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TECHNOLOGY ADOPTION IN FRENCH AGRICULTURE AND THE ROLE OF FINANCIAL CONSTRAINTS

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Abstract: Successive CAP reforms have increased the exposure of European agriculture to market forces. As a result, farmers have become preoccupied with their competitiveness and have progressively adopted best practices. However, these long-run technological adjustments could be slowed down by eventual short-run financial constraints. This contribution measures the role of these financial constraints on the catching-up component of total factor productivity for a panel of French farmers in Nord-Pas-de-Calais region during 1994-2001.For TFP estimates based on non-parametric distance functions, the second stage econometric results indicate that the technological adaptation is significantly conditioned by financial constraints.

1. INTRODUCTION

After focusing on increasing production for several decades, the Common Agricultural Policy (CAP) underwent major reforms which took it into a new direction starting around 1990. With a central emphasis on market forces, these reforms have attempted to promote a competitive agricultural sector able to benefit from existing outlets in the world markets, without excessive subsidies and while guaranteeing safe production methods. The new CAP aims to provide quality products to consumers produced by a sustainable agricultural sector. This change of public policy in agriculture, with subsidies gradually uncoupled from production, intended to rebalance the terms of trade in favour of developing countries and to decrease certain distortions in both consumers' and producers' decisions. Earlier, European farmers, benefiting from above market prices, developed production choices and resource allocations incompatible with their comparative advantages, thereby decreasing public welfare. With the new CAP orientation, the improvement of technical and allocative performance has become a major imperative for these farmers. In addition, this attempt to stop the fall in farm income thanks to increases in total factor productivity (TFP) has stimulated new farming production methods that also seem to reduce the negative environmental impacts (mainly by a reduced utilisation of fertilizers and pesticides). However, the speed to reach the best available TFP levels by adopting new technological choices must be linked to the short-run financial situation of farmers. If the latter are short in internal finance and have difficulties accessing credit, their abilities to modify existing technologies decrease. From a theoretical viewpoint, this approach is based upon the adjustment hypothesis as developed by, e.g., Paul, Johnston and Frengley (2000). These authors apply a stochastic distance frontier approach to a panel of beef and sheep farms in New Zealand over the period 1969-1991, which includes the period when regulatory reforms were undertaken. Their hypothesis is that the transition from a subsided agricultural system to a less sheltered context forces farmers to become more efficient, but this transition requires access to financial resources. Farmers with a lower debt are able to adjust more easily, and thus tend to end up being more efficient.

Several papers report the significant influence of financial constraints on productive and technical choices in agriculture (see, for example, Chavas and Aliber, 1993; Nasr, Barry and Ellinger, 1998). Various reasons explain this relationship: (*a*) farmers face substantial lags between outlays for inputs and output sales, (*b*) farm-specific capital is inflexible, (*c*) the nexus between private wealth and farm capital limits possibilities to offer financial guarantees, (*d*) most farms are relatively small, etc. Thus, the access to external financing resources (mostly debt and leasing) being limited, farmers' operations and investments heavily depend on internal financing or short-run financial constraints (Barry and Robison, 2001). As for these short-run financial constraints, several approaches exist in the literature. This paper employs the credit-constrained model initially proposed by Färe, Grosskopf and Lee (1990) and rephrased by Blancard *et al.* (2006) who model financial constraints using short- and long-run profit functions in terms of directional distance functions. Blancard *et al.* (2006) find strong empirical evidence of financial constraints: financially unconstrained farmers are larger, perform better, and seem to benefit from a virtuous circle where access to financial markets allows better productive choices. Following this line of analysis, it is interesting to test the hypothesis that short-run financial constraints, mainly related to treasury fund difficulties and market instabilities or climatic risks, exert major effects on the farmers' long-run technical and allocative decisions and hence on the technological diffusion process. More precisely, the catching-up process of the less productive farms to a production frontier composed of the best observable practices corresponds to a mechanism of technological 4 adaptation: rates of growth of technical efficiency are negatively connected to previous period levels of technical efficiency. In such a dynamic framework, it is then possible to measure catching-up speed conditional on current financial constraints.

Compared to previous studies on productivity convergence in agriculture (see e.g., Gutierrez, 2000; Ball, Hallahan and Nehring, 2004; Coelli and Prasada Rao, 2005), a first contribution of our research is to analyze technological diffusion at the microeconomic level thanks to a panel of 178 arable French farms in the Nord-Pas-de-Calais region during the years 1994–2001. A second contribution is to directly test for the impact of financial constraints on productivity convergence. These financial constraints are evaluated in the productivity catching-up process among farmers using non-parametric specifications of technology and expenditure-constrained profit functions.

A better understanding of the impact of short-run financial constraints on productivity growth can refine current agricultural policy instruments to improve the regulation of agriculture and complete the recent policies aimed at direct revenue support, especially in an EU enlargement context.

This paper is structured as follows. The next section recalls the technical and financial efficiency measures using directional distance functions. Section 3 connects these efficiency scores to the technological diffusion process by developing a convergence model for productivity levels conditional on the short-run financial constraints and other structural effects. Section 4 presents the sample and discusses the dynamic panel econometric results. Conclusions appear in the final section.

2. ASSESSING TECHNICAL AND FINANCIAL EFFICIENCIES USING NON-PARAMETRIC DISTANCE FUNCTIONS

7Usually, farm activities are modelled via a production function whose object is to transform input quantities into goods and services, taking into account the state of the art in farming knowledge. Noting the various ways of effectively combining his production factors, the producer can set up an economic calculation determining an optimal allocation of resources and outputs to guarantee the highest residual income.

