-sampling output distance function. First, for each replication *(b = 1, …, B)*, we generate a random sample of size M independently, uniformly and with replacement from the initial sample of observed farms. The associated production set is denoted by $\hat{T}_{t,VRS}^{b,M}$:

$$\hat{T}_{t,VRS}^{b,M} = \left\{ (\mathbf{x}_t, \mathbf{y}_t) : \ \mathbf{x}_t \in R_+^I, \ \mathbf{y}_t \in R_+^O, \ \sum_{m=1}^{M} z_m y_{m,t}^o \geq y_t^o, \ o = 1,\dots,O, \right.$$
$$\left. \sum_{m=1}^{M} z_m x_{m,t}^i \leq x_t^i, \ i = 1,\dots,I, \sum_{m=1}^{M} z_m = 1, z_m \geq 0, \ m = 1,\dots,M \right\} \quad (53)$$

Second, for every production plan $(\mathbf{x}_{a,t},\mathbf{y}_{a,t})$ with $a\in\{1,2,...,N\}$, the output distance function (3) relative to this sub-sample b is given by:

$$\hat{\hat{D}}^{b,M}_{T_{t,VRS}}\left(\mathbf{x}_{a,t},\mathbf{y}_{a,t}\right)=\min\left\{\theta_{a,t}:\left(\mathbf{x}_{a,t},\mathbf{y}_{a,t}+\theta_{a,t}\sum_{n}\mathbf{y}_{\mathbf{n,t}}\right)\in\hat{T}^{b,M}_{t,VRS}\right\} \quad (64)$$

In the same manner, the output distance function of the aggregate production plan $(\sum_{a=1}^{N}\mathbf{x}_{a,t},\sum_{a=1}^{N}\mathbf{y}_{a,t})$ is computed relatively to the same sub-samples *b:*

$$\hat{\hat{D}}^{G,b,M}_{T_{t,VRS}}\left(\sum_{n=1}^{N}\mathbf{x}_{n,t},\sum_{n=1}^{N}\mathbf{y}_{n,t}\right)=\min\left\{\theta^{G}_{t}:\left(\sum_{n=1}^{N}\mathbf{x}_{n,t},(1+\theta^{G}_{t})\sum_{n=1}^{N}\mathbf{y}_{n,t}\right)\in\hat{T}^{G,b,M}_{t,VRS}\right\} \quad (75)$$

Finally, with $b=1,\ldots,B$, we can derive the empirical distributions of inefficiency scores for all evaluated DMUs and the aggregate production plan:

$$\begin{aligned}
&OI^{G,b,M}_{t}=\hat{\theta}^{G,b,M}_{t}\\
&NRTI^{b,M}_{a,t}=\hat{\theta}^{b,M}_{a,t}\\
&TI^{G,b,M}_{t}=\sum_{a=1}^{N}\hat{\theta}^{b,M}_{a,t}\\
&SI^{G,b,M}_{t}=OI^{G,b,M}_{t}-TI^{G,b,M}_{t}\\
&NRSI^{b,M}_{a,t}=OI^{b,M}_{a,t}-NRTI^{b,M}_{a,t},\forall a\in\{1,2,...,N\}\\
&\text{with: } SI^{G,b,M}_{t}=\sum_{a=1}^{N}NRSI^{b,M}_{a,t}
\end{aligned} \quad (86)$$

Compared to the traditional deterministic model where the entire N observed firms are in (4), only a subsample of size M defines the sub-technology (11). Therefore, in a deterministic approach, the evaluated DMU always belongs to the production set and its inefficiency score is always positive. Conversely, in the sub-sampling approach, the sampling process used on the production set does not guarantee that the evaluated production plan is included in the referent technology. As a result, its inefficiency score can be even negative. In this case, this DMU is above the selected benchmark and is defined as superefficient.

Two parameters characterize such sub-sampling frontiers: the number of replications B and the size M of the sub-samples. The number of replications of the Monte-Carlo simulation do not seem crucial since a choice of an appropriately large B enables to control the sensitivity of the final results. The size parameter M of the sub-samples is more central. If M approaches infinity, the usual estimator (4) is found because each DMU of the initial sample has a high probability to be included into the referent technology. On the other hand if M is too small, the definition of the technology might be irrelevant. As a consequence, through the choice of an arbitrary value of M, the sub-sampling approach implies a compromise between a pertinent definition of the technology and a control of the outlier bias effects on this technology.

2.3. Efficiency Catching-Up and Structural Convergence conditional on Farms' Capabilities and on Agricultural Policy Changes.

The different concepts defined just above (namely overall, technical and structural inefficiencies) reveal that there are two processes that may cause productivity convergence: (i) reaching similar levels of technical efficiencies (ii) achieving homogenous input and output mixes. Consequently by estimating equations (1) and (6) for each replication b, we obtain the empirical distributions of the catching-up and structural convergence parameters (β and φ). The B regressions use inefficiency indexes developed in equation (14). At this stage, it is noteworthy to mention that our approach does not require to choose a particular DMU as the technical leader on a priori grounds. For all DMUs, we estimate their respective productivity gap by the distances to their own benchmarks located on the production frontier.

