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

Stéphane Blancard, Jean-Philippe Boussemart, Walter Briec, and Kristiaan Kerstens

This empirical application investigates the eventual presence of credit constraints using a panel of French farmers. The credit-constrained profit maximization 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 duality with the profit function. Second, we model credit constraints in the short-run and investment constraints in the long-run using short- and 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 credit and investment constraints. Financially unconstrained farmers are larger, perform better, and seem to benefit from a virtuous circle where access to financial markets allows better productive choices.

Key words: credit constraint, profit function, proportional distance function.

Production theory and finance developed along separate paths as if production and financial decisions and their associated risks could be neatly separated. Few production models directly integrate financing issues and risk. For instance, the production of banking services has recently been analyzed 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., 1996). One issue that did receive some attention is the impact of credit constraints on production. It is common knowledge that 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, 1998; Schiantarelli, 1996). In the empirical literature on credit rationing in finance, we are unaware of any study including farming when studying the structure of the commercial loan market (see, e.g., the Valentini, 1999 survey), probably because the focus is on companies listed on the stock market.

The problem of credit constraints and rationing is severe in agriculture for various reasons: (*a*) there is a substantial lag between purchasing inputs and selling outputs, (*b*) farm-specific capital is inflexible, (*c*) the direct link between private wealth and farm capital limits the possibilities for providing collateral, (*d*) most farms are relatively small, etc. The access to external financing resources (mostly debt and leasing) being limited, farmers' operations and investments heavily depend on internal financing (Barry and Robison, 2001).

This article directly tests 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. The differences between profit functions with and without a credit constraint yield a measure of the opportunity cost of lack of credit access, which is labeled financial efficiency (*FE*) (Färe, Grosskopf, and

Stéphane Blancard is researcher, CERESUR, University of La Réunion; Jean-Philippe Boussemart is professor, GREMARS, University of Lille 3; Walter Briec is maître de conférences, GEREM, University of Perpignan; and Kristiaan Kerstens is chargé de recherche, CNRS-LEM, IESEG.

Comments of two most constructive referees, J.M. Boussard, B.W. Brorsen, R. Chambers, N. Filimon, D. Prior, P. Vanden Eeckaut, and seminar and conference participants in Kiel, Nottingham, and Oviedo are gratefully acknowledged. D. Newlands offered stylistic advice. The usual disclaimer applies.

Lee, 1990; Lee and Chambers, 1986).[1] Inspired by traditional credit scoring models, a second stage tobit analysis relates this censored financial performance indicator to a series of factors representing various managerial, social, and other environmental characteristics. With the exception of the few papers cited below, we are unaware of European studies using this approach.

This modeling strategy is attractive, since it endogenously distinguishes between subsets of constrained and unconstrained units (in contrast to most studies: Schiantarelli, 1996). 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 maximizing input and output mix. When the credit 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 (1980) statement that firms do not maximize profits subject to a technological constraint solely, but always face a budget constraint.[2]

Several approaches document the existence of credit constraints affecting agricultural production (see the Petrick, 2005 survey). We briefly mention two other methods and highlight their advantages and shortcomings. Using a static, microeconomic 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. Phimister (1996) is an example of a study providing some simulations for France. 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 the Hubbard, 1998 survey). For U.S. data, e.g., Bierlen and Featherstone (1998) find significant influence of financial variables on investment that leads them to reject the perfect capital market model. Benjamin and Phimister (1997, 2002) provide estimates for French and British farmers: while in an earlier study financial variables do not improve model fit, in a later study they do. But, there remain minor differences among both countries (e.g., sensitivity to cash flow is higher in France).

Petrick (2005) maintains that these two alternative, microeconomic approaches are demanding in terms of data availability and depend on the validity of the assumptions used in the econometric and simulation methods (functional forms, etc.).[3] Differences among these approaches can be traced 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 optimization. Second, we employ nonparametric technologies that do not impose functional form, while the results of both other approaches may be affected by choice of particular functional forms. Third, our contribution uses frontier technologies that allow for inefficiency, while both other approaches maintain the hypothesis of perfectly static, respectively, dynamic optimizing behavior. 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. Thus, our approach allows making statements about potential profits lost due to credit constraints, which are impossible in certain other approaches.