It is well-known that the reality of a farm cannot be completely captured by this too simple framework. Indeed, the strategy of a farmer also takes into account financial decision criteria regarding the short and medium run, such as debt capacity, repayment ability or general treasury fund. These liquidity constraints play a role in farm management that is equally important to the respective roles of relative prices and technology potential.

Therefore, it appears essential to explicitly introduce financial variables into the modelling of producer behaviour. From this perspective, several approaches are conceivable.

A first way consists in setting up mathematical programming models to simulate the choices of representative producers within a given area. In these simulation models, a block of explicit financial constraints supplements the usual technical, agronomical and economical constraints to represent farm operations more realistically. Many studies simulating the successive modifications within the CAP have adopted this methodology (Flichman, 1998; Ridier and Jacquet, 2002). To show the effects of financial parameters on producer's investment decisions, Phimister (1996) uses a life cycle model integrating credit constraints.

Starting from the link between household expenses and farm investments, it highlights in an indirect way the limits of external financing and simulates three aspects of the Mac Sharry reform (land set-aside programs, cereal price decreases and compensatory payments).

One can also use a stochastic dynamic model of investment and derive its first-order conditions as a basis for econometric specification (see the Hubbard 1998 survey). For instance, Benjamin and Phimister (2002) provide such estimates for French and British 5 farmers. Although these models solve some weaknesses of the usual models of producers' behaviour, they do not escape from the restrictive assumptions imposed by parametric specifications of the production function (Petrick, 2005): unit or constant elasticity of substitution in the Cobb-Douglas or C.E.S functional forms, valid approximations in a reduced interval of variation around the average for the Translog and generalized Leontieff cases, absence of technical and/or allocative inefficiencies.

Another type of approach employs sample information to estimate the production function parameters where the specification accounts for financial constraints. For instance, Lee and Chambers (1986) adopt such a parametric methodology. Starting from Farrell's pioneering work (1957), non-parametric methods employ distance functions and constitute an alternative way to build production frontiers (see, e.g., the generalisations in Färe, Grosskopf and Lovell (1983)). Färe, Grosskopf and Lee (1990) integrated financial constraints in this framework to measure their influence on producers' choices[1]. Compared to the usual stochastic parametric approaches, non-parametric distance functions avoid the choice of a functional form and allow modelling a multi-product technology within a primal approach.

But, it also presents some disadvantages: the results are sensitive to outliers in the sample if these contribute to the determination of the production frontier, and statistical qualities of the estimators are still poorly understood (Simar and Wilson, 2000).

2.1 TECHNICAL EFFICIENCY AND DISTANCE FUNCTIONS

This section introduces the definitions of technology and the distance function, the latter being both a characterisation of technology as well as a measure of technical efficiency. In particular, the methodological framework adopted in this article takes advantage of the shortage function (Luenberger, 1995) as a representation of technology. This shortage function is dual to the profit function (Chambers, Chung, and Färe, 1998) and generalizes existing distance functions by accounting for both input contractions and output expansions. In the general case of *S* outputs and *M* inputs, the production possibility set is defined by:

$$P = \left\{(x,y) \in R_+^{M+S} : x \text{ can produce } y\right\},$$

where *y* and *x* are an output vector of dimension *S* and an input vector of dimension *M*, respectively. Only the free disposal of inputs and outputs and convexity assumptions are imposed on technology (Färe, Grosskopf and Lovell, 1985). Thus, the directional distance function $D: R_+^{M+S} \to R_+ \cup \{-\infty, \infty\}$ relative to technology *P* can be defined as:

$$D(x,y,g) = \sup_{\theta \in R} \left\{\theta \geq 0; (x - \theta.g_x, y + \theta.g_o) \in P\right\}.$$

A special case of this shortage function is the Farrell proportional distance (Briec, 1997) where the directional vector (*-gi, go*) is equal to the evaluated input-output vector (*x,y*). *D(x,y,g)* can be interpreted as the simultaneous proportional variations of all inputs and outputs. More precisely, in each period *t*, the set *P* groups the pairs (*xt, yt*) corresponding to the annual farm data. With the above

[1] Empirical applications include Arnade and Gopinath (2000), Blancard *et al.* (2006), among others.

assumptions, variable returns to scale production frontiers can be built for each period *t* using the best practices in the sample. The proportional distances of each farm to these annual frontiers are calculated with linear programs measuring the levels of technical inefficiency.

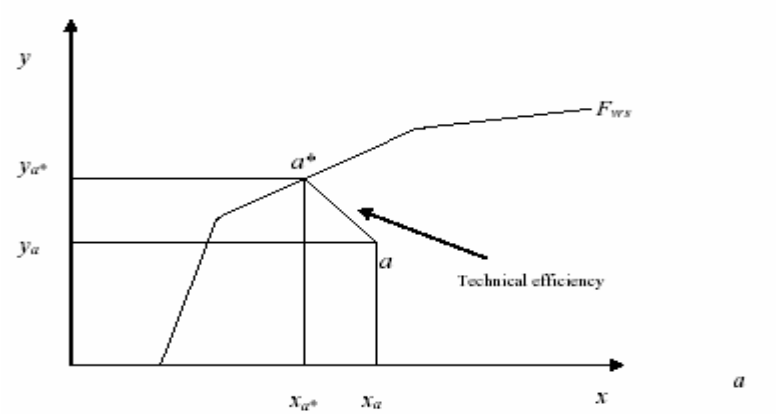

Figure 1

Proportional Distance Function and Technical Efficiency

Empirical applications include Arnade and Gopinath (2000), Blancard *et al.* (2006), among others.