However, the ability of best practice adoptions might be conditional to the farmers' current environment such as financial or economic situations. Intuitively, a more favorable financial status should generate more opportunities for the farmer to adapt his technology to the best practices located on the production frontier. Moreover, the decoupling of payments should accelerate the tendency of the producers to respond to market signals and thus to reduce their structural inefficiencies. Consequently, we conjecture that the inefficiency indexes decrease with the farms' financial potentials or policy changes. To test these hypotheses, we supplement the standard catching-up convergence models with a set of exogenous variables L describing farmers' capabilities and CAP reform and we estimate equations *(17)* and *(18)*:

$$\frac{\Delta TI_a^b}{TI_{a,t_0}^b} = \beta^b Ln(TI_{a,t_0}^b) + \phi^b L_{a,t_0} + \alpha^b + \mu_a^b \qquad (97)$$

$$\frac{\Delta SI_{a}^{b}}{SI_{a,t_0}^{b}} = \varphi^{b} Ln(SI_{a,t_0}^{b}) + \eta^{b} L_{a,t_0} + \lambda^{b} + \mu_{a}^{b} \qquad (108)$$

The coefficients ϕ^b and η^b are positive if higher levels of L lead to smaller inefficiency levels.

Through the B regressions of *(17)* and *(18)*, we get the empirical distributions for the parameters of interest. Then, by considering the 95% confidence interval of each parameter, it is therefore possible to test the influence of the related explanatory variable on the conditional technical catching-up and the structural convergence processes.

3. Empirical Application: Data and Results

This section provides the data information collected for this study, identifies the variables used in the models and gives our results.

3.1 Data and variables

An unbalanced panel of 289 field crops-specialized[7] farms were observed in the Meuse department between 1992 and 2012. Thus, a total of 2474 observations are obtained from the "Centre d'Economie Rurale de La Meuse" which audits farmers' accounts[8]. Table 1 shows the number of farms according to the different periods.

Table 1: Number of farms per year used to determine the benchmark frontier

1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
150	156	153	150	145	149	147	139	128	125	123
2003	2004(1)	2005	2006	2007	2008	2009	2010	2011	2012	
110	25	105	91	99	104	97	103	97	78	

(1) NB: the very low number of farms in 2004 forced us to ignore this year in our calculations.

7 Crops represents more than 2/3 of the farm turnover (without subsidies). A farm is declared crops-specialized if this ratio is confirmed in the majority of years of presence in the 1992-2012 period.

8 This data base was financed as part of an agreement with INRA.

Over the whole period, about 60% of farms use a land surface comprised between 100 and 200 hectares, 6% have more than 400 hectares and the same proportion have less than 100 hectares, while the smallest one occupy 60 hectares. Labour resources are, on average, around 1.8 annual full-time equivalent (FTE) per farm and range between 0.2 and 5.2. About 6% of farms use external employees.

Our technology includes one output measured by the total turnover excluding subsidies and four inputs (land, labour, intermediate inputs and fixed capital such as equipment and structure). For each farm, land cost for the owned surfaces is estimated through a fictitious price equal to the average annual rental price of the sample leased land. Labour cost comprises total compensation (wages and social contributions) of employees plus family labour cost. The latter includes observed social taxes and a fictitious wage estimated by the SMIC (minimum French salary). Intermediate inputs include operating costs (fertilizers, seeds, pesticides) plus other intermediate inputs (water, electricity, fuel, etc.). Finally, the capital expenditures aggregate amortization related to equipment and buildings and agricultural contractors cost.

Table 2 displays some descriptive statistics on these variables for each period of study: Before the Reform, BR hereafter, containing years from 1992 to 2005 (excluding 2004) and respectively After the Reform, AR hereafter, containing years from 2006 to 2012. For the purpose of this comparison, all monetary variables expressed per ha are deflated by their respective price indexes and are expressed in euros 2010. While we can notice an improvement in the turnover per ha during the period after the Reform, this increase does not seem to be due to an improvement in crop yields, as shown by Figure 3. We conjecture that during the period studied some farms, while maintaining their crop outputs, received some increase in their revenue due to other productions in their mix[9]. Concerning the size of farms, an increasing trend was observed before the reform while no more progression can be detected after the reform. During both periods, labour cost has decreased

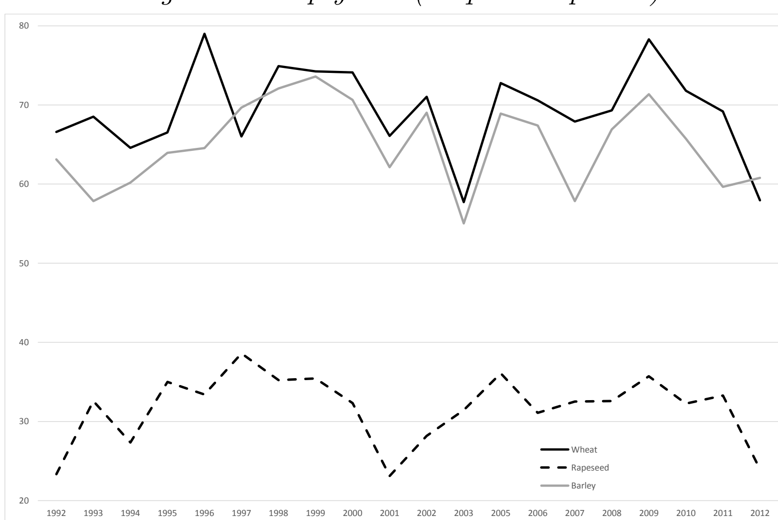
9 Total revenue used in this analysis encompasses, besides the crop revenue, the revenue relative to meat and dairy products (where the latter is subject to the quota system) and revenues from arboriculture and market gardening.

significantly. About capital services and intermediate inputs, one can note that after a decline during the first period, these costs are on the rise again after the reform.