Overall, it is clear that our modeling strategy uses as few maintained hypotheses as possible. The main qualifications are: (*a*) that the expenditure constraint only reveals problems of access to internal or external credit imperfectly, and (*b*) that the profit frontier model that builds upon minimal axioms does not account for measurement error, though the second stage tobit estimation of the measured deviations between observations and the frontier (i.e., *FE*) does. It has also the limitation to ignore farm household preferences.

The presence of credit constraints in agriculture using a similar modeling framework has so far only been considered for the United States and India. In particular, Lee and Chambers (1986) use an expenditure-constrained profit

[1] The analysis of production inefficiencies and its causes yields evidence on credit rationing as an explanatory factor of poor performance in developing and developed countries (Battese, 1992). In contrast, our model measures the presence of credit constraints directly rather than indirectly (i.e., as a determinant of measured inefficiencies).

[2] Kornai distinguishes *soft* and *hard* budget constraints. Soft budget constraints under socialist planning emerge because of state paternalism (direct subsidies, interenterprise arrears, tax arrears, etc.). By contrast, firms in market economies face hard budget constraints, because of the risk of failure and credit rationing.

[3] Petrick (2005) also points out that both approaches assume that credit rationing leads to underinvestment. This need not be the case (see De Meza and Webb, 1987).

function to study U.S. agriculture at the aggregate level for the years 1947–1980 and find compelling evidence that farmers face binding credit constraints. Tauer and Kaiser (1988) find some evidence of a downward sloping supply curve for New York dairy farmers compatible with a profit maximization model with binding cash flow constraints. For a rather small sample of Californian rice farmers, Färe, Grosskopf, and Lee (1990) discover that credit constraints bind for only about 20% of the sample. Whittaker and Morehart (1991) analyze a small sample of Midwestern U.S. grain farms and find 12% of these constrained by their assets and about an equal amount constrained by their debts. Finally, Bhattacharyya, Bhattacharyya, and Kumbhakar (1996) report for a small sample of individual jute growers in West Bengal, substantial output losses and input misallocations due to expenditure constraints.

From a policy viewpoint, our benchmarking approach is useful because efficiency measures are reliable predictors of potential financial problems and eventual bankruptcy. Moreover, a better understanding of the impact of credit constraints could help in refining current agricultural policy instruments for regulating the sector.

This article is structured as follows. The following section lays down the theoretical framework by introducing distance functions representing technology and several related profit functions. The subsequent section discusses the sample, introduces the basic empirical financial performance results, and presents the second stage tobit analysis of the observed heterogeneity in financial performance. Conclusions and extensions appear in the final section.

Productive and Financial Performance Measures Based on Profit Functions: Method

Profit Functions and Credit Constraints: Basic Intuitions

Following Färe, Grosskopf, and Lee (1990) (henceforth FGL), we 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, fertilizer, pesticides, . . .) and the harvesting of crops at the end of the production cycle. Parts of earlier plans may be revised when needed 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 the use of an axiomatic production model that 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, 1995). This literature operationalizes the basic distinction between technical and allocative efficiencies (*AE*s). Technical efficiency (*TE*) only guarantees reaching a point on the production frontier. *AE*, 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.

In reality, farmer's choices are not only constrained by technology, but also by additional constraints. Among the most important constraints are regulatory constraints linked to the Common Agricultural Policy (CAP) (e.g., land set-aside provisions), environmental constraints, and credit constraints associated with capital market imperfections.[4] In our modeling strategy, we focus on credit constraints and ignore 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 credit constraints. If maximal profits in a model with a credit constraint are 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

[4] For example, Ball et al. (1997) model land set-aside requirements in a profit function framework.

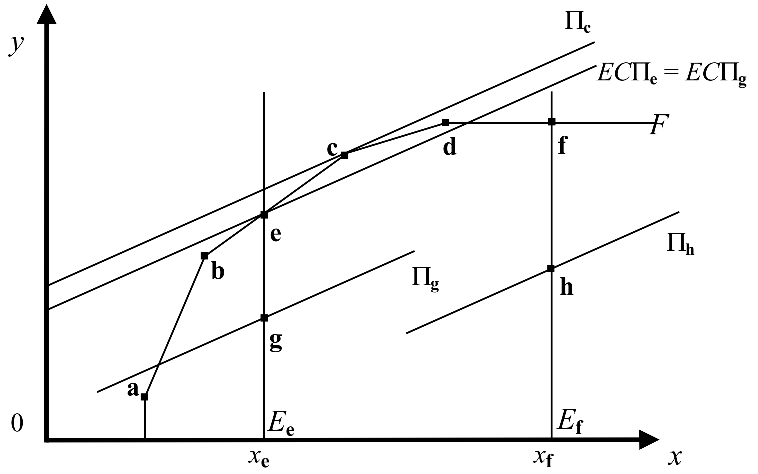

Figure 1. Expenditure-constrained profit function

allocative inefficiency due to a credit constraint is called financial inefficiency.

