Short- and Long-Run Credit Constraints in French Agriculture: A Directional Distance Function Framework Using Expenditure-Constrained Profit Functions

Stephane Blancard (CERESUR, *University of La Réunion*)
Jean-Philippe Boussemart (*GREMARS, University of Lille 3)*
Walter Briec *(JEREM, University of Perpignan)*
Kristiaan Kerstens (*CNRS-LABORES, IESEG)*

May 2005

IESEG WORKING PAPER 2005-ECO-2

IESEG School of Management, Catholic University of Lille,
3, rue de la Digue, 59800 Lille France

An earlier version has been published in the following series:

Blancard, S., J.-P. Boussemart, W. Briec, K. Kerstens (2004) Short- and Long-Run Credit Constraints in French Agriculture: A Directional Distance Function Framework Using Expenditure-Constrained Profit Functions, Lille, Université Catholique de Lille (LABORES: Document de travail 2004-03), 30 pp.

This paper contains all information, including appendices, forming the basis for the article with the same title to be published in the ***American Journal of Agricultural Economics***.

Short- and Long-Run Credit Constraints in French Agriculture: A Directional Distance Function Framework Using Expenditure-Constrained Profit Functions

Stephane Blancard (CERESUR, *University of La Réunion*)
Jean-Philippe Boussemart (*GREMARS, University of Lille 3)*
Walter Briec *(JEREM, University of Perpignan)*
Kristiaan Kerstens (*CNRS-LABORES, IESEG)**

Abstract:

This empirical application investigates the eventual presence of credit constraints using a panel of French farmers. This is the first European application using a direct modelling approach based upon axiomatic production theory. The credit constrained profit maximisation model proposed by Färe, Grosskopf and Lee is extended in three ways. First, we rephrase the model in terms of directional distance functions to allow for duality with the profit function. Second, we model the presence of credit constraints in the short-run and investment constraints in the long-run using short- respectively long-run profit functions. Third, we lag the expenditure constraint one year to account for the separation between planning and production. We find empirical evidence of both credit and investment constraints, though their relative impact on the degree of financial inefficiency is rather low in the short-run. Financially unconstrained farmers are larger, perform better, and seem to benefit from a virtuous circle where access to financial markets allows better productive choices. In the long-run, almost all farms seem to suffer from credit constraints for financing their investments.

JEL: D21, D24, Q12, Q14

Keywords: proportional distance function, profit function, credit constraint.

We thank J.M. Boussard and P. Vanden Eeckaut for comments on an early version. Comments of two most constructive referees, R. Chambers, D. Prior, N. Filimon, and participants of seminars in Kiel and Nottingham and of the 8th EWEPA conference (Oviedo) are gratefully acknowledged. D. Newlands offered some stylistic advice. The usual disclaimer applies.

* Corresponding author: CNRS-LABORES (URA 362), IESEG, rue de la Digue 3, F-59800 Lille, France, Tel: ++ / 33 / (0)3 20 54 58 92, k.kerstens@ieseg.fr

Introduction

Production theory and finance have for a long time developed along separate paths as if production and financial decisions and their associated risks could be neatly separated. Only few production models have managed to directly integrate financing issues and risk (e.g., Hughes). For instance, the production of banking services has recently been analysed not only in terms of profits but also in terms of risk preferences, the latter allowing to trade off profit for reduced risk (e.g., Hughes et al.). One issue that did receive some attention is the impact of credit constraints on production. It is meanwhile common knowledge that the presence of informational asymmetry and incentive compatibility problems lead to capital market imperfections such that external financing is more costly than internal financing. The premium tends to be inversely related to the borrower's net worth (see Hubbard; Schiantarelli). In the empirical literature on credit rationing in finance, we are not aware of any study including farming when studying the structure of the commercial loan market (see, e.g., the survey of Valentini). This is probably because most studies focus on companies listed on the stock market.

The problem of credit constraints and rationing is severe in agriculture for various well-known reasons: (i) there is a substantial lag between purchasing inputs and selling outputs, (ii) farm-specific capital is inflexible, (iii) the direct link between private wealth and farm capital limits the possibilities for providing collateral, (iv) most farms are relatively small in size, etc. Some of these characteristics are rather common among the smaller enterprises. Of course, the problem is even worse in less developed countries' agriculture, since these farmers have less collateral under the form of land. The access to external financing resources (mostly debt and leasing) being limited, farmers' operations and investments heavily depend on internal financing (Barry and Robison).

This contribution aims to directly test for the presence and impact of credit rationing in agricultural production using nonparametric specifications of traditional and expenditure constrained profit functions on a panel of French farmers in the Nord-Pas-de-Calais region during the years 1994-2001. Indeed, the differences between profit functions with and without a credit constraint yield a measure of the opportunity cost of lack of credit access (Färe, Grosskopf and Lee; Lee and Chambers). With the exception of the few papers cited below, we are unaware of European studies using this approach.

This modelling strategy is particularly attractive, since the issue of distinguishing between subsets of constrained and unconstrained units is endogenously determined (in contrast to most of the traditional literature: Schiantarelli). By specifying the credit constraint in terms of current expenditures, a sum of internal and external financing resources, one can directly verify whether units are eventually constrained in reaching the profit maximising input and output mix. Farms that are relatively large compared to the profit maximising optimal combination will never appear as credit constrained, since they can always adjust their inputs and outputs downward. But, the relatively smaller units may reveal the presence of credit constraints: when the latter constraint is binding, then the deviation between observed and optimal profits is (partly) attributable to credit constraints. This approach can be interpreted as an attempt to model Kornai's statement that firms do not maximise profits subject to a technological constraint solely, but always face a budget constraint.[1] Without entering into detail (see also below), our approach has the advantage to allow statements about potential profits lost due to credit constraints (this is impossible in certain other approaches (e.g. Euler equation estimation)), though one should admit it has also some limitations (no account of uncertainty or farm household preferences, potential identification problems, etc.).

The presence of credit constraints in agriculture using a similar modelling framework has so far only been directly considered for the USA and India. In particular, Lee and Chambers study the presence of credit constraints in U.S. agriculture using an expenditure constrained profit function at the aggregate level for the years 1947-1980. They find compelling evidence that farmers face binding credit constraints. Tauer and Kaiser find some evidence of a downward sloping supply curve for New York dairy farmers compatible with a profit maximisation model with binding cash flow constraints. For a rather small sample of Californian rice farmers, Färe, Grosskopf and Lee discover that credit constraints bind for only about 20% of the sample. Whittaker and Morehart analyse a small sample of midwestern grain farms in the USA and find 12% of these constrained by their assets and about an equal amount constrained by their debts. Finally, Bhattacharya, Bhattacharya and Kumbhakar report for a small sample of individual jute growers in West Bengal substantial output losses and input misallocations due to the presence of expenditure constraints.

From a policy viewpoint, our benchmarking approach is useful because efficiency measures are reliable predictors of potential financial problems and eventual bankruptcy (Pille and Paradi). Moreover, a better understanding of the extent and impact of credit constraints could contribute to refine current agricultural policy instruments and eventually to enlarge the

---

[1] Since it is an institutionally defined constraint, Kornai distinguishes *soft* and *hard* budget constraints as extremes in a spectrum. He focuses on soft budget constraints in the socialist planning context and sees state paternalism (direct subsidies, interenterprise arrears, tax arrears, etc.) as a cause of the softening of the budget constraint. By contrast, firms in market economies face hard budget constraints, because of the risk of failure and credit rationing. For an overview of this literature in transition economies: see Schaffer.

range of instruments available for regulating the sector. To this purpose, the article employs a Tobit analysis to investigate the determinants of the observed heterogeneity in measured efficiency results. Such knowledge is valuable for European policies in times of trade liberalisation and unstable agricultural markets.

Productive and Financial Performance Measures Based on Profit Frontiers: Methodology

Profit Frontiers and Credit Constraints: Basic Intuitions

Essentially, this article rephrases the basic approach developed in Färe, Grosskopf and Lee (henceforth FGL) who estimate both a profit function with an expenditure-constraint and another one without and test the impact of financial rationing in agriculture by the gap between both profit functions. Furthermore, we extend their article by distinguishing between the presence of credit constraints in both the short- and long-run to differentiate between credit rationing related to operational expenses and investments. Finally, while FGL employ cross-section data, the availability of panel data allows experimenting with lagged expenditure constraints to model the time gap between production decisions (sowing, fertiliser, pesticides, …) and the harvesting of crops at the end of the production cycle. Some parts of the earlier planning may be revised when necessary due to certain contingencies. Therefore, there may well be a divergence between planned and actual budgets, the difference being attributed to planning adjustments.

An important feature of FGL and our own developments is that use is made of an axiomatically founded production model and that one distinguishes between the production possibility set and its boundary. Indeed, the estimation of production frontiers via parametric or nonparametric specifications of technology and economic value functions has recently become a standard empirical methodology (Färe and Primont). This literature yields well-founded measures of economic performance and operationalises the basic distinction between technical and allocative efficiencies. Technical efficiency requires production on the technology boundary; technical inefficiency occurs when production deviates from the frontier. Technical efficiency thus only guarantees reaching a point on the production frontier, not necessarily a point on the frontier maximising, e.g., the profit function. Allocative efficiency, by contrast, measures the adjustments in input and output mixes along the production frontier needed to achieve the maximum of, e.g., the profit function given relative prices. Hence, allocative efficiency presumes the absence of technical inefficiency and verifies simply whether for given prices one manages to achieve the optimal value of the objective function or not. For instance, when production units are situated on the production frontier and assumed to maximise profits, allocative inefficiency results whenever the producer's profits fall short from the maximum.

In reality, the farmer's choices are not only constrained by the technology, but also by additional constraints. Among the most important constraints are regulatory constraints linked to the CAP (e.g., land set-aside provisions), environmental constraints, and credit constraints associated with capital market imperfections.[2] In our modelling strategy we focus on credit constraints and ignore all eventual other constraints. The reason is that most of these constraints apply to all farmers and, furthermore, that no major regulatory changes occurred during the period covered. By contrast, one can expect that not all farmers are equally affected by the existence of credit constraints. If maximal profits in a model with a credit constraint is lower than maximal profits in the basic model, then this can be interpreted as allocative inefficiency relative to the basic profit function. Since agriculture is a sector where planning and production phases are separated by time lags, optimal profits in t are constrained by the level of the credit constraint observed in $t-1$. This special form of allocative inefficiency due to the presence of a credit constraint can be called financial inefficiency.

We briefly illustrate the logic of this modelling approach with the help of figure 1. For simplicity, we focus on the long-run analysis and abstract from the time lag. Assume 4 observations on the production frontier F. For given input and output prices observation c maximises profits at the level Π_c. Consider now two sub-optimal observations: one to the left (e) and another one to the right (f) of point c. Both these observations are technically efficient, but allocatively inefficient compared to observation c. The question is now whether we can unveil any reason for these observed allocative inefficiencies.

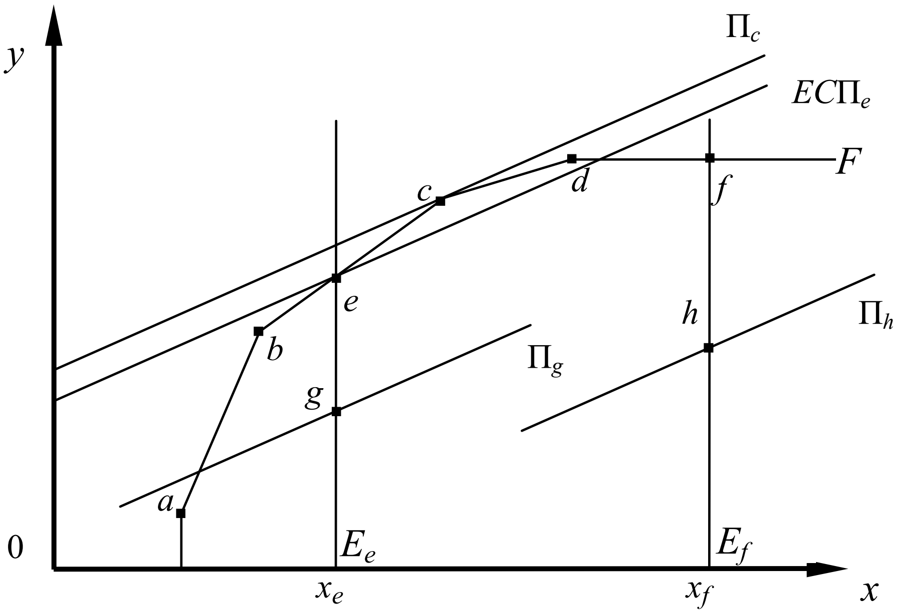
Unit e has expenditures E_e that effectively prevent the unit from increasing its inputs and expanding its outputs to behave like observation c. Unit e is financially inefficient, because the binding expenditure constraint (representing both internal and external financing) potentially explains why it fails to mimic observation c and suffers from a profit gap. Henceforth, its allocative inefficiency may be due to financial reasons. Things are different for unit f. Point f has expenditures E_f, but these expenditures do not constrain the unit in terms of its presumed objective of profit maximisation, since it could always reduce its inputs and outputs to mimic observation c. Consequently, it is financially efficient. Its allocative inefficiency must be due to other reasons (e.g., lack of managerial skills).