Table 2 : Descriptive Statistics of the Variables

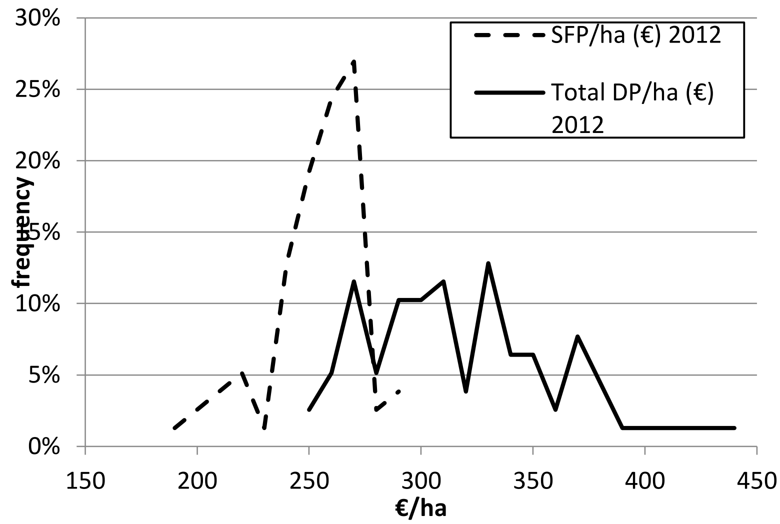
	Before the Reform		*After the Reform*	
Variables	Average	Trend	Average	Trend
Turnover excluding subsidies (constant €/ha)	805	-2%	1096	8%
Agricultural surface (ha)	195	2%	220	0%
Land cost (constant €/ha)	131	1%	138	1%
Labour cost (constant €/ha)	526	-3%	411	-2%
Intermediate input cost (constant €/ha)	444	-1%	452	2%
Capital cost (constant €/ha)	361	-2%	305	4%

Figure 3. Crop yields (in quintals per ha)



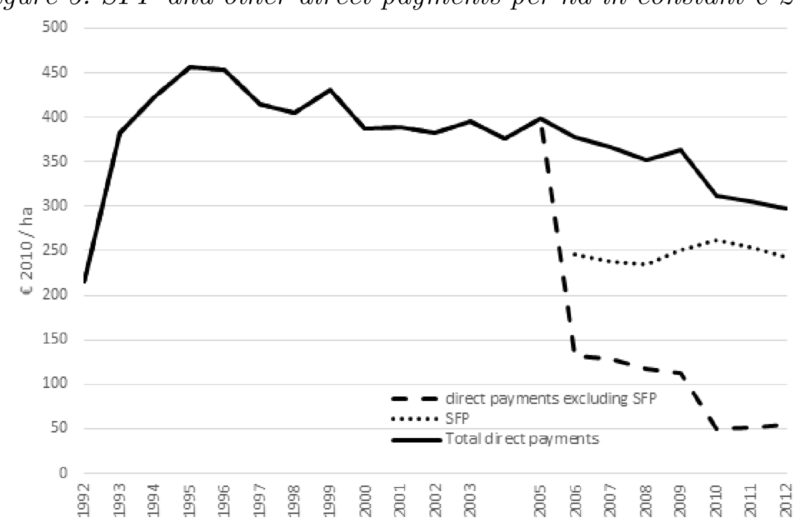
In 2012, direct payments received by farmers in our sample are around 72000 € per farm, where SFP (decoupled payments) represented more than 82%. As shown by Figure 2, this total amount of subsidies reached 310 € per ha on average while SFP amounted to 252 €. The SFP distribution was more concentrated around its mean and varied within the interval [190 € - 310 €] comparatively to the one of total subsidies [250 € - 440 €]. This reveals that SFP were calculated on a relatively similar, historic-based approach, which was not the case for the other types of direct payments.