The logic of this modeling approach is illustrated with the help of figure 1. For simplicity, we focus on the long-run analysis and ignore the time lag. Assume four observations on the production frontier F. For a given input and output price, observation **c** maximizes profits at $\Pi_\mathbf{c}$. Consider now two suboptimal observations: one to the left (**e**) and another to the right (**f**) of point **c**. Both observations are technically efficient, but allocatively inefficient as compared to observation **c**. The question is whether we can unveil any reason for these observed allocative inefficiencies.

Unit **e** has expenditures $E_\mathbf{e}$ that prevent increasing its inputs and 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. Hence, its allocative inefficiency may be due to financial reasons. Point **f** has expenditures $E_\mathbf{f}$, but these expenditures do not constrain the unit in terms of its presumed objective of profit maximization, since it could always reduce its inputs and outputs to mimic observation **c**. Consequently, it is financially efficient and its allocative inefficiency must be due to other reasons (e.g., lack of managerial skills).

The same basic story applies to observations **g** and **h**, but these are also technically inefficient. For instance, for unit g, the gap between optimal ($\Pi_\mathbf{c}$) and observed profits ($\Pi_\mathbf{g}$) is decomposed into (a) the difference between the expenditure-constrained ($EC\Pi_\mathbf{g}$) and observed ($\Pi_\mathbf{g}$) profits that measures technical inefficiency, and (b) the gap between optimal ($\Pi_\mathbf{c}$) and expenditure-constrained ($EC\Pi_\mathbf{g}$) profits that evaluates financial inefficiency. The same story told for unit **f** applies to unit **h**, except that it is also technically inefficient.

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 revealed preference argument. The total expenditures over the accounting period indicate the maximum amount the farmer can spend on organizing production. In terms of figure 1, assuming that farmers intend to maximize profits, if observation e spends only the amount $E_\mathbf{e}$, this is probably because it has no other internal or external financing source 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 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 our approach overestimates the presence of credit constraints. We end with two remarks. First, to separate 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 difference resulting from comparing a profit function with contemporaneous and lagged credit constraint reflects planning adjustments. Second, the same story told above for the long-run case 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 functions. Distance functions are inversely related to radial efficiency measures. The input distance function is dual to the cost function, while the output distance function is dual to the revenue function (Cornes, 1992; Färe and Primont, 1995). The methodological framework adopted in this article takes advantage of the shortage function (Luenberger, 1992) as a representation of technology. It generalizes existing distance functions and accounts for both input contractions and output improvements. Chambers, Chung, and Färe (1998) show that this shortage (or directional distance) function is dual to the profit function (see also Luenberger, 1995).

Technology transforms inputs $\mathbf{x} = (x_1, \ldots, x_n) \in \Re^n_+$ into outputs $\mathbf{y} = (y_1, \ldots, y_m) \in \Re^m_+$. The set of all feasible input and output vectors is the production possibility set T: $T = \{(\mathbf{x}, \mathbf{y}) \in \Re^{n+m}_+;\ \mathbf{x}$ can produce $\mathbf{y}\}$. It is standard to impose the following assumptions (e.g, Färe and Primont, 1995): (T.1) $(0, 0) \in T$, $(0, \mathbf{y}) \in T \Rightarrow \mathbf{y} = 0$, i.e., no outputs without inputs; (T.2) the set $A(\mathbf{x}) = \{(\mathbf{u}, \mathbf{y}) \in T; \mathbf{u} \leq \mathbf{x}\}$ of observations is bounded $\forall \mathbf{x} \in \Re^n_+$, i.e., infinite outputs are not allowed with a finite input vector; (T.3) T is a closed set; (T.4) $\forall(\mathbf{x}, \mathbf{y}) \in T$, $(\mathbf{x}, -\mathbf{y}) \leq (\mathbf{u}, -\mathbf{v}) \Rightarrow (\mathbf{u}, \mathbf{v}) \in T$, i.e., fewer outputs can always be produced with more inputs, and inversely; (T.5) T is convex.