---

[2] E.g., Ball et al. and Moro and Sckokai explicitly model land set-aside requirements in a profit function framework.

The same basic story applies to observations *g* and *h*, but these are also technical inefficient. For instance, in the case of unit *g* the gap between optimal (Π_c) and observed profits (Π_g) is decomposed into (i) the difference between the expenditure-constrained ($EC\Pi_g$) and observed (Π_g) profits that measures technical inefficiency, and (ii) the gap between optimal (Π_c) and expenditure-constrained ($EC\Pi_g$) profits that evaluates financial inefficiency. The same story told for unit *f* applies for unit *h*, except that it is also technically inefficient.

Figure 1. Expenditure-constrained profit function



Of course, the specification of the credit constraint is crucial in all this. Ideally, one would like to know all sources of financing, both internally (revenues and other family income) and externally (bank loans, leasing and other credit (e.g., suppliers)). Unfortunately, this information is rarely completely available (e.g., farm household expenses and other revenues are not included in the farm accounting system). Therefore, in line with FGL, we adopt a simple revealed preference argument. The total expenditures over the accounting period indicate the maximum amount the farmer can spend on organising his production. In terms of the above figure, assuming that farmers intend to maximise profits, if observation *e* spends only the amount E_e this is probably because it has no other possibility (in terms of internal or external finance) to augment its expenditures. Otherwise, since it is profitable to spend more on inputs to obtain more outputs, it would have done so. Therefore, observed expenditures reveal the eventual credit constraints in an implicit and imperfect way, since one cannot determine which of the internal or external financing sources causes the expenditure constraint to bind.

In conclusion, while the revealed preference argument leads us to interpret the expenditure constraint as an indication of credit rationing, the fact that other constraints are ignored and that the sources of financing are not fully disclosed should make us cautious in its interpretation. It thus ideally reveals the subset of potentially credit constrained farms and one should expect that our approach tends to overestimate the presence of credit constraints. A detailed comparison of the strengths and weaknesses of our approach relative to alternative modelling strategies is discussed in the last subsection. We end with some concluding remarks. First, to take account of the separation between planning and production phases, the article actually introduces two types of credit constraints: a contemporaneous one, and another one lagged one year. The eventual resulting profit difference is interpreted in terms of planning adjustments. Second, the same story is valid for a short-run analysis accounting for input fixity.

Technology and Distance Functions: Definitions

This section introduces the necessary definitions of the production possibility set, the distance and profit functions. The estimation of efficiency relative to production frontiers relies on the theory of distance or gauge functions. In economics, Shephard distance functions are inversely related to the efficiency measures introduced by Farrell. The input distance function is dual to the cost function, while the output distance function is dual to the revenue function (Cornes; Färe and Primont). The methodological framework adopted in this article takes advantage of the shortage function (Luenberger) as a representation of technology. It generalises existing distance functions and accounts for both input contractions and output improvements when gauging efficiency. Chambers, Chung and Färe show that this shortage (or directional distance) function is dual to the profit function (see also Luenberger 1992, 1995).

Technology transforms inputs $x = (x_1,...,x_n) \in R_+^n$ into outputs $y = (y_1,...,y_m) \in R_+^m$. The set of all feasible input and output vectors is the production possibility set T:

$$T = \{(x, y) \in R_+^{n+m}; \quad x \text{ can produce } y\}. \tag{1}$$

It is standard to impose the following assumptions (e.g, Färe and Primont): (T.1) $(0,0) \in T, (0, y) \in T \Rightarrow y = 0$ i.e., no outputs without inputs; (T.2) the set $A(x) = \{(u, y) \in T ; u \leq x\}$ of observations is bounded $\forall x \in R_+^N$, i.e., infinite outputs are not allowed with a finite input vector; (T.3) T is a closed set; (T.4)

$\forall (x, y) \in T, (x,-y) \le (u,-v) \Rightarrow (u, v) \in T$, i.e., fewer outputs can always be produced with more inputs, and inversely; (T.5) T is convex.

We now discuss the recently introduced directional distance function $D_T : T \to R$ that involves simultaneous proportional input and output variations:[3]

(2) $$D_T(x, y; g_i, g_o) = \sup_{\delta \in R} \{\delta \ge 0; \quad (x - \delta\, g_i, y + \delta\, g_o) \in T\}.$$

It is a special case of the shortage function (Luenberger) and the Farrell proportional distance (Briec), a generalization of the Farrell measure. Input and output distance functions also appear as special cases (see Chambers, Chung and Färe). Note that the directional distance function is defined using a general directional vector ($-g_i$,g_o).

We also need a short-run version of this directional distance function that involves simultaneous proportional variable input and output variations for a given sub-vector of fixed inputs. Therefore, the input set is partitioned into two subsets $V = \{1,\dots,N^v\}$ and $F = \{N^v + 1,\dots,N\}$. V stands for the set of the variable inputs and F represents the set of fixed inputs. Obviously, $\{1,\dots, N\} = V \cup F$. Now, inputs are partitioned such that each input vector is denoted $x = (x^v, x^f)$. Similarly, the direction g is denoted $g = (g_i^v, g_i^f, g_o)$. Fixing $g_i^f = 0$, the short-run directional distance function is then defined as:

(3) $$SRD_T(x, y; g) = D_T(x^v, x^f, y; g_i^v, 0, g_o) = \sup_{\delta \in R} \{\delta \ge 0; (x^v - \delta\, g_i^v, x^f, y + \delta\, g_o) \in T\}.$$

To analyse expenditure-constraints in production, we define two production possibility sets: (i) one with a long-run expenditure constraint:

(4) $$T^{E_L} = \{(x, y) \in R_+^{n+m}; \quad (x, y) \in T, \quad w.x \le E_L\},$$

and (ii) one with a short-run expenditure constraint:

(5) $$T^{E_S} = \{(x, y) \in R_+^{n+m}; \quad (x, y) \in T, \quad w^v.x^v \le E_S\}.$$

Clearly, the first production possibility set aims at evaluating the presence of investment constraints, while the second set targets on revealing the existence of short-run financing constraints.[4]

The next element needed for our analysis is the standard long-run profit function:

---

[3] Axiomatic properties are treated in detail in Briec and Chambers, Chung and Färe.

[4] To characterise production, it is possible to define long- and short-run versions of the proportional distance function relative to these expenditure-constrained production possibility sets. But expenditure-constrained directional distance functions are identical to their counterparts measured on technologies without expenditure constraints: since they look for reductions in inputs and expansions in outputs, they are unaffected by the presence of an expenditure constraint which only prevents selecting higher input levels.

$$
(6)\qquad \begin{aligned}\Pi(w, p) &= \sup_{x,y}\{p.y - w.x;\ (x, y) \in T\} \\ &= \sup_{x,y}\{p.y - w.x;\ D_T(x, y; g_i, g_o) \geq 0\}.\end{aligned}
$$

Luenberger and Chambers, Chung and Färe show duality between the directional distance function and the standard long-run profit function.

Distinguishing between input prices of variable and fixed inputs $w = (w^v, w^f)$, the short-run or restricted total profit function is:

$$
(7)\qquad SR\Pi(w, p, \bar{x}^f) = \sup_{x^v,y}\{p.y - w^v.x^v - w^f.\bar{x}^f;\ (x^v, \bar{x}^f, y) \in T\},
$$

while the short-run variable profit function is:

$$
(8)\qquad SRV\Pi(w^v, p, \bar{x}^f) = \sup_{x^v,y}\{p.y - w^v.x^v;\ (x^v, \bar{x}^f, y) \in T\}
$$

Obviously, $SRV\Pi(w^v, p, \bar{x}^f) \geq SR\Pi(w^v, p, \bar{x}^f)$.

It is rather straightforward to establish duality between the short-run directional distance function (3) and the short-run variable profit function (8).[5]

Proposition 1. *Under the assumptions above, we have:*

a) $SRV\Pi(w^v, p, \bar{x}^f) = \sup_{x^v,y}\{p.y - w^v.x^v;\ SRD_T(x, y; g) \geq 0\}$,

b) $SRD_T(x^v, \bar{x}^f, y; g) = \inf_{w,p\geq 0}\left\{\dfrac{SRV\Pi(w^v, p, \bar{x}^f) - (p.y - w^v.x^v)}{p.g_o + w^v.g_i^v}, (p, w) \neq 0\right\}$.

Proof: See Appendix 1.

To take account of credit-constraints when optimising profits, we first need to define the long-run expenditure-constrained profit function:

$$
(9)\qquad EC\Pi\,(w, p, E_L) = \sup\{p.y - w.x\,;(x, y) \in T^{E_L}\},
$$

where E_L is the predetermined level of expenditures the producer cannot exceed when procuring all inputs. The definition of the corresponding short-run variable expenditure-constrained profit function is:

---

[5] Actually, since we develop a difference-based version of this duality relationship, this duality result would also hold between the short-run total profit function (7) and the short-run directional distance function (3), since the fixed cost terms cancel out. However, in a ratio based approach, such duality result could not be maintained, while the former (between (3) and (8)) can. Therefore, we focus on the former duality result.

(10) $$SRVEC\Pi\,(w, p, \bar{x}^f, E_S) = \sup\left\{p.y - w^v.x^v\ ; (x, y) \in T^{E_S}, x^f = \bar{x}^f\right\},$$

where E_S is the amount of outlays one can spend on variable inputs solely.[6]

Integrating Credit Constraints into Profit Efficiency Decompositions

Having defined all basic elements for gauging performance, we can treat the problem of defining a proper decomposition of efficiency. First, we repeat the basic additive decomposition of profit efficiency developed in Chambers, Chung and Färe and briefly indicate how it can be defined for the short-run case. Then, transforming the FGL ratio approach to the additive context, we extend the analysis for the expenditure-constrained context in both the long- and the short-run.

Chambers, Chung and Färe first define the overall efficiency (*OE*(*x,y,p,w*)) index as the quantity:

(11) $$OE(x, y, p, w) = \frac{\Pi(p, w) - (p.y - w.x)}{pg_o + wg_i}$$

Then, they continue by characterising a technical efficiency (*TE*(*x,y*)) index as the quantity:

(12) $$TE(x, y) = D_T(x, y)$$

Finally, the allocative efficiency (*AE*(*x,y,p,w*)) index is defined as the quantity:

(13) $$AE(x, y, p, w) = OE(x, y, p, w) - D_T(x, y)$$

Thus, *OE*(*x,y,p,w*) is simply the ratio between (i) the difference between maximum profit and the observed profits for the observation evaluated and (ii) the normalised value of the direction vector $g = (-g_i, g_o)$ for given output and input prices (*p,w*). Chambers, Chung and Färe call this Nerlovian efficiency. Having previously defined technical and allocative efficiency in detail, the notion of overall efficiency ensures that both these ideals of technical and allocative efficiency are realised simultaneously. Obviously, the following additive decomposition identity holds:

(14) $$OE(x, y, w, p) = AE(x, y, w, p) + TE(x, y)$$

Notice that all three components are semi-positive, with zero indicating efficiency. This implies that increases in efficiency are reflected in decreasing scores.[7]

---

[6] These profit functions are dual to long-run respectively short-run expenditure-constrained directional distance functions mentioned in the preceding footnote.

[7] Balk defines all three components such that they are semi-negative, with zero again indicating efficiency and increasing efficiency scores now reflecting increases in efficiency.

Similar components of overall efficiency based upon the short-run variable profit function can be defined. Setting the fixed input dimensions in the directional vector equal to zero ($g_i^f = 0$), short-run overall efficiency ($SROE(x^v, \bar{x}^f, y, w, p)$) is defined as the quantity:

$$SROE(x^v, \bar{x}^f, y, w, p) = \frac{SRV\Pi(w\ , p, \bar{x}^f) - (p.y - w^v.x^v)}{pg_o + w^v g_i^v} \tag{15}$$

We briefly spell out the above decomposition. Short-run technical efficiency corresponds to the short-run directional distance function ($SRTE(x^v, \bar{x}^f, y) = SRD_T(x, y, g).$). A short-run allocative efficiency ($SRAE(x^v, \bar{x}^f, y, w, p)$) index again bridges the gap between $SROE(x^v, \bar{x}^f, y, w, p)$ and $SRTE(x^v, \bar{x}^f, y)$. Since in the empirical section we cannot separate the latter components, we ignore this basic taxonomy in the extended decompositions of overall efficiency developed below.

Next, we turn to the issue of adopting the FGL decomposition for the additive context. They distinguish between actual and financial short-run efficiency. Actual efficiency is defined as the ratio between observed profits and a short-run expenditure-constrained profit function. Financial efficiency is identified as the short-run expenditure-constrained profit function divided by the short-run profit function. Inspired by FGL, we can now start adapting the above overall efficiency components for the expenditure-constrained context. The decomposition needs mainly adaptation since lagged expenditure constraints are included in the empirical analysis, representing the separation between planning and production phases in agriculture. This leads us to add a planning efficiency component to the above decomposition. We first develop the extended decomposition from a long-run perspective. Thereafter, we switch to a short-run viewpoint taking account of short-term fixities in inputs.