Figure 4: Sampling distribution of SFP and total direct payments in 2012



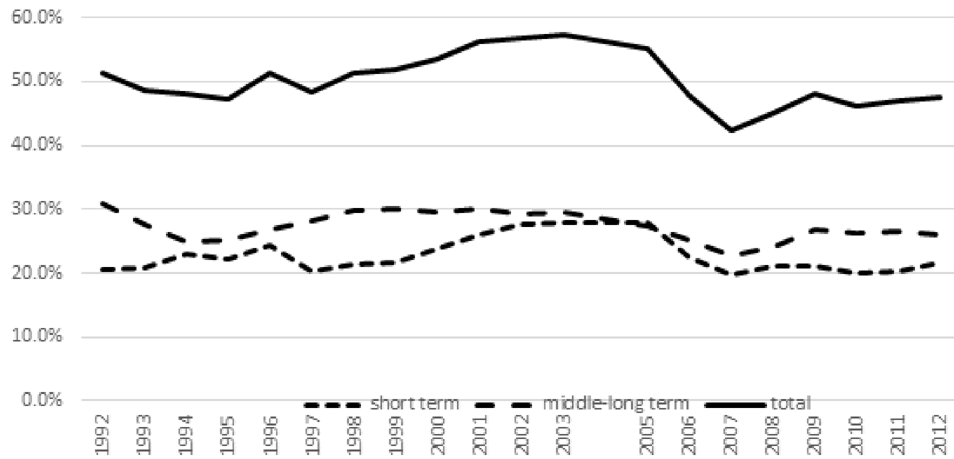
According to the gradual implementation of the 2003 CAP reform, the weights of SFP on total direct payments vary from 66% in 2006 to 82% in 2012. Before 2006, direct payments are on average 31% of the farm turnover. However Figure 3 highlights that after an initial rise between 1992 and 1995 (MacSharry reform), direct payments per ha, expressed in constant euros 2010, suffered a continuous decrease at a rate of -2.1% per year.

Figure 5: SFP and other direct payments per ha in constant € 2010



Concerning the middle-long term and the short term debts, they represent on average 27% and 23% of total assets respectively. As shown by Figure 6, the relative weighting of total debts varies between 42% and 57%.

Figure 6. Debt structure in percentage of total assets



3.2 An analysis of technical and structural inefficiency scores

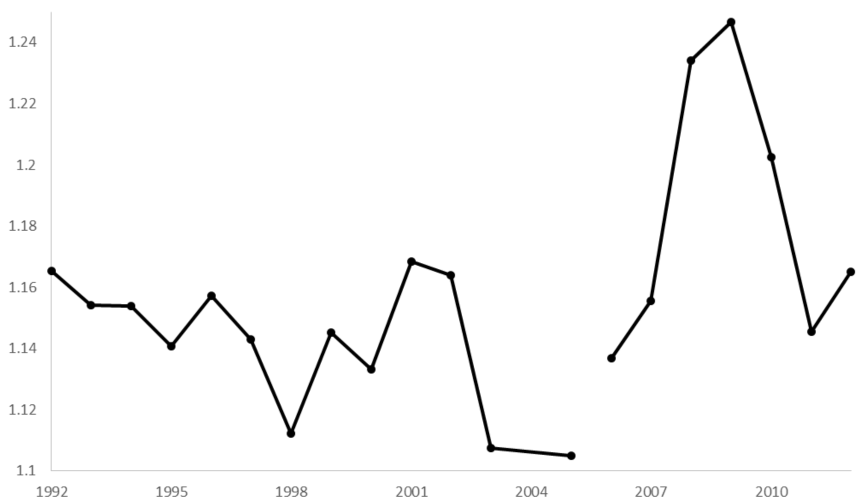
The methodology developed in Section 2 was adapted to our data set. A sub-sampling approach of technical and structural efficiency requires we determine the values for the parameters B, the total number of Monte Carlo independent, uniform replications and M, the size of the sub-set of farms that constitute the referent technology. In this study, B was set at 500 while M was fixed at 75. While the value of B does seem high enough in order to ensure a sound control over the final results, the value of M seemed to be an appropriate compromise between a pertinent technology (the total number of farms varies from 156 to 78 in our data set) and the control of possible outliers bias effect. Note that, since the parameter M is identical for all replications, we will no longer mention it in our formulae.

Using the group inefficiency scores (equation 11), we determined, for each year in our data set, two distributions of 500 technical and respectively structural sector or group (G) inefficiency scores. The average of these scores gives us the group average technical (equation 19) inefficiency scores.

$$\overline{TI}^{G} = \frac{1}{B}\sum_{b=1}^{B} TI_{t}^{G,b} \quad (19)$$

Figure 7 depicts the yearly evolution of the technical inefficiency scores. Although no clear tendency emerges from this figure, one notes after the Reform a peak for the years 2008 and 2009, which can be related to a significant decrease in the prices of cereals and oilseeds and protein-rich plant. In fact, during these two years, farmers reacted to the high prices registered in 2007 by improving their yields through an increase in their intermediate inputs. This process was especially observed for the least efficient farmers, which may explain their movement away from the benchmark.

Figure 7. Average group technical inefficiency over the period of study



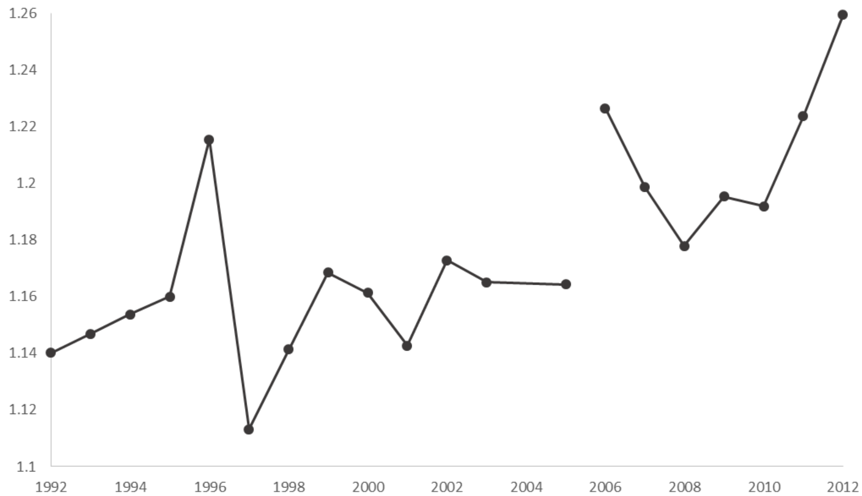
Concerning the yearly evolution of the group structural inefficiency, this variable is calculated by:

$$\overline{SI}^{G} = \frac{1}{B}\sum_{b=1}^{B} SI_{t}^{G,b} \quad (20)$$

Figure 8 shows that the average level of the degree of structural inefficiency is higher after 2006 (the first year when the MTR Reform started to be implemented) than before this period[10]. This result may be due to the rise in volatility for output prices after 2006. Thus, farmers' attempts to homogenize their input-output mixes become even more difficult to achieve.

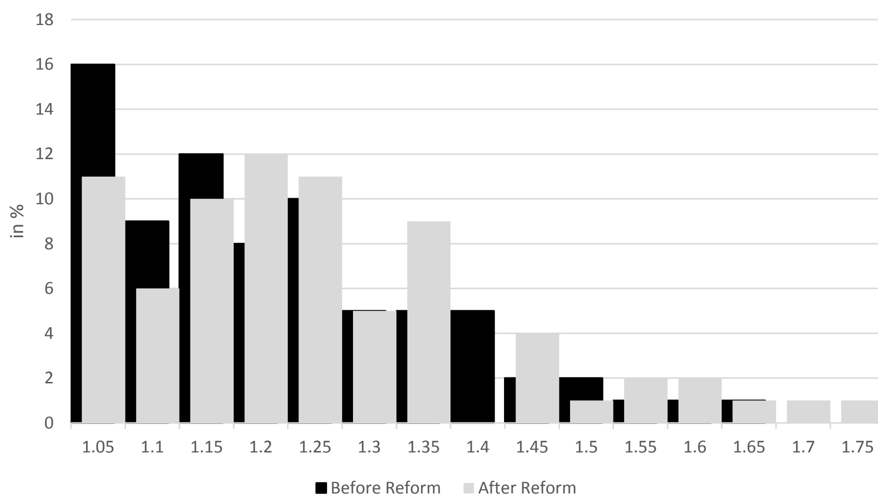
[10] This is confirmed by a significant (at 95%) Mann-Whitney test.

Figure 8. Average group structural inefficiency over the period of study



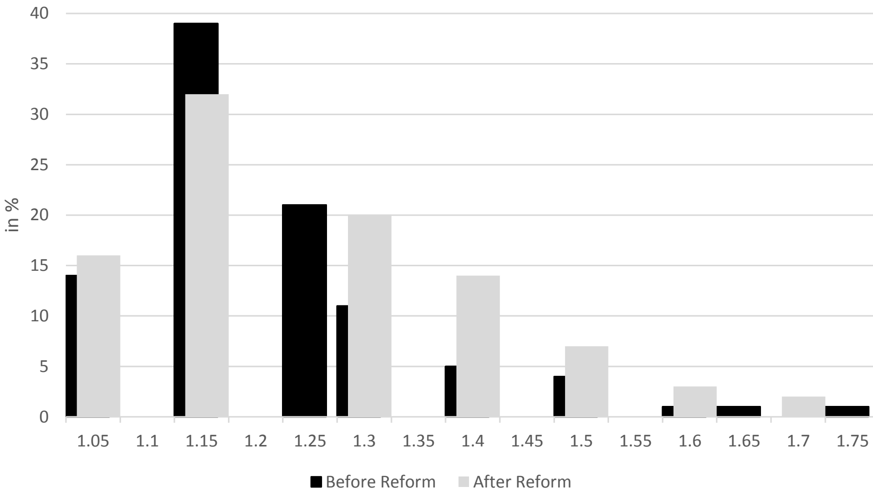
The previous results, established at the group level are reinforced by an analysis of the individual score distributions. Figures 9 and 10 show that after the Reform, both technical and structural inefficiency levels and dispersions increase.

Figure 9: Distribution of the technical inefficiency scores before and after the Reform[11]



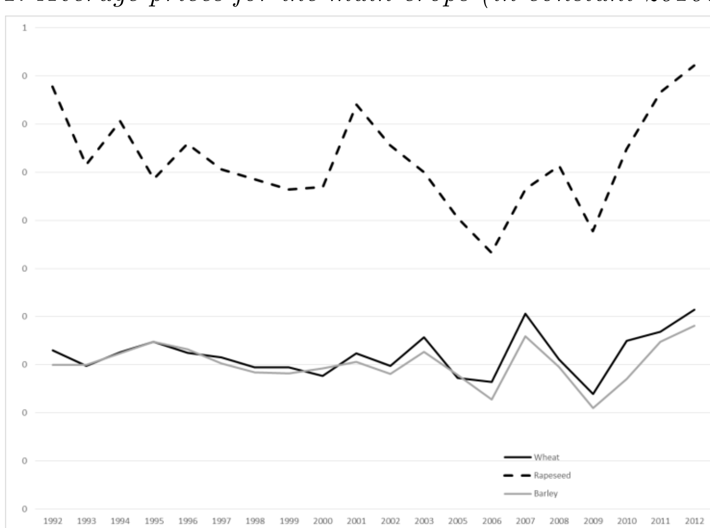
11 Note that before the Reform, the part of efficient farms is 20% while, after the Reform, this share drops to 12%.