According to Figure 1, if farm adopted the best practices of the group determined by the production frontier under variable returns to scale (*Fvrs*), it could reduce its inputs *xa* to *xa** and simultaneously improve its outputs *ya* to *ya**. Excluding zero values, its level of relative inefficiency (θ_a) measures the percentage of economies in each input as well the percentage of possible expansion in its outputs, hereby:

$$\frac{x_{a^*}}{x_a} = 1 - \theta_a \text{ and } \frac{y_{a^*}}{y_a} = 1 + \theta_a .$$

The measurement of technical efficiency by the proportional distance of decision making unit (DMU) *a* among *N* farms belonging to technology *P* are given by the following linear program:

$$\begin{aligned} &\underset{(\theta_a,\lambda)}{\text{Max}}\ \theta_a \\ &\text{subject to:} \\ &\sum_{n=1}^{N} \lambda_n y_{s,n} \geq (1+\theta_a) y_{s,a},\ \forall\, s \in \{1,2,\ldots,S\} \\ &\sum_{n=1}^{N} \lambda_n x_{m,n} \leq (1-\theta_a) x_{m,a},\ \forall\, m \in \{1,2,\ldots,M\} \\ &\sum_{n=1}^{N} \lambda_n = 1 \\ &\lambda_n \geq 0,\ \forall\, n \in \{1,2,\ldots,N\} \end{aligned} \qquad \text{[LP1]}$$

where , $y_{s,n}$ is the *s*th output and , $x_{n,m}$ is the *m*th input of farm *n*. □is the intensity vector which enables the benchmark or best practice frontier to be constructed from convex combinations of observed inputs and outputs. If DMU *a* is efficient, then □*a* = 1 and *a n* □, □*n* = 0 and □*a* = 1. DMU *a* is positioned on the best practice frontier. In *P*, it is not possible to find another farm or combination of farms producing more of each output and using a lower quantity of inputs than DMU *a*. Coefficient □*a* is applied to the whole of the input-output vector and is assimilated to a coefficient of resources as a radial measure of efficiency.

2.2 VARIABLE PROFIT FUNCTION AND SHORT-RUN DIRECTIONAL DISTANCE FUNCTION

To analyze the role of short-run financial constraints on the long-run technological catchingup process, the input set can be partitioned into two subsets *V*={1, ..., m^v } and *F*= { m^v +1,…. *m*}, where *V* and *F* represents the sets of variable and fixed inputs respectively, with *V* □*F* □□1,...,*m*□

Therefore, each input vector is denoted (*xv*, *xf*), the direction *g* becomes (*gvi* , *gfi* , *go*). Fixing *gfi* = 0, the short-run directional distance function is then defined as:

$$SRD(x^v, x^f, y, g) = \sup_{\theta \in \mathbf{R}} \left\{ \theta \geq 0; (x^v - \theta . g_i^v, x^f, y + \theta . g_o) \in P \right\}.$$

Another technology can be defined with a short-run expenditure constraint (*EC*) representing the maximal amount of expenditures one can spend on variables inputs:

$$P^{EC} = \left\{ (x, y) \in R_+^{M+S};\ (x, y) \in P, w^v . (x^v)^T \leq EC \right\}$$

where

$$w = (w^v, w^f)$$

prices and index *T* indicating the transposition of a vector. Therefore, a standard variable profit function is defined as:

$$V\Pi(w^v, p, x^f) = \sup_{(x^v, y)} \left\{ p.y^T - w^v . (x^v)^T ; (x^v, x^f, y) \in P \right\},$$

while the short-run variable expenditure-constrained profit function is:

$$V\Pi EC(w^v, p, x^f, EC) = \sup_{(x^v, y)} \left\{ p.y^T - w^v . (x^v)^T ; (x^v, x^f, y) \in P^{EC} \right\}$$

Following Luenberger (1992) and Chambers, Chung and Färe (1998) who established duality between directional distance function and long-run profit function, Blancard *et al.* (2006) showed a duality between the short-run directional distance function and the standard variable profit function.

2.3 FINANCIAL EFFICIENCY AND PROFIT DECOMPOSITIONS

For any decision making unit *a*, *V* can be evaluated with the following linear program [LP2]:

$$V\Pi_a(p, w^v, x_a^f) = \max_{(y, x^v, \mu)} [p.y^T - w^v . (x^v)^T]$$

subject to:

$$\sum_{n=1}^{N} \mu_n y_{s,n} \geq y_s,\ \forall\ s \in \{1, \ldots, S\}$$

$$\sum_{n=1}^{N} \mu_n x_{m,n}^v \leq x_m^v,\ \forall\ m \in \{1, \ldots, m^v\} \qquad \text{[LP2]}$$

$$\sum_{n=1}^{N} \mu_n x_{m,n}^f = x_m^f,\ \forall\ m \in \{m^v + 1, \ldots, M\}$$

$$\sum_{n=1}^{N} \mu_n = 1$$

$$\mu_n \geq 0,\ \forall\ n \in \{1, \ldots, N\}$$

while, introducing an additional constraint $w^v . (x^v)^T \leq EC$, [LP2] becomes [LP3] and measures *V E C* For the particular case of a mono-output and mono-input technology, Figure 2 enables to better understand linear program [LP3]. Observations *a* and *b* are technically inefficient while DMU's *c*, *d* and *e* are on the production frontier. If farm *a* wishes to maximize its observed profit corresponding to the line (*JJ'*), it needs to reach the isoprofit line (*HH'*) tangent with the production frontier at *c*. At its optimum level, *a* should adopt the production plan of *c*. Among these five DMU's, only *c* maximizes its profit, all the others are overall inefficient (i.e., they forgo some profits). Considering this level of overall inefficiency, our objective is to separate a financial term from the usual technical inefficiency component. The latter comes from a bad management of inputs, while the first could be partially explained by the presence of a short-run financial constraint

EC illustrated on Figure 2 with the line *EE'*.Graphically, we note than *a*, which is financially constrained, is not able to produce *yc* with*xvc*.

$$x^v = \frac{EC}{w^v}.$$

Instead, it may try to get to the production frontier at *A* and to produce with The corresponding maximum profit level decreases from (*HH'*) to (*II'*). The resulting loss of profit due to the financial constraint is simply the gap between the optimal profits calculated with [LP2] and [LP3] respectively.