First, one can define long-run financial efficiency as the difference between overall efficiencies without and with a lagged expenditure constraint:

$$\begin{aligned} LRFE(x^v, \bar{x}^f, y, w, p, E_L) &= OE(x, y, w, p) - ECOE(x, y, w, p, E_L^{t-1}) \\ &= \frac{\Pi(w, p) - EC\Pi(w, p, E_L^{t-1})}{pg_o + wg_i} \end{aligned} \tag{16}$$

where the long-run expenditure-constrained overall efficiency (*ECOE*) index incorporating a lagged expenditure constraint is defined as the quantity:

$$ECOE(x, y, w, p, E_L^{t-1}) = \frac{EC\Pi(w, p, E_L^{t-1}) - (p.y - w.x)}{pg_o + wg_i} \tag{17}$$

This component is positive whenever the lagged expenditure constraint turns out be binding in the long-run expenditure-constrained profit function. When this expenditure constraint is active, then the long-run overall efficiency is larger than the long-run expenditure-constrained overall efficiency. This component indicates the loss of profits due to the expenditure constraint. It thereby reveals any eventual difficulties farmers encounter when financing their investments.

Then, long-run planning efficiency can be characterised as the difference between long-run overall efficiencies with lagged and current expenditure constraints:

$$\begin{aligned} LRPE(x, y, w, p, E_L^t, E_L^{t-1}) &= ECOE(x, y, w, p, E_L^{t-1}) - ECOE(x, y, w, p, E_L^t) \\ &= \frac{EC\Pi(w, p, E_L^{t-1}) - EC\Pi(w, p, E_L^t)}{pg_o + wg_i} \end{aligned} \tag{18}$$

where the long-run expenditure-constrained overall efficiency index incorporating a contemporaneous expenditure constraint reads:

$$ECOE(x, y, w, p, E_L^t) = \frac{EC\Pi(w, p, E_L^t) - (p.y - w.x)}{pg_o + wg_i} \tag{19}$$

Since parts of the earlier planning may be revised when necessary due to certain contingencies, lagged planning and actual budgets may well slightly diverge. This eventual difference shows up in the associated long-run expenditure-constrained profit functions. This long-run planning efficiency component can be interpreted as a planning adjustment, since it takes both positive and negative values.

Finally, long-run actual efficiency is:

$$LRACTE(x, y, w, p, E_L^t) = ECOE(x, y, w, p, E_L^t) \tag{20}$$

It is the difference between the long-run expenditure-constrained profit function and observed profits, normalised by the value of the directional vector.

Clearly, the complete decomposition now reads:

$$LROE(x, y, w, p) = LRFE(x, y, w, p, E_L) + LRPE(x, y, w, p, E_L^t, E_L^{t-1}) + LRACTE(x, y, w, p, E_L^t) \tag{21}$$

Basically, this is just the difference-based equivalent of the ratio-based efficiency decomposition of FGL, extended with a long-run planning efficiency component, because of the presence of a lagged expenditure constraint.[8]

---

[8] The last component, i.e., long-run actual efficiency, can be decomposed into technical and allocative efficiencies. The same remark also applies to the short-run equivalent expression developed further down the text.

Turning to a short-run perspective, one first defines short-run financial efficiency as the difference between overall efficiencies without and with a lagged expenditure constraint:

$$\begin{aligned} SRFE(x^v, \bar{x}^f, y, w, p, E_s) &= SROE(x^v, \bar{x}^f, y, w, p) - SRECOE(x^v, \bar{x}^f, y, w, p, E_s^{t-1}) \\ &= \frac{SRV\Pi(w\ , p, \bar{x}^f) - SRVEC\Pi(w, p, \bar{x}^f, E_S^{t-1})}{pg_o + w^v g_i^v} \end{aligned} \tag{22}$$

where the short-run expenditure-constrained overall efficiency (*SRECOE*) index incorporating a lagged expenditure constraint is defined as the quantity:

$$SRECOE(x^v, \bar{x}^f, y, w, p, E_S^{t-1}) = \frac{SRVEC\Pi(w, p, \bar{x}^f, E_S^{t-1}) - (p.y - w^v.x^v)}{pg_o + w^v g_i^v} \tag{23}$$

This component is positive whenever the lagged expenditure constraint turns out be binding in the short-run expenditure-constrained profit function. When this expenditure constraint is active, then the short-run overall efficiency is larger than the short-run expenditure-constrained overall efficiency. Consequently, a positive component measures short-run profits foregone because of the expenditure constraint.

Then, short-run planning efficiency can be characterised as the difference between short-run overall efficiencies with lagged and current expenditure constraints:

$$\begin{aligned} SRPE(x^v, \bar{x}^f, y, w, p, E_s^t, E_s^{t-1}) &= SRECOE(x^v, \bar{x}^f, y, w, p, E_s^{t-1}) - SRECOE(x^v, \bar{x}^f, y, w, p, E_s^t) \\ &= \frac{SRVEC\Pi(w, p, \bar{x}^f, E_S^{t-1}) - SRVEC\Pi(w, p, \bar{x}^f, E_S^t)}{pg_o + w^v g_i^v} \end{aligned} \tag{24}$$

where the short-run expenditure-constrained overall efficiency index incorporating a contemporaneous expenditure constraint reads:

$$SRECOE(x^v, \bar{x}^f, y, w, p, E_S^t) = \frac{SRVEC\Pi(w, p, \bar{x}^f, E_S^t) - (p.y - w^v.x^v)}{pg_o + w^v g_i^v} \tag{25}$$

Since parts of the earlier planning may be revised, when necessary due to certain contingencies, lagged planning and actual budgets may well slightly diverge. This eventual difference shows up in the associated short-run variable expenditure-constrained profit functions. This short-run planning efficiency component can be interpreted as a planning adjustment, since it can take both positive and negative values.

Finally, short-run actual efficiency is:

$$SRACTE(x^v, \bar{x}^f, y, w, p, E_s^t) = SRECOE(x^v, \bar{x}^f, y, w, p, E_s^t) \tag{26}$$

It is the difference between the short-run expenditure-constrained variable profit function and observed variable profits, normalised by the value of the directional vector.

Clearly, the complete decomposition now reads:

(27)

$$SROE(x^{v}, \bar{x}^{f}, y, w, p) =$$

$$SRFE(x^{v}, \bar{x}^{f}, y, w, p, E_{s}) + SRPE(x^{v}, \bar{x}^{f}, y, w, p, E_{s}^{t}, E_{s}^{t-1}) + SRACTE(x^{v}, \bar{x}^{f}, y, w, p, E_{s}^{t})$$

Details about the computations of the underlying frontier technologies are spelled out in appendix 2 (available upon request).

Contrast with Other Methodologies

Several approaches yield evidence of the existence of credit constraints affecting agricultural production. We briefly mention these methods and highlight their advantages and shortcomings as they have been surveyed by Petrick. First, one can attempt to directly measure loan transaction costs (cost of information collection, application, etc.). But, this is problematic because (i) rationing here becomes a price rather than a quantity concept, and (ii) there are evaluation problems of opportunity cost both on the side of clients (e.g., time) and suppliers, among others. Second, qualitative information can be obtained via interviews asking whether people would have liked to borrow more at prevailing interest rates. This method mainly suffers (i) from the subjective nature of responses and (ii) it cannot assess the severity of rationing. A variation on this second method is to ask the respondent for his credit limit, i.e., the maximum amount a lender is offering. But, while answers to this question yield quantitative information, this type of question turns out to be difficult to understand and to respond precisely. Third, the access of farmers to alternative sources of credit (e.g., informal and trade credit) yields a picture of the spillover effects of eventual limited access to the primary source of formal credit channels. This approach offers valuable information when the assumption that secondary credit sources are more expensive than primary sources proves valid.

Fourth, using a static, micro-economic household model the impact of credit restrictions can be tested by checking whether farmer's consumption and investment decisions are mutually dependent and by comparing marginal revenues of credit to observable interest rates.[9] Finally, another theoretically well-founded approach uses a stochastic dynamic model of investment and derives its first-order conditions as a basis for econometric specification (see also the survey by

---

[9] Phimister is an example of a study providing some simulations for France (and ignored by Petrick).

Hubbard).[10] For USA data, e.g., Hubbard and Kashyap and Bierlen and Featherstone find significant influence of financial variables on investment that lead them to reject the perfect capital market model. Benjamin and Phimister provide estimates for French and British farmers: while in the earlier study financial variables do not improve model fit, the later study finds significant financial variables. But, there are some minor differences among both countries: e.g., sensitivity to cash flow is higher in France. Petrick maintains that the last two approaches are very demanding in terms of data availability and depend on the validity of the assumptions used in the econometric and simulation methods (functional forms, specification, etc.).[11] We return to the evaluation of both approaches below.

To complete the taxonomy of methodologies in Petrick, it is eventually useful to mention two more approaches. First, bio-economic simulation models have marginally touched upon the eventual presence of credit constraints (see Oriade and Dillon for a review). For instance, Boussard has found some evidence of credit rationing for French farmers. Second, the analysis of inefficiencies in production and its underlying causes yields some perspectives on the influence of credit rationing (see the survey by Battese). Since our approach is situated within this literature, we offer a small selection of studies. Ali and Flinn report credit constraints among the socio-economic factors explaining profit inefficiencies in Pakistan. Other studies corroborating the influence of credit constraints as an explanatory factor of poor performance include Kalirajan using Philippine data and Liu and Zhuang studying Chinese data, among others. Similar results have been reported for agriculture in developed countries. Brümmer and Loy evaluate the European Farm Credit Program (FCP) whereby selected “competitive” farms obtain investment loans at subsidised interest rates. This improved access to capital and hence new technologies should increase farmers’ productivity. However, for a large panel of dairy farms in North Germany they find the FCP fails to increase technical efficiency of participating farms. Nasr, Barry and Ellinger, testing several explanations for the relation between financing and farm efficiency, find some support for Jensen’s free cash flow concept whereby a greater dependence on debt to finance current operations improves technical efficiency.

Compared to the main literature on production inefficiencies, our model measures the presence of credit constraints directly rather than indirectly, i.e., as a determinant of measured inefficiencies in a second stage regression. We believe our own approach shares with the two last approaches mentioned in the Petrick survey that it is well-founded in micro-economic

---

[10] These dynamic investment models often include a debt ceiling constraint: Chatelain shows how to obtain an explicit expression for the Lagrange multiplier of such a binding constraint.

theory. A more detailed comparison with these two approaches can be made along the following lines. First, while our contribution remains entirely static just like the household model investigating farm consumption and investment, the investment Euler equations involve dynamic optimisation behaviour. Second, we employ nonparametric technologies that do not impose any functional form on technology, while the results of both other approaches may well be affected by choice of particular functional forms. Third, our contribution uses frontier technologies that allow for any eventual inefficiency, while both other approaches maintain the hypothesis of perfectly static respectively dynamic optimising behaviour. Fourth, the binding nature of the credit constraint is endogenously determined in our approach just like in the farm household model, but unlike the investment models where this is often added under the form of prior information.

Overall, from the above comparison it should be clear that our empirical modeling strategy uses as few maintained hypotheses as possible.[12] The main qualifications are (i) that the expenditure constraint only reveals problems of access to internal or external credit imperfectly, and (ii) that the profit frontier model that builds upon minimal axioms does not account for measurement error, though the second stage statistical analysis explaining the measured deviations between observations and the frontier (i.e., inefficiency) does. After this extensive methodological discussion, we can turn to the empirical analysis.

Description of the Sample and Empirical Results

Sample: Description and Details on Model Specifications

The sample from CER (Centre d'Economie Rurale du Pas-de-Calais) contains 178 French farms in the Nord-Pas-de-Calais observed from 1994 to 2001. The farms in this balanced panel are specialised in cash crops (grain, sugar beets, etc.). Livestock is of little or no importance for them. One French bank (Crédit Agricole) has an almost monopoly on agricultural financing. Its position is reinforced by the fact that it is also an agent for government policies (e.g., subsidised credit). It grew out of a regional system of co-operative banks and was privatised in 1988 (see Benjamin and Phimister).

Financial data are expressed in Euro in constant 1994 prices and are deflated using their own price indices. Turning to the specification of technology, output is measured by total sales

---

[11] Petrick also points out that both approaches assume that credit rationing leads to underinvestment. This need not be the case (see De Meza and Webb).

[12] This simply responds to a suggestion of Fuss, McFadden and Mundlak (p. 223): "Given the qualitative, non-parametric nature of the fundamental axioms, this suggests […] that the more relevant tests will be non-parametric, rather than based on parametric functional forms, even very general ones."

(SALES). We define two variable inputs and three fixed inputs. Variable inputs are: (i) materials and operational expenses (seed, fertilizers, pesticides, energy, gas, water, etc.) (OPERATIONAL EXPENSES), (ii) taxes and salaries of hired labour (EMPLOYEES) expressed as full time equivalent (2,400 working hours/year) farm employees. The three fixed inputs are: (i) An annual depreciation (over a period of 15 years) of building and capital equipment services (IMMOBILIZATIONS). (ii) The cost of land is based on rental rates and the opportunity cost of ownership. The surface area is weighted by yield per unit to account for fertility differences (SURFACE AREA). More precisely, the yield per hectare per year divided by the average yield per hectare per year in the sample corrects empirically observed fertility differences.[13] (iii) The cost of family labour is the sum of minimum wages and the social security taxes paid by employers. One unit of family labour equals 2,400 hours a year. Their wage is the minimum (defined by the French SMIC) plus social security contributions by employer.