Figure 10: Distribution of the structural inefficiency scores before and after the Reform[12]



To complete our understanding of the results regarding structural inefficiency, Figure 11 shows the high volatility for the crop prices after the reform. According to the objectives stated in the MTR reform, we should have observed an improvement in the structural inefficiency score through a process of homogenization of input-output mixes to in response to the market signals. However in this context of price volatility, no clear tendency can be detected by farmers.

Figure 11. Average prices for the main crops (in constant 2010€/quintal)



In what follows, we characterize, in each period of analysis, the most efficient farms and the least inefficient ones. For both inefficiency scores (technical and structural) the

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12 Here, the proportion of efficient farms is of 1% before the reform and respectively 2% after the reform.

efficient class is composed of the first quartile of farms in the ascending order score distribution. Conversely, the least efficient class is the last quartile of farms. Systematic series of Mann Whitney tests compared the two categories of farms on a number of chosen variables: inefficiency scores, financial situations and ratio of subsidies.

Table 3: Chosen variables used in the study

INEFFICIENCIES	$TI_{a,t}$	the technical inefficiency score of the DMU
	$SI_{a,t}$	the structural inefficiency score of the DMU
SUBSIDIES	$SUB_{a,t}$	the ratio of subsidies (Single farm payments and coupled payments) to the total turnover
FINANCIAL SITUATION	$ST_{a,t}$	the ratio of short-term debts to the total assets
	$LT_{a,t}$	the ratio of long-term debts to the total assets

Tables 4 and 5 below summarize our findings representing the median values in each distribution of quartiles *Q1* and *Q4* for the technical and the structural components respectively. When the comparison test came out insignificant the sign of equality (=) was used between the two concerned distributions. When the (one –tailed) comparison test came out significant, the appropriate signs show the direction of the change (< or >).

Table 4. Comparison of the least technical inefficient farms to the most technical inefficient ones Before and After the Reform

	Before the reform			*After the reform*		
Variable	**Q1**	sig	**Q4**	**Q1**	sig	**Q4**
IT	1	<	1.3	1	<	1.4
IS	1.1	=	1.1	1.2	>	1.1
LT	0.3	<	0.3	0.3	=	0.2
ST	0.2	=	0.2	0.2	>	0.1
SUB	0.3	<	0.4	0.2	<	0.3

We can outline several main results concerning technical inefficiency:

1. Before Reform, the most technically efficient farms do not seem to be distinct from the least technically efficient ones in terms of structural inefficiency. This is no

longer the case After the Reform, since the former increase significantly their structural inefficiency.

2. Before the Reform, the least technical efficient farms are more indebted on the long-run than their counterparts. Long-term financial debts appear as a constraint on the productive performance. After the Reform, this effect is no more detected by our significance test.
3. One expected effect of the Reform was to decrease the level of short-term loans through decoupled subsidies which can be considered as cash facilities. However, our results show that this seems to have been the case only for the least technical efficient farms.

Table 5. Comparison of the least structural inefficient farms to the most structural inefficient ones Before and After the Reform

	Before the reform			*After the reform*		
Variable	**Q1**	sig	**Q4**	**Q1**	sig	**Q4**
IT	1.1	=	1.1	1.1	>	1.1
IS	1	<	1.3	1	<	1.4
LT	0.3	>	0.2	0.2	=	0.2
ST	0.2	=	0.2	0.2	=	0.2
SUB	0.3	<	0.3	0.2	<	0.3

Turning to structural inefficiency, we have the following results:

4. After the Reform, the most structural efficient farms deteriorate their technical scores. Consequently, After the Reform, farms do not seem to be able to improve technical and structural efficiencies simultaneously.
5. Before the Reform, the more indebted on the long-run the farms are, the lower their structural inefficiency. Similarly to the technical inefficiency, this significant difference Before the Reform is no longer observed afterwards for the structural component.
6. No significant relationship is detected between the short term financial situation and the structural inefficiency.

Finally some common effects on both types of inefficiency can be established:

7. The ratio of subsidies to total turnover is systematically lower for the most efficient quartile of farms (whatever the efficiency indicator retained) than for the last quartile.
8. We notice a deterioration of the scores after the Reform for the least efficient categories while no such tendency is detected for the leaders[13].

3.3 An analysis of the technical catching-up and structural convergence processes

The benchmark production frontier was determined through a sub-sampling approach described in 2.2. However, for the purpose of the analysis presented here, the evaluated DMUs are only those that are present in our data set for two consecutive years (see Table 6).

Table 6 : Number of farms evaluated in each year and present for two consecutive years

1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
139	139	138	140	133	132	131	131	118	119	112	109

2005	2006	2007	2008	2009	2010	2011	2012
87	87	85	87	90	92	93	73

Extended technical catching-up and structural convergence phenomena are studied with the help of a series of pooled-data regressions described by *(17)* and *(18)*. The dependent variable is the average per Reform-related period of the growth rate of the inefficiency score in two consequent years. The explanatory variables are also calculated as farm averages over the period of interest. Besides the technical and the structural inefficiency scores, the other farm specific explanatory variables are defined in Table 3. The effect of the introduction of decoupled payments is captured by the variable $DEC_{a,t}$, calculated as the ratio of decoupled payments (Single farm payments) to the total amount of subsidies granted to the farm. Moreover, two dummy variables, related to the Reform adoption are used in this model. They replace the intercept that was initially presented in equations (*17*) and (*18*).