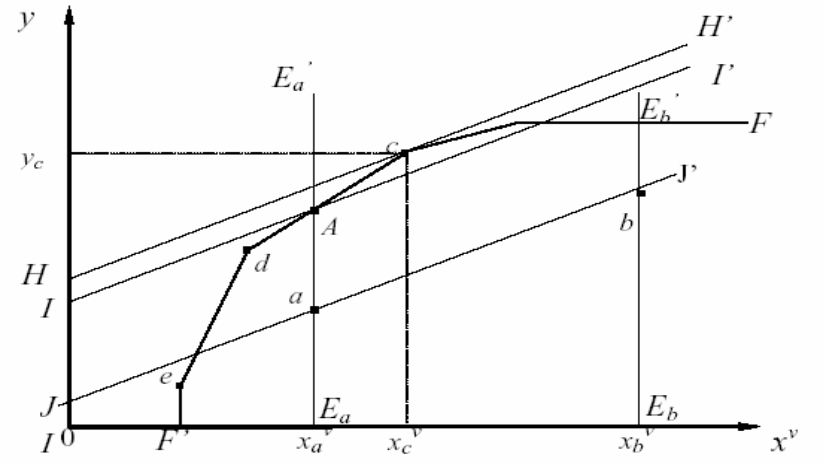

Figure 2

Financial Efficiency and Profit Decompositions

Comparing the two linear programs, we note that

$$V\Pi(w^v, p, x_a^f) \geq V\Pi EC(w^v, p, x_a^f, EC) \geq V\Pi^{observed}(w^v, x_a^v, p, y_a, x_a^f)$$

Therefore, excluding zero values, short-run overall efficiency *(SROE)* and short-run financial efficiency *(SRFE)* for *a* can be defined as:

$$SROE_a = \frac{V\Pi_a^{observed}}{V\Pi_a}$$

respectively

$$SRFE_a = \frac{V\Pi EC_a}{V\Pi_a}$$

with $0 \leq SROE_a \leq SRFE_a \leq 1$. If $SRFE_a = 1$, then the last constraint of [LP3] is not binding. When *SRFEa* < 1, then *a* undergoes a relative profit loss of [*1-SRFEa*] due to the financial constraint. Inversely, for observation *b*, *EE'* is located to the right of *xvc*, the treasury constraint is not binding and the level of profit *OH* can be reached. Therefore, when its observed variable cost exceeds the optimum level, a firm always can reduce its expenditures *xvb to xvc* and adjust its output with *yc*. Consequently, the financial constraint is never binding and *SRFEb* = 1.

Therefore, in line with Färe, Grosskopf and Lee (1990), we adopt a revealed preference argument which leads us to cautiously interpret the expenditure constraint as an indication of possible financial rationing (see Blancard *et al.*, 2006, for a detailed discussion). The total expenditures over the year t indicate the maximum amount the farmer can spend on organizing production. The measure of short-run financial efficiency also requires data both on quantities and prices of input-output vectors. If only value data are available, it is not possible to distinguish these two components and we are led to modify the previous linear programs. Under the assumption that all farms face the same prices, Färe, Grosskopf and Lee
(1990) show that the linear programming optima remain identical. This assumption is not very restrictive for observations located in the same region where prices differ little from one firm to another. On the one hand, crop prices are controlled at the European level. On the other hand, the

agricultural sector remains essentially made up of small organizational structures compared with the firms in other industries. Hence, despite size differences between farms, their capacities to negotiate input prices are not significantly different from one another.

3. PRODUCTIVITY CATCHING-UP PROCESS AND SHORT-RUN FINANCIAL CONSTRAINTS

The convergence debate has revealed that there are two processes that may cause convergence: (i) achieving similar levels of capital intensity and (ii) reaching similar levels of technology. At the macroeconomic level and with the perfect capital mobility and identical technology assumptions, the first process has received most attention (Islam, 2001). But, at the microeconomic level the second process is predominant. In addition, standard growth theory assumes that technological progress is exogenous and is available to all at no cost and thus it says little about technology adoption. Consequently, to examine the catching-up mechanism with an approach which relaxes these above restrictive assumptions, we test for the catching-up hypothesis across farms using technical efficiency indexes developed in subsection 2.1. The methodology employed does not require specifying a particular DMU as the technical leader on a priori grounds and allows estimating productivity gaps as differences in technology among farms. Moreover, by integrating the short-run financial constraints, we dispense with the assumption that technological diffusion is costless. Instead, it depends on the financial position. Therefore, we build a model of productivity catch-up, which assumes that the relative growth in total factor productivity for DMU *i* is determined by a catching-up factor as well as by an individual structural effect and conditional upon the current financial status.