Descriptive statistics for this sample are provided in table 1. The sample contains some heterogeneity in size for certain variables, though in general the spread is rather low. The coefficients of variation are smaller than unity, except for hired labour. The real annual growth rates are (i) total labour 0.73%, (ii) surface area 1.11%, (iii) operational expenses 2.04%, (iv) immobilizations 4.97%, and (v) sales 2.59%. Details on the evolution of inputs and outputs over time are displayed in figures in appendix 3 (available upon simple request).

Table 1. Descriptive Statistics of the Sample over the Years 1994-2001

	Average	Standard Deviation	Coefficient of Variation	Minimum	Maximum
Family Labour (FTE)	1.37	0.56	0.41	0.00	3.80
Employees (FTE)	0.43	0.73	1.69	0.00	4.00
Surface area (ha)	112.24	60.52	0.54	20.80	340.00
Operational expenses (€)*	51 350.73	31 438.88	0.61	6 162.90	185 931.52
Immobilizations (€)*	38 863.54	30 100.25	0.77	1 612.66	268 997.05
Sales (€)*	225 343.04	138 343.95	0.61	24 678.06	937 601.64

* Constant prices of 1994.

---

[13] Unfortunately, there is no agronomical fertility index available for these individual farms. Notice that the analysis has also been performed without correcting for yield differences: these results are qualitatively very similar and are available in appendix 3 that can be obtained from the authors upon simple request.

Although the price evolution over time is known, the sample does not contain any prices at the farm level, but only revenues (costs) per output (input) category. The assumption that all farmers face identical prices each year is plausible because most output prices are regulated by the Common Agricultural Policy (CAP), and most inputs are procured within the same regional markets where prices between firms differ little. Strong price variations over time (especially for the outputs) have been corrected each year by deflating values by their respective price indices. In summary, the data available were adjusted to maintain the assumption of identical prices at any point in time.

Under the assumption of identical prices, FGL (page 577) shows all profit functions defined above can be estimated using revenue and cost categories. The resulting optimal profit levels are identical. Since no input and output quantities are available, technical efficiency cannot be computed. Allocative efficiency, closing the gap between technical and overall efficiency, is also unavailable. Since the technical and allocative efficiency components drop out, this simplifies the short- and long-term profit efficiency decompositions. The identical prices assumption does not imply anything about the competitiveness of the concerned markets. Should markets be uncompetitive, the principal issue is that farmers have the same market power. This is plausible given their similar structure and size. Maximum allowable expenditures are calculated as the observed expenditures on variable inputs (E_S), following the specification in FGL, respectively all inputs (E_L), inspired by Whittaker and Morehart.

With respect to the panel nature of the sample, we opted to estimate non-parametric production technology frontiers for each year separately imposing minimal assumptions (i.e., strong input and output disposability, convexity, and variable returns to scale).[14] In agriculture technology shifts are partly subject to random (e.g., climatic) variations. Estimating production technologies year-by-year imposes minimal assumptions with respect to the nature of technological change. Other options are available that imply alternate and stronger hypotheses. For example, it is possible to estimate an intertemporal frontier by including all observations in the reference technology immediately while disregarding the time dimension (Tulkens and Vanden Eeckaut (1995)). In other words, the panel data set is treated as if it were a cross-section. While this presupposes the absence of technological change, it may enhance the precision of estimates. It is possible to simplify the latter assumption by correcting the data entering into the intertemporal frontier for technological change. Following a strategy adopted and inspired by Tauer and Stefanides, this can be done using the technological change component of recent productivity indices/indicators (e.g., Malmquist or Luenberger (Chambers)). These indices/indicators essentially compare observations relative to two production technologies each representing a given year. In this case the time dimension in the second stage panel estimation only is supposed to capture variations in technical efficiency.

To minimise bias when estimating the presence of credit constraints, a minimalist strategy is selected in terms of maintained hypotheses and we compute year-by-year frontiers. However, the results for the other two specifications of technology (i.e., intertemporal frontier with and without correcting for technological change) are also computed. These are available in appendix 3 (available upon request).[15]

Empirical Results: The Extent of Credit Rationing among French Farmers

Short-run expenditure-constrained and -unconstrained profits were estimated using a profit frontier per year over the period 1995-2001. Indeed, the introduction of a one-year lagged expenditure constraint in some models leads to a loss of one year. Consequently, profit calculations only relate to the years 1995-2001. In addition, all monetary data were deflated to obtain real terms.

Table 2 lists the average efficiency scores for the various components at the sample level. On average, overall efficiency is 30.24% and 76.59% respectively in the short- and the long-run. This implies that farms could improve their normalised profits by about 30% and 76%. In the short-run, overall efficiency is explained by actual efficiency at 23%, financial efficiency at 8% and planning efficiency at -1.5%. A battery of nonparametric test statistics clearly confirms that all these efficiency scores, except the planning component, are significantly different from zero (see appendix 3).[16]

Thus, while mismanagement and technical problems explain most of the gap between the level of observed and maximal profits of farms, the short-run financial constraints also have undeniable effects. In the long-run perspective financial constraints become the predominant source of ill functioning. In particular, limited access to financial resources explains 49% of overall efficiency. Actual inefficiencies remain substantial, but are secondary in importance,

---

[14] See Färe and Primont (1995). There is a minor methodological quibble here: the popular strongly disposable, convex non-parametric technology imposing variable returns to scale -also used for our estimates- satisfies all assumptions mentioned in § II.2, except inaction.

[15] Data are adjusted using a Luenberger productivity indicator (Chambers). Since the latter is based upon directional distance functions, it is compatible with the hypothesis of profit maximising behaviour maintained throughout the paper.

[16] Since distributions of efficiency scores are clearly non-normal, traditional parametric tests are inappropriate.

while planning efficiency again turns around zero. The planning efficiency component is close to zero on average in both perspectives. This clearly confirms the interpretation about the possibility of farmers to align initial and planned budgets when needed.

Table 2. Average Efficiency Scores over the Years 1995-2001

	Short-Run	Long-Run
Financial Efficiency	8.34%	48.81%
Actual Efficiency	23.39%	28.81%
Planning Efficiency	-1.48%	-1.02%
Overall Efficiency	30.24%	76.59%

Observe that FGL focusing on a sample of 82 farms producing rice in 1984, have estimated the loss of profit due to credit-constraints to 8 %. Finally, using a parametric approach, Bhattacharyya, Bhattacharyya and Kumbhakar estimate the loss of efficiency for a small sample of individual jute growers in West Bengal at around 6.4 %. These numbers are of the same order as our short-run results. Unfortunately, we have no point of comparison for our long-run results. It is useful to add that short-run financial efficiency improves until 1999 to deteriorate again thereafter, while the long-run financial efficiency deteriorates continuously within our time period (see the figures in appendix 3).

Table 3 summarises whether the credit constraint is binding or not in the short- and long-run, as well as the average shadow prices. This provides some indicative information about the severity of credit constraints in this French region. On average, we observe that about 67% of farms are financially constrained in the short-run. However, nearly all farms face investment constraints in the long-run. By contrast, FGL report that only 21% of farms were financially constrained in the short-run. This result is probably due to the fact that their farms are relatively bigger in size, resulting in an apparently easier access to credit. Of course, also their small sample size may well have an influence. Whittaker and Morehart, in another study analysing a sample of large Midwest grain farms, note that only one in five farms is financially constrained in either the short or the long-run. Only a small minority of farms (about 1.8 %) are found to be simultaneously financially constrained in short- and long-run. Again their focus on larger size farms may partly explain the differences with our results.

The average value of the shadow price of the credit constraint reveals that a one-unit relaxation adds almost 1.60 to the profit in the short-run, while it adds more than 1.35 to the long-run profit. These average shadow interests rates are far above market interest rates. Just as in the indirect method to model consumption and production decisions in the farm household, this divergence is evidence of credit rationing and the mark-up quantifies its severity. It seems clear that both the short- and long-run development of these farms is seriously jeopardised by a lack of access to credit respectively investment capital. A disaggregated analysis of shadow prices per year is available in appendix 3

Table 3. Status of Credit Constraint and Average Shadow Prices over the Years 1995-2001

	Binding Credit Constraint	Non-binding Credit Constraint
Short-run	67.2%	32.8%
	1.60	n.a[*]
Long-run	99.7%	0.3%
	1.35	n.a.

[*] n.a. = Not applicable.

One plausible mechanism behind the overwhelming presence of binding credit constraints is that the majority of farms faces increasing returns to scale. Indeed, determining local returns to scale information for each farm using the directional distance function reveals that almost 61.6% of farms enjoy increasing returns to scale, while about 28,9% are subject to decreasing returns to scale, and 9.5% have optimal scale (Fukuyama).

Summarising the empirical results so far, financial efficiency is important in the short- and especially in the long-run and is costly in terms of foregone profits. The returns to scale results suggest that the relative small size of many farms is related to their limited access to the credit market and this lack of credit availability is expensive in terms of forgone profits. Of course, other structural factors (like CAP, increasingly restrictive environmental regulations, land market rigidities, adjustment costs, etc.), may also contribute to explaining the survival of farms of heterogeneous sizes in Europe. Evidently, it is useful to recall the important proviso that strictly speaking our approach only identifies farms that are potentially credit constrained, a superset of the effectively credit constrained farms. This implies an upward bias in our estimates of the presence of credit constraints that may partly explain the pervasive nature of credit rationing in our sample and the high value of the shadow prices.

Empirical Results: A Tobit Analysis of Financial Efficiency

In this subsection, we use Tobit analysis to investigate the determinants of observed heterogeneity in measured financial efficiency scores to shed some light on credit rationing. Since financial inefficiency basically measures the profits foregone because of the presence of expenditure constraints (proxying credit and investment constraints), one expects that its determinants are more or less similar than the ones figuring in agricultural credit scoring models. The latter type of models evaluates credit applications in terms of their default risk. Hence, it is custom in this literature to identify several categories of variables when evaluating agricultural loans: solvency, repayment capacity and profitability, collateral, managerial performance, and social and environmental characteristics (see, e.g., Ellinger, Splett and Barry).

First, variables representing the financial structure of the farm should play a role under capital market imperfections. Therefore, following Bierlen and Featherstone we include a debt to asset ratio (variable *Debt to asset ratio*) representing the dependency and access to external finance. The less one is constrained in terms of access to credit, the lower the resulting financial inefficiency. In addition, we add the variable *Rate of debt charges* reflecting a standard measure employed by banks to evaluate the default risk of potential lenders. It indicates the financial effort (principal and interest rate payments) relative to profitability measured by the operating result (sales minus all costs except financing costs). A high *Rate of debt charges* is expected to deteriorate financial efficiency.

Second, the production structure of farms may well affect their financial efficiency. Relative to other specialisations, cash crops farms are more land intensive and their total (own and hired) land size represents the highest share of all tangible assets.[17] Thus, due to its role as collateral, the variable *Surface area* is the main variable determining loan grants by French agricultural banks. To account more precisely for the role of farm size in our analysis, we also add the explicit returns to scale characteristics discussed previously, i.e., dummy variables representing constant (*DCRS*) and increasing (*DIRS*) returns to scale. Furthermore, within the context of our specialised farms focusing mainly on cereals and sugar beets, the ratio of value added (VA) over sales (variable *Rate VA*) can only improve by cultivating at least also some higher value-added crops (andives, cauliflower, etc.). Therefore, in our context of almost monoculture farming, it can reveal a strategy of diversification. It is well known that the simultaneous existence of a variety of technologies allows farms to have some flexibility to

---

[17] This is especially the case in Northern France where a new tenant must repay the right to cultivate the land to the previous tenant. This compensation almost equals the market price for land. Therefore, even hired land can be considered an asset.

adopt their size and that economies of scope are substantial, but seem to diminish with size (Chavas). Finally, the ratio of own capital to value added (variable *Own capital/Value added*) is included as a measure of own capital intensity. It represents the immobilisation of fully owned financial means in the production structure.

Third, we control for managerial performance, business cycle and life cycle effects by adding some additional variables. To begin with, we add a variable *Sales/Surface* as a proxy of the main crops weighted yields. In addition, we add a series of year dummies *D1995* to *D2000* relative to the reference year 2001 to account for any temporal variations. Finally, the farmer's age (variable *Age*) is well-known to impact credit demand, because of life-cycle effects (Bierlen and Featherstone).

Turning to a comparative statistical analysis of the characteristics of farms according to their financial situation, we utilise the above discussed potential explanatory variables.[18] More precisely, we report in table 4 the results of a multivariate panel regression model between financial efficiency and these criteria. Given the relative nature of benchmarking, efficiency scores are bounded below by zero to indicate relative efficiency. Therefore, negative signs indicate improvements of financial efficiency, while positive signs indicate the reverse. Furthermore, to account for this censored nature of efficiency scores, a random effect panel Tobit regression estimator is employed.[19] The p-values are underneath the estimates between brackets. The low p-values for the Wald test indicate that the independent variables contribute to explaining the variation of financial efficiencies. To quickly assess the pertinence of a panel approach we look at the value of ρ. This number measures the relative contribution of the variance of individual specific error terms to the total variance of residuals. Its values between 30% and 53% clearly point to the usefulness of the panel estimators.