13 A series of Mann Whitney tests showed a significant difference in the inefficiency scores of the least efficient farms after the reform compared to their counterparts before the reform.

The model that we used for this series of regressions is a pooled-data model. In what follows, the regression model is given for the technical catching-up effect (*21*). Substituting *SI* for *TI* will lead to the model used to study structural convergence. A different regression is run for each replication *b* in the sub-sampling approach which determined the inefficiency scores. As usual with this type of models, we obtain a different equation along the period of study, identified here by the superscript with $R \epsilon \{BR; AR\}$[14].

$$
\begin{aligned}
&\overline{\left(\frac{\Delta TI_a^b}{TI_{a,t-1}^b}\right)} = \beta^{R,b}\,\overline{Ln\left(TI_{a,t-1}^R\right)} + \phi^{R,b}\,\overline{SUB_a^R} + \varphi^{R,b}\,\overline{DEC_a^R} + \theta^{R,b}\,\overline{ST_a^R} + \omega^{R,b}\,\overline{LT_a^R} + \alpha^{R,b} + \mu^{R,b} \\
&\overline{\left(\frac{\Delta TI_a^b}{TI_{a,t-1}^b}\right)} = \frac{1}{|t_i|-1}\frac{\sum_{t_i \in \Re}\left(TI_{a,t_i}^b - TI_{a,t_i-1}^b\right)}{\sum_{t_i \in \Re} TI_{a,t_i-1}^b} \\
&\overline{Ln\left(TI_{a,t-1}^R\right)} = \frac{1}{|t_i|-1}\sum_{t_i \in \Re} Ln\left(TI_{a,t_i-1}^b\right) \\
&\overline{SUB_a^R} = \frac{1}{|t_i|-1}\sum_{t_i \in \Re} SUB_{a,t_i} \\
&\overline{DEC_a^R} = \frac{1}{|t_i|-1}\sum_{t_i \in \Re} DEC_{a,t_i} \\
&\overline{ST_a^R} = \frac{1}{|t_i|-1}\sum_{t_i \in \Re} ST_{a,t_i} \\
&\overline{LT_a^R} = \frac{1}{|t_i|-1}\sum_{t_i \in \Re} LT_{a,t_i}
\end{aligned}
\qquad (21)
$$

Obviously, for each coefficient, we obtain a distribution of 500 estimated values. A 95% confidence interval is proposed, where the extreme bottom and respectively top 2.5% values are eliminated.

Table 7 summarizes the results of the regressions dealing with the technical catching up process. We first notice that this process took place in both periods, the coefficients β related to the inefficiency score (*Ln*(*TI*)) being negative and significant both before and after the Reform. However, a Mann-Whitney Test showed that the technical catching-up process coefficient decelerated after the implementation of the Reform. Moreover, this process is conditional to the other variables used in the model. Subsidies granted (be they coupled, or decoupled) have a positive and significant sign meaning a slowing down effect on the technical catching up process. By comparing the distributions for this coefficient

14 The period from 1992 to 2003, thus prior to the MTR 2003 is called "BR", while the period following the Reform is called "AR" and covers the years from 2005 to 2012.

before and after the reform, we notice that the effect of this variable increased when the subsidies are decoupled (the average coefficient is 0.408 against 0.275). In what the financial situation of farms is concerned, we observe that, as expected, long-term debts (LT) impeded on farm's managers technical efficiency both before and after the Reform. However, short-term debts do not interfere with this process, in either period.

Table 7. Technical catching-up model:
Confidence intervals and averages for the technical catching-up process

	Before the reform			*After the reform*		
Variables	Percentile 2.5	Percentile 97.5	Average	Percentile 2.5	Percentile 97.5	Average
Ln(TI)	**-0.329**	**-0.083**	**-0.212**	**-0.173**	**-0.033**	**-0.098**
SUB	**0.133**	**0.409**	**0.275**	**0.173**	**0.636**	**0.408**
DEC	-	-	-	-0.0004	0.0001	-0.0002
ST	-0.056	0.012	-0.022	-0.072	0.009	-0.033
LT	**0.031**	**0.096**	**0.064**	**0.033**	**0.124**	**0.078**
Intercept	**-0.115**	**-0.03**	**-0.07**	**-0.138**	**-0.0145**	**-0.0776**

The existence of a technical catching up process established, we now inquire further into the nature of the process. As our discussion around Figure 1 stressed it, this process can actually take two different forms. First, the catching up process takes place on the frontier, with the least efficient farms reducing their inefficiencies and approaching the farms that are already on the benchmark. Second, the most efficient farms move away from the benchmark and the distances with the least efficient ones are reduced. In order to distinguish between these two forms of catching-up (on the frontier and below the frontier), it is necessary to calculate the intersection point of the estimated regression line with the X-axis (here $Ln(TI)$), cf. equation (1). In the case of a multiple regression, the threshold (T_{tech}) is given by:

$$T_{tech}^{b,R} = -\frac{\phi^b \overline{\overline{SUB^R}} + \varphi^b \overline{\overline{DEC^R}} + \theta^b \overline{\overline{ST^R}} + \omega^b \overline{\overline{LT^R}} + \alpha}{\beta}$$
$$with \ R \in \{BR, AR\} \qquad (22)$$

and where variables under the double overline represent the period averages.