3.1 CONDITIONAL PRODUCTIVITY CATCHING-UP WITH FARMS' STRUCTURAL CAPABILITIES

The technology adoption process can be defined as the structural tendency of the least, productive farms to catch up with the more technically efficient ones. Identifying the DMU's having adopted the best practices (i.e., farms forming the production frontier), the gaps of the other farms to this frontier measure their relative efficiencies. If these distances decrease over time, they reveal a technological catching-up process. In other words, the least productive DMU's align themselves gradually to the more efficient ones if there is a significant negative correlation between the initial level of total factor productivity and its growth rate. Therefore, for each farm *n*, we assume that its productivity growth rate at period *t* depends on the lagged technology gap between the desired and observed level of productivity:

$$\ln(q_{n,t}) - \ln(q_{n,t-1}) = \lambda . \ln\left(\frac{qd_{n,t-1}}{q_{n,t-1}}\right) + u_{n,t} \qquad (1)$$

where , *n t q* and , *n t qd* respectively are the observed and the desired level of productivity of farm *n*. Using a desired level of productivity amounts to assuming that all farms are not immediately able to obtain the same level of productivity.

According to Leibenstein's (1966) concept of "X-inefficiency" (i.e., his theory of technical inefficiency), farms may differ in their ability to recognise, incorporate and use available technology. In an attempt to incorporate this concept in the model at hand, we postulate that the desired level of productivity may be considered as some fraction of the leader's productivity, and that fraction is determined by the farm's aggregate level of specific structural capability:

$$qd_{n,t} = P_{n,t} \cdot q_{L,t} \qquad (2)$$

,where , *L t q* is the leader's productivity corresponding to the projection of the entity on the production frontier built by the linear combinations of the best practices. It is determined by the previous directional distance function *D* and calculated by [LP1]. The concept of "structural capabilities" , *n t P* may encompass many agronomic or economic factors such as land fertility,

farmer's education level, farm's organization and adjustment costs. Thus, no single variable may adequately measure farms' ability to adopt the technology gap. We thus include an individual effect to capture the farm heterogeneity due to structural capabilities in adopting available technology.
Substituting (2) in equation (1) and rearranging yields the following equation:

$$\ln(q_{nt}) - \ln(q_{n,t-1}) = \lambda . \ln\left(\frac{q_{Lt-1}}{q_{nt-1}}\right) + \lambda . \ln\left(P_{nt-1}\right) + u_{nt} \qquad (3)$$

Equation (3) is then rewritten as:

$$\ln(q_{nt}) - \ln(q_{n,t-1}) = \mu_n - \lambda \ln\left(\frac{q_{n,t-1}}{q_{L,t-1}}\right) + u_{nt} \qquad (4)$$

Subtracting (4) from the productivity levels of the projection *L* on the production frontier, finally leads to the equation that we estimate:

$$\ln(\hat{q}_{nt}) - \ln(\hat{q}_{nt-1}) = \mu_n - \lambda \ln\left(\hat{q}_{n,t-1}\right) + u_{n,t} \quad (5)$$

where a "hat" stands for a ratio between a variable of farm *n* and the same variable for its projection *L* on the production frontier.

One can note that the differential of total factor productivity between *n* and *L* at time *t* is linked to the proportional distance function *D* with the relation:

$$\hat{q}_{nt} = \frac{1-\theta_{nt}}{1+\theta_{n,t}}$$

with $\theta_{n,t}$ = optimal level of the LP1 objective function
The logic of this result is illustrated with the help of Figure 1 for *n* = *a* and *L* = *a*:*

$$\hat{q}_a = \frac{\frac{y_a}{x_a}}{\frac{y_{a^*}}{x_{a^*}}} = \frac{1-\theta_a}{1+\theta_a} \qquad (6)$$

3.2 CONDITIONAL SPEED OF CATCHING-UP WITH THE SHORT-RUN FINANCIAL EFFICIENCY

The ability of best practice adoptions is conditional to the farmers' current financial situation. Intuitively, a more favourable short-run financial situation generates more liquidities for the farmer to make the necessary expenditures to adapt its technology to the structural tendencies of the agricultural markets in response to policy changes. Consequently, we conjecture that the total factor productivity growth rate increases in the farm's financial potential. To test this hypothesis, we supplement equation (5) with the short-run financial efficiency (*SRFE*) described previously and estimate equation (7):

$$\ln(\hat{q}_{n,t}) - \ln(\hat{q}_{n,t-1}) = \mu_n - \lambda \ln(\hat{q}_{nt-1}) + \omega . \ln(SRFE_{nt}) + u_{nt} \qquad (7)$$

The coefficient has to be significantly positive: a higher financial efficiency should lead to a larger productivity growth rate.

4. EMPIRICAL ANALYSIS OF THE PRODUCTIVITY CATCHING-UP PROCESS

This section describes the sample, the technology, the results relating to the scores of technical and financial efficiencies, as well as the principal econometric results of the conditional catching-up equation.

4.1 TECHNOLOGY SPECIFICATION AND SAMPLE DESCRIPTION

Our balanced panel data is provided by the Centre d'Economie Rurale (CER) of Pas-de-Calais and concerns 178 farms over the 1994-2001 period. These farms are specialized in cash crops (grain, sugar beets, etc.) and livestock yields only marginal revenues. Following the recommendations of professional advisers, the technology specification retains one output and four inputs:
1. Output is measured by total sales.
2. Number of hectares or surface area.

3. Number of Full-Time Employees (FTEs) on the farm[2].
4. Cost of immobilizations includes mechanization and building expenses (tools, equipment and building depreciations, rent, maintenance and repairs).
5. Intermediate consumption includes operational expenses (fertilizer, seeds, pesticide) and other costs (fuel, lubricants, water, gas, electricity).
Monetary data are deflated using their price indices and expressed in constant 1994 Euros, to neutralize strong price variations over time (especially for the outputs).