Focusing first on the effects common to both short- and long-run, this table indicates that, all things otherwise being equal, a lower level of financial inefficiency goes hand in hand with: (i) a bigger size in terms of surface area (variable *Surface area*); (ii) higher productive performance, defined in terms of sales per surface area (variable *Sales/Surface area*). By contrast, a higher rate of value added increases financial inefficiency in the short- as well as in the long-run. A plausible explanation is that obtaining a production with a high rate of value added requires specialisation and such a specialisation strategy is conditional upon major investments. Furthermore, compared to the reference year 2001, short- and long-run financial

---

[18] Except for all dummy variables, this choice of variables corresponds to the ones figuring in the CER credit scoring models upon which they base their financial advice to the farms in our sample.

[19] The procedure xttobit in STATA 8 has been employed.

efficiencies improved respectively in the years 1996-2000 respectively 1995-2000, as can be inferred from the year dummies *D1995* to *D2000*.

Table 4. Panel Data Tobit Regression Results for Short- and Long-Run Financial Efficiency

Variables	Short-Run Estimated Coefficients	Long-Run Estimated Coefficients
Debt to asset ratio	0.0433291	-0.0504733
	(0.180)[*]	(0.057)
Rate of debt charges	-0.0000218	0.0001635
	(0.867)	(0.061)
Surface area	-0.0008798	-0.0031271
	(0.000)	(0.000)
DIRS	-0.0121511	0.0113666
	(0.216)	(0.091)
DCRS	-0.0585617	0.0313486
	(0.000)	(0.001)
Rate of Value Added	0.6591358	0.1596414
	(0.000)	(0.002)
Own capital/Value added	0.0225639	-0.0113561
	(0.005)	(0.101)
Sales/Surface area	-0.000046	-0.0000824
	(0.000)	(0.000)
D1995	0.0072528	-0.2051412
	(0.527)	(0.000)
D1996	-0.0377872	-0.1833912
	(0.001)	(0.000)
D1997	-0.0763258	-0.1349793
	(0.000)	(0.000)
D1998	-0.0777006	-0.1087459
	(0.000)	(0.000)
D1999	-0.1202487	-0.1058361
	(0.000)	(0.000)
D2000	-0.0471898	-0.050278
	(0.000)	(0.000)
Age	-0.0030418	0.0007228
	(0.000)	(0.268)
Constant	-0.1044891	0.9817489
	(0.214)	(0.000)
Log likelihood	478.168	1387.824
Wald test (Chi^2)	385.02	3549.54
	(0.000)	(0.000)
ρ	0.302	0.526

[*] P values are in parenthesis, ρ measures the relative contribution of the variance of individual specific error terms to the total variance of residuals; Wald test is distributed Chi^2, with $y_{it} = x_{it}B + u_i + e_{it}$ (H_0: B_j=a vs. H_1 : $B_j \neq$a).

There is an opposite effect in the short- versus the long-run concerning the impact of producing at constant returns to scale (as indicated by the dummy variable *DCRS*). While producing at optimal scale enhances the short-run financial efficiency, in the long-run it contributes to financial inefficiency. Furthermore, there are some variables that are only significant in either the short- or the long-run. This is notably the case for the age (variable *Age*) that improves the short-run financial efficiency, but yields no significant impact on long-run financial efficiency. According to the farm life cycle model, liquidity shortages (savings, cash, …) are a more crucial managerial problem for young farmers in the short-run. Similar effects concerning the age of farmers have been reported by, for example, Tauer and Kaiser. Moreover, a higher rate of debts, identified using the ratio of total debts to assets (variable *Debt to asset ratio*), improves long-run financial efficiency, but exerts no significant effect in the short-run. The ratio own capital to value added (variable *Own capital/Value added*) damages short-run financial efficiency only. Finally, the rate of debt charges, defined in terms of the repayment of capital and interests divided by the operating result (variable *Rate of debt charges*) generates no significant impact on the short-run, but it does affect the long-run financial efficiency of most farms negatively.

These results taken together suggest the existence of a leverage effect, in the sense that debts are profitable for the biggest farms that can offer better financial and technical guarantees. Since they have an easier access to credit, they enjoy more flexible possibilities to adapt their technologies. Thus, debts seem to create a virtuous circle eventually improving the global performance of the larger farms. Similar conclusions have been reported elsewhere. For instance, O'Neill and Matthews conclude that more indebted Irish dairy farmers experience limited technical inefficiency to ensure that debts can be repaid. Chavas and Aliber identify a positive relation between the debt to assets ratio and technical efficiency for Wisconsin farms in 1987. All these results support the free cash flow hypothesis (see also supra) suggesting that indebted farmers are motivated to improve their efficiency to ensure their repayment capabilities. These results indicate that technical efficiency facilitates capital accumulation via external credit. This capital accumulation improves productivity, which in turn increases profitability and financial efficiency.

In the literature also a few other effects have been reported. For instance, Whittaker and Morehart report that debt-constrained farms owe their debt predominantly to federally subsidised institutions. Since the latter can be considered as lenders of last resort, this may well indicate these farms suffer serious financial difficulties. In our sample, we have no information on these characteristics, which inhibits any comparison between studies in this respect.

Conclusions

This contribution has studied the presence of credit constraints in French agriculture. To the best of our knowledge, it is the first empirical application investigating the presence of credit constraints in European agriculture using a direct modelling approach based upon axiomatic production theory. In particular, the credit constrained profit maximisation model of FGL is extended in three ways. First, the model is rephrased in terms of directional distance functions and a duality relationship between the short-run directional distance function and the short-run profit function is formulated. Second, the presence of credit constraints in the short-run and investment constraints in the long-run is modelled using short- respectively long-run credit constrained profit functions. Third, the expenditure constraint is lagged one year to account for the separation between planning and production in agriculture.

The empirical application focuses on a panel of French farmers in the Nord-Pas-de-Calais region. We find evidence on the presence of both credit and investment constraints. While in the short-run there are important actual inefficiencies linked to a poor management of factors that inhibit farm profitability, the financial situation has an incontestable influence on performance. Financially unconstrained farmers tend to be larger and perform better. Our results are coherent with the intuition that these farmers suffer less from credit constraints, because they can offer better guarantees to lenders. These farms seem to benefit from a virtuous circle where access to financial markets allows better productive choices. In the long-run, almost all farms seem to suffer from credit constraints for financing their investments.

Being the first study focusing on European agriculture, it would be good to see some additional work corroborating these results. With all reservations because of this need for duplication, it is probably evident that the European CAP should pay more attention to credit rationing. Indeed, it is fair to say that the CAP, even after several reform packages, largely ignores the financing problems faced by European farmers. However, our results point out that facilitating access to both short- and long-run credit offers a valuable, additional policy instrument. This additional instrument could well improve the regulation of agriculture and complete the recent European policies aimed at direct revenue support developed in a context of liberalisation and instability of agricultural markets. For instance, it may be desirable to consider a system of public sector financial guarantees similar to certain existing private initiatives, mostly at a cooperative level, to alleviate problems of collateral. Furthermore, an additional source of external financing could be the creation of loans with annuities varying over the agricultural business cycle. Finally, making leasing operations more attractive by extending their fiscal deductibility could free additional internal financial resources. These are but a series of policy proposals that merit further attention in the European context (especially given the EU enlargement process and the challenge of modernising agricultural technologies in new member states). The policy experience in other developed countries may well provide an additional source of inspiration for these matters (see Barry and Robison).

We end with one suggestion for future work. When information on both quantities and prices would be available, this type of credit-constrained profit maximisation model could well be used to isolate the impact of financial constraints and price policies on the production choices of farmers (e.g., in realistic models explicitly accounting for land set-aside provisions: see Ball et al. and Moro and Sckokai).

References

Ali, M., and J.C Flinn. "Profit Efficiency among Basmati Rice Producers in Pakistan Punjab." *American Journal of Agricultural Economics* 71(1989):303–310.

Balk, B.M. *Industrial Price, Quantity, and Productivity Indices: The Micro-Economic Theory and an Application*. Boston: Kluwer, 1998.

Ball, V., J.-C. Bureau, K. Eakin, and A. Somwaru. "CAP Reform: Modelling Supply Response Subject to the Land Set-Aside." *Agricultural Economics* 17(1997):277–288.

Barry, P.J., and L.J. Robison. "Agricultural Finance: Credit, Credit Constraints, and Consequences." In B. Gardner and G. Rausser, ed. *Handbook of Agricultural Economics,* vol. 1a, Elsevier: Amsterdam, 2001., pp. 513–571.

Battese, G.E. "Frontier Production Functions and Technical Efficiency: A Survey of Empirical Applications in Agricultural Economics." *Agricultural Economics* 7(1992):185–208.

Benjamin, C., and E. Phimister. "Does Capital Market Structure Affect Farm Investment? A Comparison Using French and British Farm-Level Panel Data." *American Journal of Agricultural Economics* 84(2002):1115–1129.

—. "Transaction Costs, Farm Finance and Investment." *European Journal of Agricultural Economics* 24(1997):453–466.

Bhattacharyya, A., A. Bhattacharyya, and S. Kumbhakar. “Governmental Interventions, Market Imperfections, and Technical Inefficiency in a Mixed Economy: A Case Study of Indian Agriculture.” *Journal of Comparative Economics*, 22(1996):219–241.

Bierlen, R., and A.M. Featherstone. “Fundamental q, Cash Flow, and Investment: Evidence from Farm Panel Data.” *Review of Economics and Statistics* 80(1998): 427–435.

Boussard, J.-M. *Economie de l’agriculture*. Paris: Economica, 1987.

Briec, W. “A Graph-Type Extension of Farrell Technical Efficiency Measure.” *Journal of Productivity Analysis* 8(1997):95–110.

Brümmer, B., and J.-P. Loy. “The Technical Efficiency Impact of Farm Credit Programmes: A Case Study of Northern Germany.” *Journal of Agricultural Economics* 51(2000):405–418.

Chambers, R.G. “Exact Nonradial Input, Output, and Productivity Measurement.” *Economic Theory* 20(2002): 751–765.

Chambers, R.G., Y. Chung, and R. Färe. “Profit, Directional Distance Functions, and Nerlovian Efficiency.” *Journal of Optimization Theory and Applications* 98(1998):351–364.

Chatelain J.-B. “Explicit Lagrange Multiplier for Firms Facing a Debt Ceiling Constraint.” *Economics Letters* 67(2000):153–158.

Chavas, J.-P. “Structural Change in Agricultural Production: Economics, Technology and Policy”, In B. Gardner, and G. Rausser, ed. *Handbook of Agricultural Economics,* vol. 1a, Elsevier: Amsterdam, 2001., pp. 263–285.

Chavas J.-P. and M. Aliber. “An Analysis of Economic Efficiency in Agriculture: A Non-Parametric Approach.” *Journal of Agricultural and Resource Economics* 18(1993):1–16.

Cornes, R. *Duality and Modern Economics*. Cambridge: Cambridge University Press, 1992.

De Meza, D., and D. Webb. “Too Much Investment: A Problem of Asymmetric Information.” *Quarterly Journal of Economics* 102(1987):281–292.

Ellinger, P., N. Splett, and P. Barry. “Consistency of Credit Evaluations at Agricultural Banks.” *Agribusiness* 8(1992):517–536.

Färe, R., S. Grosskopf, and H. Lee. “A Nonparametric Approach to Expenditure-Constrained Profit Maximization.” *American Journal of Agricultural Economics* 72(1990):574–581.

Färe, R., and D. Primont. *Multi-Output Production and Duality: Theory and Applications*, Boston: Kluwer, 1995.

Farrell, M. “The Measurement of Productive Efficiency.” *Journal of the Royal Statistical Society Series A: General* 120(1957):253–281.

Fukuyama, H. “Scale Characterizations in a DEA Directional Technology Distance Function Framework.” *European Journal of Operational Research* 144(2003):108–127.

Fuss, M., D. McFadden, and Y. Mundlak. “A Survey of Functional Forms in the Economic Analysis of Production.” In M. Fuss, and D. McFadden, ed. *Production Economics: A Dual Approach to Theory and Applications,* Vol. 1. Amsterdam: North-Holland, 1978., pp. 219–268.

Hubbard, R. “Capital-Market Imperfections and Investment.” *Journal of Economic Literature* 36(1998):193–225.

Hubbard, G.R., and A.K. Kashyap. “Internal Net Worth and the Investment Process: An Application to U.S. Agriculture.” *Journal of Political Economy* 100(1992):506–534.

Hughes, J.P. “Incorporating Risk into the Analysis of Production.” *Atlantic Economic Journal* 27(1999):1–23.

Hughes, J.P., W.W. Lang, L.J. Mester, and C.-G. Moon. “Efficient Banking under Interstate Branching.” *Journal of Money, Credit, and Banking* 28(1996):1045–1071.

Kalirajan, K.P. “An Analysis of Production Efficiency Differentials in the Philippines.” *Applied Economics* 23(1991):631–638.