If the calculated threshold is negative, then all farms in the data set converge to the frontier. If it is positive, then we infer that the catching up process contains a mix of the two forms.

We obtain, for each period, a distribution of thresholds for which the confidence intervals is determined by eliminating the two extreme 2.5 per cent values (see Table 8). We notice that in both periods these thresholds are positive, implying that each process contains a mix of cases. However, the Mann Whitney test for the comparison of distributions of thresholds between the two periods is significant. This implies that the proportion of cases of catching up below the frontier is relatively higher after the reform than before its adoption.

Table 8. Technical catching up thresholds

	Before the reform			*After the reform*		
Variables	Percentile 2.5	Percentile 97.5	Average	Percentile 2.5	Percentile 97.5	Average
T_{tech}	0.12	0.29	0.17	0.24	0.86	0.42

Turning to the structural convergence process (Table 9), we notice that, in none of the two periods, such a process occurred. Thus, while the adoption of the Reform was meant, amongst other things, to urge farms to better to market signals and consequently to lead to homogenize practices amongst them, our results point towards a failure of the Reform in this sense.

Table 9. Confidence intervals and averages for the structural convergence process

	Before the reform			*After the reform*		
Variables	Percentile 2.5	Percentile 97.5	Average	Percentile 2.5	Percentile 97.5	Average
Ln(SI)	-0.297	0.056	-0.105	-0.2703	0.1444	-0.0607
SUB	**0.357**	**1.172**	**0.706**	-0.299	1.157	0.366
DEC	-	-	-	-0.00004	0.0016	0.0007
ST	-0.052	0.098	0.024	-0.071	0.08	-0.003
LT	-0.086	0.068	-0.01	-0.105	0.08	-0.006
Intercept	**-0.316**	**-0.082**	**-0.192**	-0.216	0.102	-0.047

4. Discussion and conclusions

Thanks to our results, we can draw several main conclusions.

First, over the whole period of analysis, 1992-2012, technical efficiency catching-up is revealed by significant β estimators, although this process has slowed down since 2006. Blancard and Boussemart (2006) had already emphasized the existence of a technical catching up process affecting a selection of French farms in the Nord- Pas-de-Calais region in France between 1994 and 2001. We can thus infer that this phenomenon began with the introduction of coupled direct payments in 1992.

The analysis concerning the thresholds has shown that after the reform the situations of convergence below the frontier are more common than before the reform. In that sense, the catching-up process is mainly due a decrease of the leaders' efficiency. More precisely, in what the technical catching-up effect is concerned, we notice that it is negatively impacted by subsidies. In general, this result is in line with a large body of literature concerning the effects of subsidies on farmers' productive performances. However this catching-up effect is conditional to the type of subsidies granted. Indeed, this phenomenon is even more slowed down with SFP. This conclusion is in contradiction with Rizov et al. (2013) who showed a positive correlation between decoupled payments and productivity growth for a majority of European countries over the period 1990-2008.

Second, no structural convergence process can be detected over the two periods. Moreover table 3 shows a negative relationship between technical and structural efficiencies after the reform. This result points that the technical leaders react to the introduction of decoupled payments by an increase in their heterogeneity in their input-output mixes while the followers maintain more homogenized activities. This phenomenon seems to indicate a specialization process for the most technical efficient farms after the reform which validates the structural inefficiency increase in this period. As mentioned by Blancard et al. (2015), productivity gains from specialization further to the reorganization activities were effectively observed in the Meuse Department.

Third, we notice that least technical efficient farmers substitute decoupled payments for short-term debts in order to solve cash flow issues. However, decoupled payments do not substitute to mid and long-term debts which slow down the process of technical catching-up over the entire period of analysis. The more indebted farms are on the mid and the long run, the bigger their difficulties to finance the necessary investments that would allow them to improve their productivity level. Paul et al (2000) also established, through a different methodology, that in what sheep and beef farming in New Zeeland were concerned, debt to equity ratios were also responsible for large inefficiency levels.

Finally, results obtained in this paper are not in line with the main objectives of the MTR 2003 Reform which were to urge farmers to come up with adequate responses to the market signals and consequently to adapt their activities by improving the management system of their inputs. This could be related to the crop price environment which was very volatile after the implementation of the reform. Thus there is no clear tendency in the market signals for farmers to adapt their structures in the mid-long run.

The 2014 CAP Reform reintroduces targeted coupled aids towards specific objectives, such as the support to vulnerable sectors. This important switch in the philosophy of subsidy grant, and in relation with our results, could lead one to question the merits of the decoupled payments. Thus, this analysis can be extended to include the 2014 CAP Reform which puts greater stress on the environmental issues in addition to a simple cross-compliance procedure, as it was the case for the MTR 2003 Reform. Thus, we could investigate whether there is a catching up effect in terms of eco-efficiency.

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