Descriptive statistics of the variables used to provide efficiency measures are detailed in Table 1. On average, the farms have a turnover of 225 000 € on an area of 112 hectares with 1.8 FTEs. The sample contains some heterogeneity in size for some variables, but in general the variation is rather low. The coefficients of variation are less than one. Over the period, the annual growth rate was faster for turnover (2.59%) than for hectares (1.11%) and for total worked hours (0.73%). Thus, the volume of sales per hectare or per FTE increased. Also note that output increases faster than intermediate consumption (2.04%), but more slowly than the expenditure relating to immobilizations (4.97%).

Table 1

Descriptive Statistics of the Variables (period 1994-2001)

Table 1: Descriptive Statistics of the Variables (period 1994-2001)

	Mean	Std. dev.	Min	Max	Annual growth rate
Sales (€ 1994)	225 343	138 343	24 678	937 601	2.59%
Intermediate consumption (€ 1994)	51 350	31 438	6 162	185 931	2.04%
Cost of immobilizations (€ 1994)	38 863	30 100	1 612	268 997	4.97%
Surface area (ha)	112.24	60.52	20.80	340.00	1.11%
Full-Time Employees (hired + family labour)	1.80	0.95	0.50	6.50	0.73%

Considering the short-run profit function, we define two variable inputs and three fixed inputs. Variable inputs are: (*a*) intermediate consumption, (*b*) taxes and salaries of hired labour expressed as FTE farm employees. The three fixed inputs are as follows: (*a*) the cost of immobilisations, (*b*) the cost of land is computed by applying rental rates to both hired and owned land, (*c*) the cost of family labour is the sum of minimum wages and the social security taxes paid by employers. As for hired labour, one unit of FTE of family labour equals 2,400 hours per year. Their wage is the minimum wage (defined by the French SMIC), plus social security contributions by the employer.

4.2 TECHNICAL AND FINANCIAL EFFICIENCY RESULTS

Three frontiers are estimated for each of the years[3]. These correspond to the technology under variable returns to scale assumptions, the variable profit function, and the expenditure constrained variable profit functions, respectively. We measured technical and short-run financial efficiency levels using the linear programs, presented in subsections 2.1 and 2.3. The technical efficiency score enables comparing each farmer with all others (including his own) previous total factor productivity. If a farm improves its relative position (technical efficiency increases) over time, then its distance to the production frontier decreases and thus it catches up with the performance of the most efficient farms defining the benchmark.

Table 2 presents the various scores of technical and short-run financial inefficiencies[4]. Over the observation period, average technical inefficiency is around 12%. In other words, the potential gains in total factor productivity would be about 21% (cf. equation 6) if farms were aligned on the

[2] A FTE represents 2,400 hours of labour per year. Blancard *et al.* (2006) disaggregate the labour variable.
[3] To account for a climatic effect, we prefer to calculate a different technology per year. This implicitly integrates this risk into the time dimension of our analysis (instead of computing a common benchmark on the whole of accumulated sample (178 farms over 8 years)).
[4] Inefficiency score = 1-Efficiency score

observable best practices. On average, short-run financial inefficiency is 10%. This implies that farms could improve their profits by about 10% if their variable input expenditures were not financially constrained. Thus, one can note that the mismanagement of the farms is partly explained by technical problems, but that the role of the short-run financial constraints is nearly of the same order of importance.

Table 2

Technical and Financial Inefficiency Scores

Table 2: Technical and Financial Inefficiency Scores

	Technical Inefficiency		Short-run Financial Inefficiency	
	Average	Standard deviation	Average	Standard deviation
1994	16.52%	9.83%	16.82%	15.60%
1995	10.84%	7.56%	13.33%	13.21%
1996	10.95%	6.98%	9.67%	10.82%
1997	9.25%	6.80%	7.84%	9.50%
1998	13.95%	9.19%	7.45%	11.64%
1999	11.06%	7.76%	2.30%	4.98%
2000	10.17%	7.58%	10.36%	11.78%
2001	11.03%	7.57%	12.40%	12.84%

During the sub-period going from 1994 to 1997 the farms improved gradually their technical efficiency and then they underwent a substantial deterioration in 1998 to converge again towards their benchmark between 1999 and 2001. This chaotic evolution of the score dispersion does not make it possible to conclude a phenomenon of technological diffusion among farmers. In fact, this apparent rupture of convergence in 1998 can be partly explained by several facts: the abundance of cereals caused a price decrease and the variance of yield for wheat and sugar-beet were amplified. Does this mean an absence of a technological catching up process?

4.3 ECONOMETRIC ESTIMATIONS

To analyze the process of technological diffusion among farms, equations (5) and (7) are estimated with two alternative estimation methods: cross-section Ordinary Least Squares

(OLS) and dynamic panel data analysis with Generalized Method of Moments (GMM). To account for a climatic effect, we prefer to calculate a different technology per year. This implicitly integrates this risk into the time dimension of our analysis (instead of computing a common benchmark on the whole of accumulated sample (178 farms over 8 years)).

The simple OLS cross-section approach allows testing for absolute or complete catching-up of total factor productivity. However, while this cross-section OLS estimator has been widely used in the growth literature, it has also been criticized on econometric grounds for not controlling unobservable individual effects and for generating potentially confusing results. Another procedure is used in this paper to address these inconveniences: a dynamic panel data estimator integrating a specific structural effect and a short-run financial status for each DMU.

For any dynamic panel equation such as equations (5) and (7), the usual within or error components estimators introduce correlation between the lagged endogenous variable and the error term and are therefore biased and non-convergent (except if N and T go to infinity). A possible solution to this problem consists of first-differentiating the model and then estimating the resulting equation by GMM, using lagged levels as instruments (Arellano and Bond, 1991). In our application,

we chose to instrument the levels of the lagged endogenous variable with the successive first differences and we examine the validity of our instruments by the Sargan/Hansen test. This approach has the advantage of providing more robust estimators compared to the usual Arellano and Bond method (Blundell and Bond, 1998).