Kornai, J. “Resource–Constrained versus Demand–Constrained Systems.” *Econometrica* 47(1979):801–819.

Kornai, J. *Economics of Shortage*, Amsterdam: North-Holland Publishing Company, 1980.

Lee, H., and R.G. Chambers. “Expenditure-Constraints and Profit Maximization in U.S. Agriculture.” *American Journal of Agricultural Economics* 68(1986):857–865.

Liu, Z., and J. Zhuang. “Determinants of Technical Efficiency in Post-Collective Chinese Agriculture: Evidence from Farm-Level Data.” *Journal of Comparative Economics* 28(2000):545–564.

Luenberger, D.G. *Microeconomic Theory*. New York:McGraw-Hill Book Co., 1995.

––. “New Optimality Principles for Economic Efficiency and Equilibrium.” *Journal of Optimization Theory and Applications* 75(1992):221–264.

Moro, D., and P. Sckokai. “Modelling the CAP Arable Crop Regime in Italy: Degree of Decoupling and Impact of Agenda 2000.” *Cahiers d’Economie et Sociologie Rurale* 53(1999):49–73.

Nasr, R.E., P.J. Barry, and P.N. Ellinger. “Financial Structure and Efficiency of Grain Farms.” *Agricultural Finance Review* 58(1998):33–48.

O'Neill, S., and A. Matthews. "Technical Efficiency in Irish Agriculture." *Economic and Social Review* 32(2001):263−284.

Oriade, C.A., and C.R. Dillon "Developments in Biophysical and Bioeconomic Simulation of Agricultural Systems: A Review." *Agricultural Economics* 17(1997), 45−58.

Petrick, M. "Empirical Measurement of Credit Rationing in Agriculture: A Methodological Survey", Discussion Paper, Institute of Agricultural Development in Central and Eastern Europe, IAMO, Halle, 2003.

Phimister, E. "Farm Household Production under CAP Reform: The Impact of Borrowing Restrictions." *Cahiers d'Economie et Sociologie Rurale* 38(1996): 62−78.

Pille, P., and J.C. Paradi. "Financial Performance Analysis of Ontario (Canada) Credit Unions: An Application of DEA in the Regulatory Environment." *European Journal of Operational Research* 139(2002):339−350.

Schaffer, M.E. "Do Firms in Transition Economies Have Soft Budget Constraints? A Reconsideration of Concepts and Evidence." *Journal of Comparative Economics* 26(1998):80−103.

Schiantarelli, F. "Financial Constraints and Investment: Methodological Issues and International Evidence." *Oxford Review of Economic Policy* 12(1996):70−89.

Shephard, R.W. *Cost and Production Functions*. Princeton: Princeton University Press, 1953.

Tauer, L.W., and H.M. Kaiser. "Negative Milk Supply Response under Constrained Profit Maximizing Behavior." *Northeastern Journal of Agricultural and Resource Economics* 17(1988):111−117.

Tauer, L.W., and Z. Stefanides. "Success in Maximizing Profits and Reasons for Profit Deviation on Dairy Farms." *Applied Economics* 30(1998):151−156.

Tulkens, H., and P. Vanden Eeckaut. "Non-parametric Efficiency, Progress and Regress Measures for Panel Data: Methodological Aspects." *European Journal of Operational Research* 80(1995):474−499.

Valentini, L. "Credit Rationing and Capital Structure: A Survey of Empirical Studies." Dept. of Economics. DP 9905, University of Southampton, 1999.

Whittaker, G.W., and M.J. Morehart. "Measuring the Effect of Farm Financial Structure on Efficiency." *Agricultural Finance Review* 51(1991):95−105.

Appendix 1. Duality between Short-Run Directional Distance and Variable Profit Functions

Proof: a) First, consider the affine subspace defined by $H(\bar{x}^f) = \{(x^v, x^f, y) \in R^{N+M}; x^f = \bar{x}^f\}$. By definition, we have $\{(x^v, \bar{x}^f, y) \in T\} = T \cap H(\bar{x}^f)$. Since $g^f = 0$, $SRD_T(x^{\mathrm{v}}, \bar{x}^{\mathrm{f}}, y; g) \geq 0 \Leftrightarrow$ $(x^{\mathrm{v}}, \bar{x}^{\mathrm{f}}, y) \in T \cap H(\bar{x}^f)$ and the result is immediate. b) The set $\{(x^v, \bar{x}^f, y) \in T\} = T \cap \{(x^v, x^f, y) \in R^{N+M}; x^f = \bar{x}^f\}$ is convex and using a usual dual characterisation we obtain:

$$T \cap H(\bar{x}^f) = \bigcap_{w,p\geq 0} \left\{ (x^v, \bar{x}^f, y) \in R_+^{N+M}; p.y - w^v.x^v - w^f.\bar{x}^f \leq \sup_{(x^v, x^f, y) \in H(\bar{x}^f)} \{p.y - w^v.x^v - w^f.\bar{x}^f\} \right\}$$

$$= R_+^{N+M} \cap \bigcap_{w,p\geq 0} M\left(w, p, \bar{x}^f\right)$$

where $M\left(w, p, \bar{x}^f\right) = \left\{(x^v, \bar{x}^f, y) \in R^{N+M}; p.y - w^v.x^v - w^f.\bar{x}^f \leq SR\Pi\left(w, p, \bar{x}^f\right)\right\}$. But, it is immediate to show that:

$$SRD_T(x^v, \bar{x}^f, y; g) = \inf_{\delta \in R}\{\delta\, ; (x^v - \delta g_i^v, 0, y + \delta g_o) \notin T \cap H(\bar{x}^f)\}$$

$$= \inf_{\delta \in R}\left\{\delta\, ; (x^v - \delta g_i^v, 0, y + \delta g_o) \notin \bigcap_{w,p\geq 0} M\left(w, p, \bar{x}^f\right)\right\}$$

$$= \inf_{\delta \in R}\left\{\delta\, ; (x^v - \delta g_i^v, 0, y + \delta g_o) \in \bigcup_{w,p\geq 0} R^{N+M} \big/ M(w, p, \bar{x}^f)\right\}$$

$$= \inf_{w,p\geq 0}\, \inf_{\delta \in R}\{\delta\, ; (x^v - \delta g_i^v, 0, y + \delta g_o) \in R^{N+M} \big/ M(w, p, \bar{x}^f)\}$$

$$= \inf_{w,p\geq 0}\, \inf_{\delta \in R}\left\{\delta\, ; p.(y + \delta g_o) - w^v.(x^v - \delta g_i^v) - w^f.\bar{x}^f > SR\Pi\left(w, p, \bar{x}^f\right)\right\}$$

$$= \inf_{w,p\geq 0}\left\{\frac{SR\Pi\left(w, p, \bar{x}^f\right) - p.y + w^v.x^v + w^f.\bar{x}^f}{p.g_o + w^v.g_i^v}, (p, w) \neq 0\right\}$$

and, utilising expression (8) the fixed costs terms cancel out and the result is obtained. Q.E.D.

Appendix 2. Distance Functions and Profit Functions: Computational Aspects

This appendix briefly describes the mathematical programs that must be solved for each observation in the years 1995 to 2001 to compute the nonparametric specifications of the profit frontiers described in the main body of the text. We first define the standard profit functions, and then we specify the expenditure-constrained profit functions. For each of these cases we first treat the long-run case and only thereafter the short-run counterpart.

The year 1994 drops out, since we need one year with lagged observations to formulate a lagged credit constraint based on observed expenditures in the preceding year. We develop the linear programs underneath for the most general specification, i.e., the intertemporal production technologies. This implies summing the technologies over the years 1995-2001. Notice that the year-by-year technologies are obtained by simply dropping the summation operator over the T time periods. When correcting for technical change in the intertemporal frontier, this amounts to modifying the parameters (in particular, (x_{kn}^t, y_{km}^t)) of the mathematical programs using the technological change component of the Luenberger productivity indicator (see the main text).

First, the intertemporal long-run total profit function is computed as:

$$\Pi(p, w, |VRS) = \max_{z_k^t, x_n^t, y_m^t} \sum_{m=1}^{M} p_m^t y_m^t - \sum_{n=1}^{N} w_n^t x_n^t$$

$$\begin{aligned} \textit{subject to} \quad & -y_m^t + \sum_{t=1}^{T}\sum_{k=1}^{K} y_{km}^t z_k^t \geq 0, \quad m = 1,\cdots,M, \\ & -x_n^t + \sum_{t=1}^{T}\sum_{k=1}^{K} x_{kn}^t z_k^t \leq 0, \quad n = 1,\cdots,N, \\ & \sum_{t=1}^{T}\sum_{k=1}^{K} z_k^t = 1, \\ & z_k^t \geq 0, y_m^t \geq 0, x_n^t \geq 0, \quad k = 1,\cdots,K. \end{aligned}$$

Second, the intertemporal version short-run total profit function is:

$$
\begin{aligned}
SR\Pi(p,w,\bar{x}^{f}\,|VRS) = \max_{z_k^t,x_n^{t,v},x_n^{t,f},y_m^t} & \sum_{m=1}^{M} p_m^t y_m^t - \sum_{n=1}^{N^v} w_n^{t,v} x_n^{t,v} - \sum_{n=N^v+1}^{N} w_n^{t,f} x_n^{t,f} \\
\textit{subject to} \quad & -y_m^t + \sum_{t=1}^{T}\sum_{k=1}^{K} y_{km}^t z_k^t \geq 0, \quad m=1,\cdots,M, \\
& -x_n^{t,v} + \sum_{t=1}^{T}\sum_{k=1}^{K} x_{kn}^{t,v} z_k^t \leq 0, \quad n=1,\cdots,N^v, \\
& -x_n^{t,f} + \sum_{t=1}^{T}\sum_{k=1}^{K} x_{kn}^{t,f} z_k^t \leq 0, \quad n=N^v+1,\cdots,N, \\
& x_n^{t,f} = \bar{x}_{nk}^{t,f}, \\
& \sum_{t=1}^{T}\sum_{k=1}^{K} z_k^t = 1, \\
& z_k^t \geq 0, y_m^t \geq 0, x_n^t \geq 0, \quad k=1,\cdots,K.
\end{aligned}
$$

Third, the intertemporal version of the expenditure-constrained long-run total profit function with a lagged credit constraint requires computing:

$$
\begin{aligned}
EC\Pi(p,w,E_L\,|VRS) = \max_{z_k^t,x_n^t,y_m^t} & \sum_{m=1}^{M} p_m^t y_m^t - \sum_{n=1}^{N} w_n^t x_n^t \\
\textit{subject to} \quad & -y_m^t + \sum_{t=1}^{T}\sum_{k=1}^{K} y_{km}^t z_k^t \geq 0, \quad m=1,\cdots,M, \\
& -x_n^t + \sum_{t=1}^{T}\sum_{k=1}^{K} x_{kn}^t z_k^t \leq 0, \quad n=1,\cdots,N, \\
& \sum_{t=1}^{T}\sum_{k=1}^{K} z_k^t = 1, \\
& \sum_{n=1}^{N} w_n^t x_n^t \leq E_L^{t-1}, \\
& z_k^t \geq 0, y_m^t \geq 0, x_n^t \geq 0, \quad k=1,\cdots,K.
\end{aligned}
$$

Fourth, the intertemporal version of the expenditure-constrained short-run total profit function with a lagged credit constraint can be calculated as follows:

$$SREC\Pi(p, w, \bar{x}^{f}, E_S | VRS) = \max_{z_k^t, x_n^{t,v}, x_n^{t,f}, y_m^t} \sum_{m=1}^{M} p_m^t y_m^t - \sum_{n=1}^{N^v} w_n^{t,v} x_n^{t,v} - \sum_{n=N^v+1}^{N} w_n^{t,f} x_n^{t,f}$$

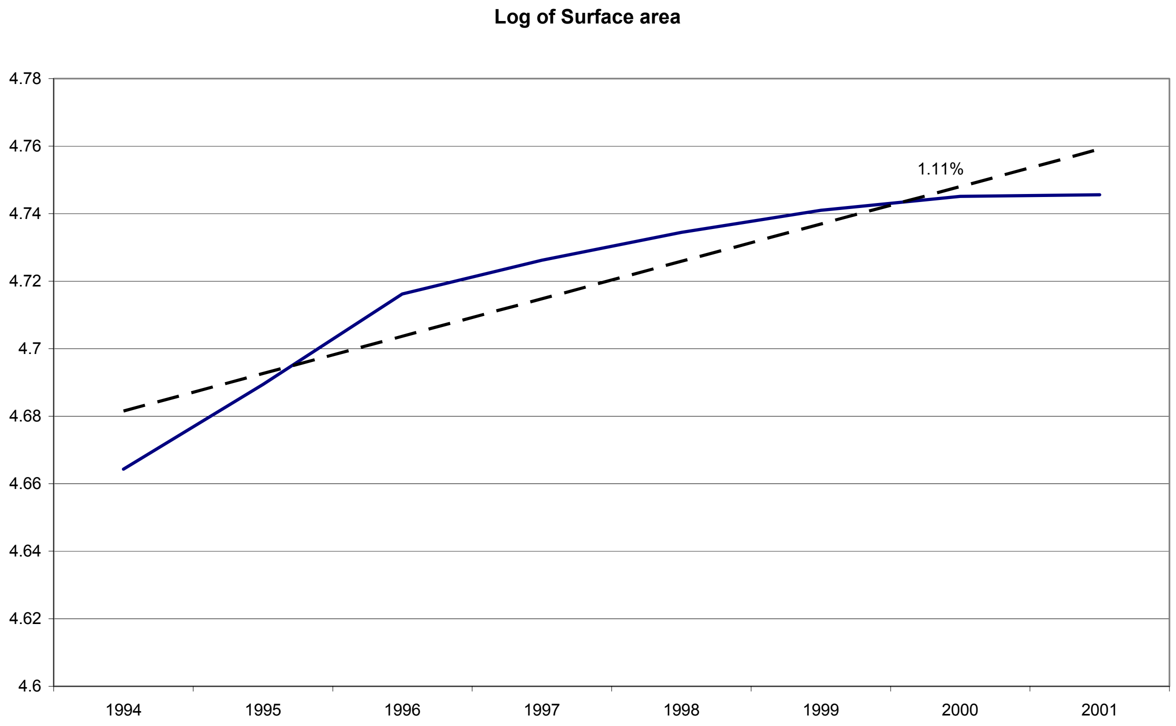
$$\begin{aligned}
\textit{subject to} \quad & -y_m^t + \sum_{t=1}^{T}\sum_{k=1}^{K} y_{km}^t z_k^t \geq 0, \quad m = 1, \cdots, M, \\
& -x_n^{t,v} + \sum_{t=1}^{T}\sum_{k=1}^{K} x_{kn}^{t,v} z_k^t \leq 0, \quad n = 1, \cdots, N^v, \\
& -x_n^{t,f} + \sum_{t=1}^{T}\sum_{k=1}^{K} x_{kn}^{t,f} z_k^t \leq 0, \quad n = N^v + 1, \cdots, N, \\
& x_n^{t,f} = \bar{x}_{nk}^{t,f}, \\
& \sum_{t=1}^{T}\sum_{k=1}^{K} z_k^t = 1, \\
& \sum_{n=1}^{N^v} w_n^{t,v} x_n^{t,v} \leq E_S^{t-1}, \\
& z_k^t \geq 0, y_m^t \geq 0, x_n^t \geq 0, \quad k = 1, \cdots, K.
\end{aligned}$$

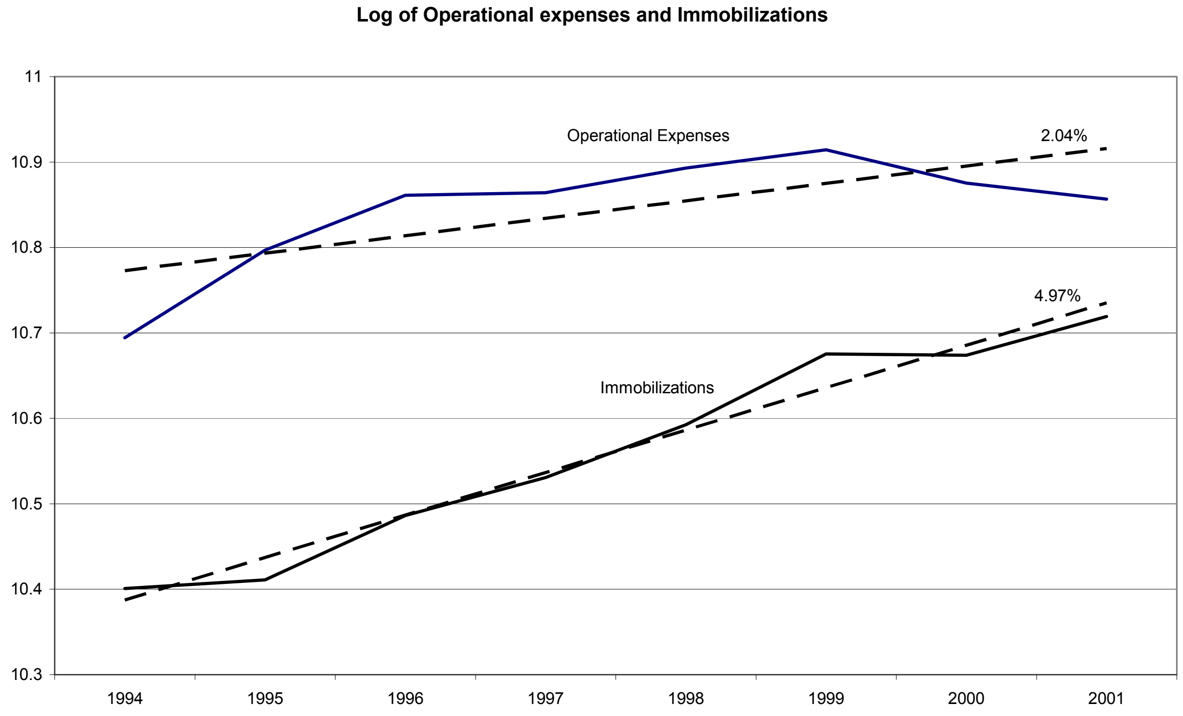
Appendix 3. Additional Empirical Results

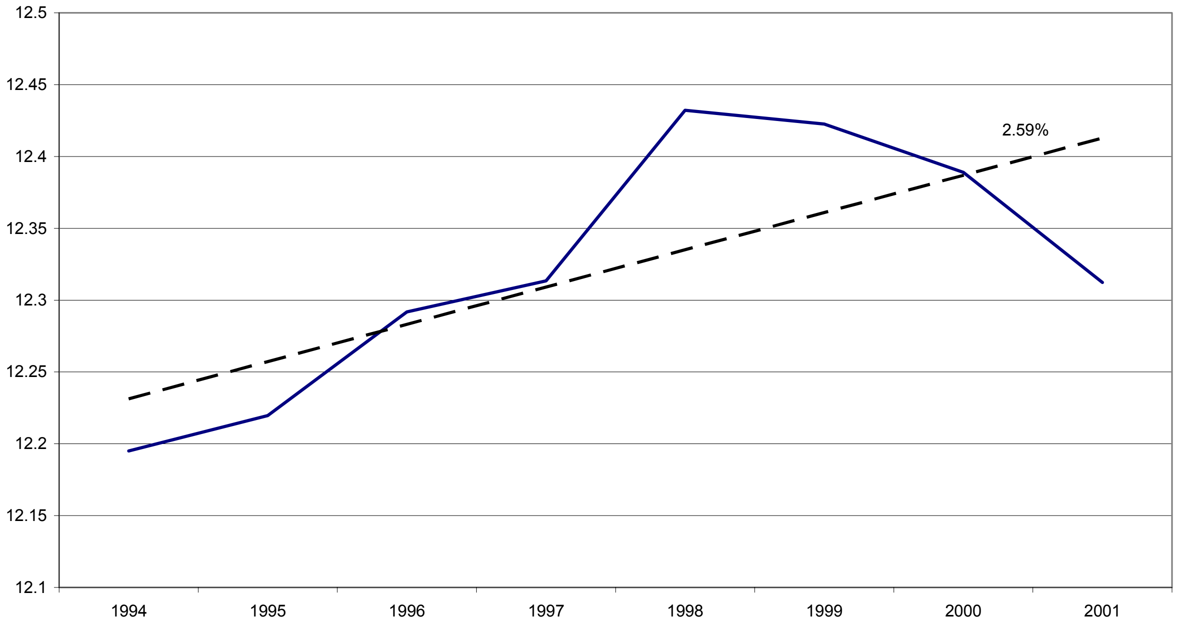
This appendix with additional empirical results contains several parts. It strictly follows the order in which the complementary results are mentioned in the main text. First, it describes the evolution of inputs and outputs over time. Second, the impact of the three technologies (i.e., year by year frontiers, intertemporal frontier with and without correcting for technological change) on the efficiency decomposition is reported. Third, we report a nonparametric test statistic confirming that all efficiency scores, but the planning component, are significantly different from zero. Fourth, both short- and long-run financial efficiency is traced over time. Fifth, the evolution of the shadow prices is disaggregated over time. Finally, the effect of correcting for yield differences is analysed the Tobit analysis.

Recall that the real annual growth rates of (i) total labour, (ii) surface area, (iii) operational expenses, (iv) immobilizations, and (v) sales are respectively 0.73%, 1.11%, 2.04%, 4.97%, and 2.59%. Figure A3.1 plots the evolution of these inputs and outputs over time and adds a trend line to each series as well. In sequence, one finds a plot of the detailed evolution in the following series: (i) labour, (ii) surface area, (iii) operational expenses and immobilisations (on one figure to save some space), and (iv) sales. Notice that all inputs increase moderately over time, while sales suffer from a serious dip near the end of the period.

Figure A3.1. Evolution of inputs and outputs and real average annual growth rates


Log of Surface area
4.78
4.76
4.74
4.72
4.7
4.68
4.66
4.64
4.62
4.6
1.11%
1994
1995
1996
1997
1998
1999
2000
2001


Log of Operational expenses and Immobilizations
11
10.9
10.8
10.7
10.6
10.5
10.4
10.3
Operational Expenses
2.04%
4.97%
Immobilizations
1994
1995
1996
1997
1998
1999
2000
2001



Log of Sales

Tables A3.1 and A3.2 contain the descriptive statistics for the short-run respectively the long-run efficiency scores for the three different specifications of technology. For these different specifications of technology, the short-run results indicate that mismanagement and technical problems explain most of the gap between the level of observed and maximal profits of farms. However, the financial constraints also have effects. For each year (except 1998 in the case of the year by year frontier), we observe that a large majority of farms are financially constrained. Turning to the long-run perspective, financial constraints are by far the main source of ill functioning. Limited access to financial resources explains between 40% and 60% of overall efficiency according to the technology specification. Actual inefficiencies remain substantial, but have now become secondary in importance. Just like in the short-run case, the long-run planning efficiency component is close to zero. Clearly, the average efficiency scores have about the same order and indicate common causes for the poor performance across technology specifications, though the relative importance differs in short- and long-run.

Table A3.1. Descriptive Statistics of Short-Run Efficiency Scores for Three Different Specifications of Technology

Short-Run Efficiency Scores for Year-By-Year Production Technologies

Years	Overall Efficiency	Actual Efficiency	Financial Efficiency	Planning Efficiency	Binding Credit Constraints
1995	30.81%	22.18%	13.84%	-5.21%	83.71%
1996	30.45%	23.41%	9.53%	-2.48%	74.16%
1997	26.67%	20.77%	6.83%	-0.93%	60.11%
1998	34.20%	29.94%	6.66%	-2.40%	52.25%
1999	27.90%	25.12%	2.61%	0.17%	56.74%
2000	29.18%	20.55%	7.72%	0.91%	70.79%
2001	32.47%	21.74%	11.17%	-0.44%	72.47%
Average	30.24%	23.39%	8.34%	-1.48%	67.17%

Short-Run Efficiency Scores for an Intertemporal Frontier with Correction for Technological Change

Years	Overall Efficiency	Actual Efficiency	Financial Efficiency	Planning Efficiency	Binding Credit Constraints
1995	44.2%	36.1%	9.5%	-1.5%	78.7%
1996	42.5%	35.1%	9.6%	-2.2%	79.8%
1997	35.9%	28.5%	6.9%	0.5%	70.2%
1998	46.8%	40.2%	11.7%	-5.1%	87.1%
1999	42.3%	34.8%	6.2%	1.4%	70.2%
2000	39.5%	30.4%	7.3%	1.7%	66.3%
2001	40.7%	31.3%	8.4%	1.0%	69.7%
Average	41.7%	33.8%	8.5%	-0.6%	74.6%

Short-Run Efficiency Scores for an Intertemporal Frontier Without Correction for Technological Change

Years	Overall Efficiency	Actual Efficiency	Financial Efficiency	Planning Efficiency	Binding Credit Constraint
1995	46.1%	39.8%	10.8%	-4.5%	77.0%
1996	43.3%	37.6%	8.9%	-3.3%	69.1%
1997	44.2%	38.4%	6.1%	-0.3%	65.2%
1998	39.5%	34.6%	6.2%	-1.3%	64.0%
1999	41.6%	35.9%	5.2%	0.5%	59.6%
2000	42.0%	34.5%	6.0%	1.5%	56.7%
2001	48.6%	40.7%	8.0%	-0.2%	62.4%
Average	43.6%	37.4%	7.3%	-1.1%	64.8%

Table A3.2. Descriptive Statistics of Long-Run Efficiency Scores for Three Different Specifications of Technology

Long-Run Efficiency Scores for Year-By-Year Production Technologies

Years	Overall Efficiency	Actual Efficiency	Financial Efficiency	Planning Efficiency	Binding Credit Constraint
1995	72.9%	34.4%	40.7%	-2.2%	98.3%
1996	72.6%	32.5%	41.5%	-1.5%	100.0%
1997	74.0%	28.8%	46.2%	-0.9%	99.9%
1998	78.1%	31.7%	48.3%	-1.8%	99.8%
1999	76.7%	28.6%	49.1%	-1.0%	100.0%
2000	79.1%	23.0%	55.4%	0.6%	99.8%
2001	82.7%	22.5%	60.4%	-0.3%	99.8%
Average	76.6%	28.8%	48.8%	-1.0%	99.7%

Long-Run Efficiency Scores for an Intertemporal Frontier with Correction for Technological Change

Years	Overall Efficiency	Actual Efficiency	Financial Efficiency	Planning Efficiency	Binding Credit Constraint
1995	82.3%	29.0%	52.4%	0.9%	98.9%
1996	80.8%	29.3%	53.3%	-1.8%	100.0%
1997	77.0%	24.5%	51.5%	1.1%	98.9%
1998	81.2%	34.8%	52.6%	-6.1%	99.4%
1999	78.8%	31.2%	46.4%	1.2%	98.3%
2000	77.5%	28.3%	47.6%	1.6%	97.8%
2001	78.9%	28.2%	49.2%	1.5%	98.3%
Average	79.5%	29.3%	50.4%	-0.2%	98.8%

Long-Run Efficiency Scores for an Intertemporal Frontier Without Correction for Technological Change

Years	Overall Efficiency	Actual Efficiency	Financial Efficiency	Planning Efficiency	Binding Credit Constraint
1995	85.49%	36.36%	51.47%	-2.33%	98.88%
1996	83.45%	36.11%	49.14%	-1.80%	100.00%
1997	83.02%	36.78%	47.34%	-1.09%	98.31%
1998	78.15%	33.63%	46.25%	-1.73%	98.88%
1999	79.73%	36.31%	44.52%	-1.10%	98.88%
2000	80.92%	36.69%	43.42%	0.81%	97.75%
2001	84.94%	41.10%	44.24%	-0.40%	98.31%
Average	82.24%	36.71%	46.62%	-1.09%	98.72%

From now onwards, we restrict attention to the preferred year-by-year technology (see the arguments in the main text). Hence, we drop the two intertemporal specifications from the analysis.