Table 3

Productivity Catching-Up Results

Table 3: Productivity Catching-Up Results

	Equation 5 Cross Section - OLS	Equation 5 Panel Data – GMM	Equation 7 Panel Data – GMM
$\hat{\mu}$	-0.131 (0.0%)	-0.081 (2.8%)	-0.090 (1.7%)
$\hat{\lambda}$	0.169 (0.0%)	0.390 (2.2%)	0.518 (0.4%)
$\hat{\omega}$			0.126 (3.9%)
χ^2		5.001 (41.6%)	4.959 (54.9%)

The regressions results of equations (5) and (7) are reported in Table 3: the parameter $\hat{\mu}$ is the common constant estimator of the specific effects μ_n, $\hat{\lambda}$ estimates the annual catching-up speed coefficient[5], and $\hat{\omega}$ measures the short-run financial inefficiency influence on the productivity growth rate. Finally, χ^2 corresponding to the Sargan test statistic validates the instruments for the GMM procedure. All associated p-values are in brackets.

In equation (5) with the OLS procedure, the positive and significant value of $\hat{\lambda}$ signals an absolute productivity catching-up process. Farms with a larger initial gap of productivity converge faster to the production frontier, so that they have caught up with the more efficient ones over the eight year period in our sample. The same equation (5) estimated with the panel data GMM procedure provides a higher productivity catching-up estimator conditional to individual effects capturing the farm heterogeneity due to structural capabilities. Our interpretation of the gap between OLS and GMM estimators of equation (5) is that the diffusion of technology is not precisely captured with cross-section OLS estimators and a large time span of eight years. Indeed, the cross-section procedure encounters an important limitation: having only one observed point per DMU offers a weak basis for estimation of the catching-up coefficient, which refers also to a within-DMU movement. There is far too much heterogeneity across farms to accept that cross section data can be considered as multiple points of a hypothetic homogenous DMU. Therefore, our dynamic panel data model with a yearly time span may be a better statistical tool for evaluating the total factor productivity catching-up process. Moreover, this interpretation is in line with Islam (2003) who shows that the speed of a convergence process increases significantly when using panel data estimation as opposed to cross-section estimation.

Finally, in equation (7), $\hat{\omega}$ is positive and significant indicating a beneficiary effect of the current short-run financial efficiency on the productivity growth rate. These results are compatible with a long-run technological diffusion model conditional upon the current short run financial constraints. Therefore, these econometric results corroborate the hypothesis developed by Paul, Johnston and Frengley (2000). A shift from a subsided agricultural scheme to a less protected context strongly incites farmers to improve their productivity levels conditional upon the availability of financial resources. The farmers with the least short-run debt can adapt their technological choices more easily and thus more quickly obtain better levels of productivity.

Several previous studies carried out on French farms facing the successive CAP reforms have led to comparable results and predicted that the Mac Sharry reform would constitute a strong incentive to reduce technical inefficiencies. Using a different methodological approach, Colson, Chatellier and

[5] With the cross section OLS procedure, the time span of eight years requires to calculate $\hat{\lambda}$ (i.e., the annual rate of catch-up to the benchmark) from the slope coefficient estimate $\hat{\lambda}$ as follows $\hat{\lambda} = -(1/7).\ln(1+\hat{\lambda})$.

Ulmann (1995) showed in their study on field crop farms that the CAP reform had a differentiated favourable effect for the less productive farms. However, their static approach applied the prices and subsidies on the observed farm structures and did not take account of the capacities of the producers' technical adaptations. Thanks to a recursive bio-economic model completed with financial constraints and applied to several farms located in seven different areas, Boussard *et al.* (1997) revealed that the expected effects of the CAP reform would differ according to the areas and structures.

The reform appeared most favourable to farms having the lower technical performances. Moreover, it envisaged using less intensive technology and developing the cultures which benefit from a good agronomic potential at the regional level. Therefore, with the new context of the CAP, the technology adoption process reveals significant changes in farm management.

To prevent the output price decreases and other environmental or supply measures (e.g., land set aside program, pesticide and fertilizer reductions), farmers had to carry out technical efficiency improvements. These latter appeared stronger as the producers were initially distant from their optimal levels of productivity and did not suffer from too hard short-run financial constraints.

5. CONCLUSIONS

The two step approach adopted in this contribution seems particularly adapted to apprehend the phenomena of technological diffusion among farms. Firstly, the use of non-parametric distance functions to estimate various efficiencies does not retain any restrictive assumptions when modelling producer's behaviour (no particular functional form, no technical or allocative efficiency, etc.) Secondly, these efficiency scores are integrated in a productivity catching-up stochastic model conditionally estimated to short-run financial constraints and farm heterogeneity due to structural capabilities in adopting available technology.

The successive CAP reforms and their consequences in terms of price reductions and uncoupled subsidies make farmers re-orient their productive choices on the comparative advantages of their area. Thus, within a particular region the levels of productivity must converge: less efficient farmers are constrained to catch-up with the more productive ones if they want to survive. Moreover, short-run financial constraints significantly influence this process of convergence. Thus, financial resources seem to be key parameters in farm development and should be explicitly integrated into the policies adopted by national governments to complement the CAP.