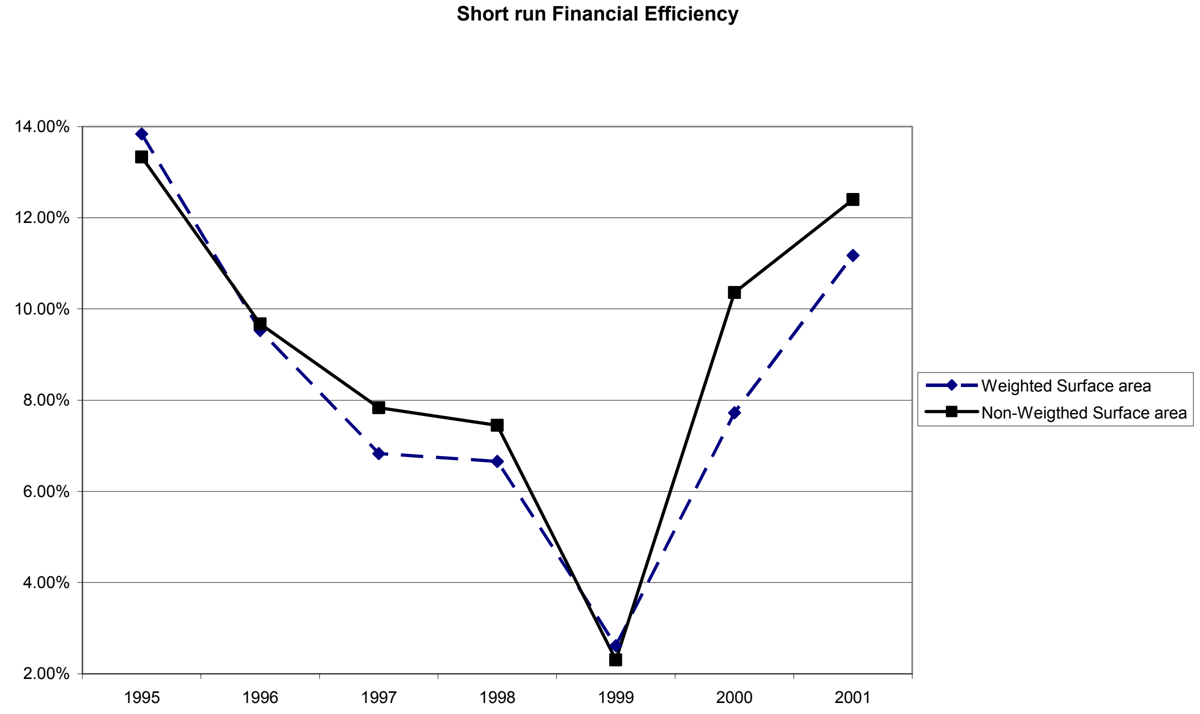
To save some space, table A3.3 only reports the results of the nonparametric sign test over the whole sample. For each of the short and long run efficiency scores reported in Table 2 of the main text, we report the test statistic in the first line and the resulting p-value in the second line. A quick look at this table reveals that financial, actual and overall efficiencies are significantly different from zero. Only for the planning efficiency one cannot reject the hypothesis that it equals zero. But, the latter result is compatible with our proposed interpretation.

Table A3.3. Sign Test Statistic of Efficiency Scores

	Short-Run	Long-Run
Financial Efficiency	663	1165
	0.0126	0.0001
Actual Efficiency	981	1100
	0.0001	0.0001
Planning Efficiency	582	644
	0.9907	0.1227
Overall Efficiency	1070	1234
	0.0001	0.0001

Next, we trace short- and long-run financial efficiency over time while focusing on the eventual impact of either correcting the surface area for yield differences or not. In the main text, we reported results with the correction. Here we also report some results under the alternative assumption. Figure A.3.2 plots both short- and long-run financial efficiency over time with or without correcting the surface area. In both cases, short-run financial efficiency improves until 1999 to deteriorate again thereafter. By contrast, the long-run financial efficiency deteriorates continuously within our time period. Plausible partial explanations for this divergence between short- and long-run results are that (i) in the short-run average yields for wheat have augmented by about 20% between 1995 and 1999 and have decreased by 20% for the two last years, while (ii) in the long-run the prices of outputs relative to inputs have regularly diminished by about 10% over the whole period.

Figure A.3.2. Evolution of short- and long-run financial efficiency with or without correcting surface area by yields



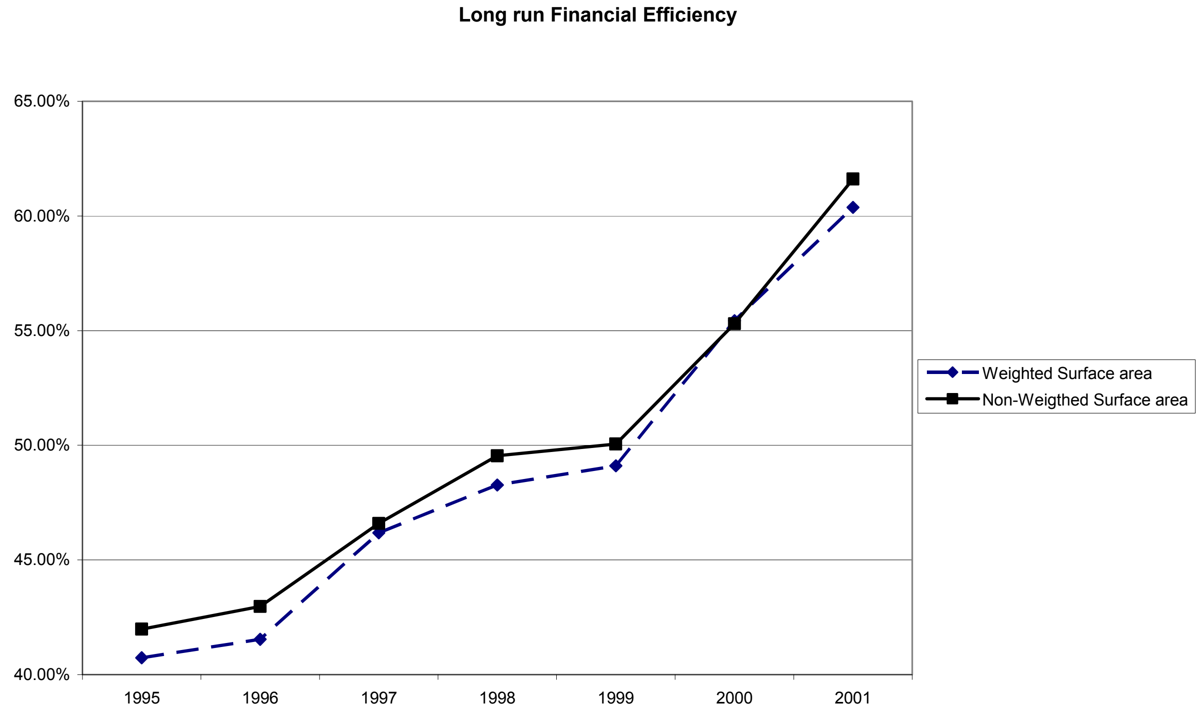


Table A3.4 traces the evolution of the shadow prices over the years 1995 to 2001. There is quite some change from one year to another. But given the lack of detailed knowledge about the eventual changes in the credit policies of the banks involved and the existence of a whole series of other potential influencing factors (e.g., the agricultural business cycle, climatic variations, etc.), it is probably prudent to conclude that the shadow price foregone due to credit constraint is substantial and probably above unity. The upward bias in our identification of potentially credit constrained farms (see also, the main text) is an additional argument for this prudent conclusion.

Table A3.4. Average Shadow Prices per Year (1995-2001)

	Short-run	Long-run
1995	1.1943	2.3454
1996	1.2796	1.8680
1997	1.1177	1.4374
1998	2.0646	1.8123
1999	1.5340	0.8817
2000	1.1907	1.3165
2001	1.0977	1.5272

Table A.3.5 allows checking that the correction of surface area by yields does not modify our statistical analysis in any sense. Notice that the first two columns are identical to table 4 in the main text. Again the low p-values for the Wald test point at the significance of the specified models. The value of ρ confirms the relevance of employing a panel estimator. The panel Tobit model results reported are clearly robust between the two approaches. Hence, the correction of surface area for yield differences changes neither the sign nor the level of significance for any of the reported parameters explaining the financial efficiency scores.

Table A.3.5. Panel Data Tobit Regression Results for Financial Efficiency (With and Without Weighted Surface Area)

	Weighted Surface area		Non-Weighted Surface area	
Variables	Short-Run Estimated Coefficients	Long-Run Estimated Coefficients	Short-Run Estimated Coefficients	Long-Run Estimated Coefficients
Debt to asset ratio	0.0433291	-0.0504733	0.0473475	-0.0493733
	(0.180)	(0.057)	(0.149)	(0.046)
Rate of debt charges	-0.0000218	0.0001635	0.0000156	0.0001589
	(0.867)	(0.061)	(0.904)	(0.063)
Surface area	-0.0008798	-0.0031271	-0.0009012	-0.003159
	(0.000)	(0.000)	(0.000)	(0.000)
DIRS	-0.0121511	0.0113666	-0.0176897	0.0063049
	(0.216)	(0.091)	(0.077)	(0.372)
DCRS	-0.0585617	0.0313486	-0.0629117	0.0261729
	(0.000)	(0.001)	(0.000)	(0.007)
Rate of VA	0.6591358	0.1596414	0.6949811	0.1616421
	(0.000)	(0.002)	(0.000)	(0.002)
Own capital/Value added	0.0225639	-0.0113561	0.0265671	-0.0114372
	(0.005)	(0.101)	(0.001)	(0.065)
Sales/Surface area	-0.000046	-0.0000824	-0.0000611	-0.0000815
	(0.000)	(0.000)	(0.000)	(0.000)
D1995	0.0072528	-0.2051412	-0.0099453	-0.2041352
	(0.527)	(0.000)	(0.388)	(0.000)
D1996	-0.0377872	-0.1833912	-0.0495292	-0.1814646
	(0.001)	(0.000)	(0.000)	(0.000)
D1997	-0.0763258	-0.1349793	-0.0763731	-0.1440876
	(0.000)	(0.000)	(0.000)	(0.000)
D1998	-0.0777006	-0.1087459	-0.0731919	-0.1094881
	(0.000)	(0.000)	(0.000)	(0.000)
D1999	-0.1202487	-0.1058361	-0.1579475	-0.1081236
	(0.000)	(0.000)	(0.000)	(0.000)
D2000	-0.0471898	-0.050278	-0.0337229	-0.0652263
	(0.000)	(0.000)	(0.002)	(0.000)
Age	-0.0030418	0.0007228	-0.0029715	0.0009404
	(0.000)	(0.268)	(0.000)	(0.130)
Constant	-0.1044891	0.9817489	-.0964715	0.9862071
	(0.214)	(0.000)	(0.258)	(0.000)
Log likelihood	478.168	1387.824	476.649	1379.287
Wald test (Chi^2)	385.02	3549.54	426.09	3111.00
	(0.000)	(0.000)	(0.000)	(0.000)
ρ	0.302	0.526	0.320	0.505

P values are in parenthesis, ρ measures the relative contribution of the variance of individual specific error terms to the total variance of residuals; Wald test is Chi^2 with $y_{it} = x_{it}B + u_i + e_{it}$ (H_0: B_j=a vs. H_1 : $B_j \neq$a).