Therefore, a more flexible access to short-run financial resources by adapted credit and treasury management tools could become a valuable strategic instrument for the agricultural sector. For example, extension of public systems of guarantee or mutual funds at the regional level could allow farms, having some cash difficulties, to obtain necessary credits to finance new projects and thus avoids the slowdown of their growth path. More attractive leasing possibilities, thanks to a fiscal policy facilitating its deduction, could free internal liquidities to manage productive activity. Complementing traditional loans with subsidized rates by offering credit funds with variable annuities linked to the market cycle would allow to partly smooth treasury problems over a limited period.

REFERENCES

1. Arellano, M., S. Bond, 1991, Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations, Review of Economic Studies 58:277-297.
2. Arnade, C., M. Gopinath, 2000, Financial constraints and output targets in Russian agricultural production. Journal of International Development 12: 71-84.
3. Ball, V. E., C. Hallahan, R. Nehring, 2004, Convergence of productivity: An analysis of the catch-up hypothesis within a panel of states, American Journal of Agricultural Economics 86: 1315-1321.
4. Barry, P. J., L. J. Robison, 2001, Agricultural finance: Credit, credit constraints, and consequences. In Gardner, B., G. Rausser, (eds), Handbook of Agricultural Economics, vol. 1a. Amsterdam: Elsevier, 513-571.
5. Benjamin, C., E. Phimister, 2002, Does capital market structure affect farm investment? A comparison using French and British farm-level panel data, American Journal of Agricultural Economics 84: 1115-1129.

6. Blancard, S., J. P. Boussemart, W. Briec, K. Kerstens, 2006, Short- and long-run credit constraints in French agriculture: A directional distance function framework using expenditure-constrained profit functions, American Journal of Agricultural Economics 88: 351-364.
7. Blundell, R., S. Bond, 1998, Initial conditions and moment restrictions in dynamic panel data models. Jounal of Econometrics 87: 115-143.
8. Boussard, J. M., J. P. Boussemart, G. Flichman, F. Jacquet, H. B. Lefer, 1997, Les effets de la réforme de la PAC sur les exploitations de grande culture, Economie rurale 239: 20-29.
9. Briec, W. (1997). A graph type extension of Farrell technical efficiency measure, Journal of Productivity Analysis 8: 95-110.
10. Chambers, R. G., Chung, Y., R. Färe, 1998, Profit, directional distance functions, and Nerlovian efficiency, Journal of Optimization Theory and Applications 98: 351-364.
11. Chavas, J. P., M. Aliber, 993, An analysis of economic efficiency in agriculture: A non-parametric approach. Journal of Agricultural and Resource Economics 18: 1-16.
12. Coelli, T. J., D. S. Prasada Rao, 2005, Total factor productivity growth in agriculture: A Malmquist index analysis of 93 countries, 1980-2000, Agricultural Economics 32 : 115-134.
13. Colson, F., V. Chatellier, L. Ulmann, 1995, Réforme de la PAC et répartition des paiements directs aux exploitations agricoles, Economie rurale 227: 11-20.
14. Färe, R., S. Grosskopf, H. Lee, 1990, A nonparametric approach to expenditureconstrained profit maximization, American Journal of Agricultural Economics 72:574-581.
15. Färe, R., S. Grosskopf, C. A. K. Lovell, 1983, The structure of technical efficiency, Scandinavian Journal of Economics 87: 594-604.
16. ***, 1985, The measurement of efficiency in production. Kluwer-Nijhoff, Boston, 216 p. Farrell, M.J. (1957). The measurement of productive efficiency. Journal of the Royal Statistical Society Part 3, 120: 253-282.
17. Flichman, G., 1998, Modelling agricultural and environmental policy using a bioeconomic approach, Metu Studies in Development Journal 25, 61-74.
18. Gutierrez, L., 2000, Convergence in US and EU agriculture, European Review of Agricultural Economics 27: 187-206.
19. Hubbard, R., 1998, Capital-market imperfections and investment. Journal of Economic Literature 36: 193–225.
20. Islam, N., 2001, Different approaches to international comparison of total factor productivity. In Hulten, C. R., Dean, E. R., Harper, M. J (eds), New Developments in Productivity Analysis, University of Chicago Press, Chicago, 465-502.
21. ***, 2003, What have we learnt from the convergence debate? Journal of Economic Surveys 17: 309-363.
22. Lee, H., R. G. Chambers, 1986, Expenditure-constraints and profit maximization in U.S. agriculture. American Journal of Agricultural Economics 68: 857-865.
23. Leibenstein, H., 1966, Allocative efficiency and X-efficiency. American Economic Review 56: 392-415.
24. Luenberger, D. G., 1992, New optimality principles for economic efficiency and equilibrium.
25. Journal of Optimization Theory and Applications 75: 221-264.
26. ***, 1995, Microeconomic Theory, New York: McGraw-Hill.
27. Nasr, R. E., P. J. Barry, P. N. Ellinger, 1998, Financial structure and efficiency of grain farms, Agricultural Finance Review 58: 33-48.
28. Paul, C. J. M., W. E. Johnston, G. A. G. Frengley, 2000, Efficiency of New Zealand sheep and beef farming: The impacts of regulatory reform, Review of Economics and Statistics 82: 325-337.
29. Petrick, M., 2005, Empirical measurement of credit rationing in agriculture: A methodological survey, Agricultural Economics 33: 191-203.
30. Phimister, E., 1996, Farm household production under CAP reform: The impact of borrowing restrictions, Cahiers d'Economie et Sociologie Rurales 38: 62-78.
31. Ridier, A., F. Jacquet, 2002, Decoupling direct payments and the dynamic of decisions under price risk in cattle farms, Journal of Agricultural Economics 53: 549-565.
32. Simar, L., P. W. Wilson, 2000, Statistical inference in nonparametric frontier models: The state of the art. Journal of Productivity Analysis 13: 49-78.