The directional distance function $D : T \to \Re$ involves simultaneous proportional input and output variations:[5]

$$(1) \qquad D(\mathbf{x}, \mathbf{y}; \mathbf{g}_i, \mathbf{g}_o) = \sup_{\delta \in R}\{\delta \geq 0; (\mathbf{x} - \delta\mathbf{g}_i, \mathbf{y} + \delta\mathbf{g}_o) \in T\}.$$

It is a special case of the shortage function (Luenberger, 1992) and the Farrell proportional distance (Briec, 1997), a generalization of the radial efficiency measure. Input and output distance functions also appear as special cases (see Chambers, Chung, and Färe, 1998). Note that the directional distance function is defined using a general directional vector $(-\mathbf{g}_i, \mathbf{g}_o)$.

The short-run version of this directional distance function involves simultaneous proportional variable input and output variations for a given subvector of fixed inputs. Therefore, the input set is partitioned into two subsets $V = \{1, \ldots, n^v\}$ and $F = \{n^v + 1, \ldots, n\}$, where $V(F)$ represents the set of variable (fixed) inputs. Obviously, $\{1, \ldots, n\} = V \cup F$. Inputs are partitioned such that each input vector is denoted $\mathbf{x} = (\mathbf{x}^v, \mathbf{x}^f)$. Similarly, the direction g is denoted $\mathbf{g} = (\mathbf{g}_i^v, \mathbf{g}_i^f, \mathbf{g}_o)$. Fixing $\mathbf{g}_i^f = 0$, the short-run directional distance function is then defined as:

$$(2) \qquad SRD(\mathbf{x}, \mathbf{y}; \mathbf{g}) = D\left(\mathbf{x}^v, \mathbf{x}^f, \mathbf{y}; \mathbf{g}_i^v, 0, \mathbf{g}_o\right) = \sup_{\delta \in R}\left\{\delta \geq 0; \left(\mathbf{x}^v - \delta\mathbf{g}_i^v, \mathbf{x}^f, \mathbf{y} + \delta\mathbf{g}_o\right) \in T\right\}.$$

To analyze expenditure constraints in production, we define two production possibility sets: (*a*) one with a long-run expenditure constraint (E_L): $T^{E_L} = \{(\mathbf{x}, \mathbf{y}) \in \Re^{n+m}_+; (\mathbf{x}, \mathbf{y}) \in T,\ \mathbf{w}.\mathbf{x} \leq E_L\}$, where $\mathbf{w} = (\mathbf{w}^v, \mathbf{w}^f)$ is a vector of variable and fixed input prices and the inner product is defined as follows: $\mathbf{w}.\mathbf{x} = \sum_{i=1}^{N} w_i x_i$, and (*b*) one with a short-run expenditure constraint (E_S): $T^{E_S} = \{(\mathbf{x}, \mathbf{y}) \in \Re^{n+m}_+;\ (\mathbf{x}, \mathbf{y}) \in T,\ \mathbf{w}^v.\mathbf{x}^v \leq E_S\}$. The first technology aims at evaluating the presence of investment constraints, while the second targets on revealing the existence of short-run financing constraints.[6]

[5] Axiomatic properties are treated in detail in Briec (1997) and Chambers, Chung, and Färe (1998).

[6] To characterize production, it is possible to define long- and short-run versions of the proportional distance function relative

The standard long-run profit function is:

$$(3) \qquad \Pi(\mathbf{w}, \mathbf{p}) = \sup_{x,y}\{\mathbf{p}.\mathbf{y} - \mathbf{w}.\mathbf{x}; D(\mathbf{x}, \mathbf{y}; \mathbf{g}_i, \mathbf{g}_o) \geq 0\}.$$

Luenberger (1992, 1995) and Chambers, Chung, and Färe (1998) show duality between the directional distance function and the standard long-run profit function. The short-run or restricted total profit function is:

$$(4) \qquad SR\Pi(\mathbf{w}, \mathbf{p}, \bar{\mathbf{x}}^f) = \sup_{x^v,y}\{\mathbf{p}.\mathbf{y} - \mathbf{w}^v.\mathbf{x}^v - \mathbf{w}^f.\bar{\mathbf{x}}^f; (\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y}) \in T\}$$

while the short-run variable profit function is:

$$(5) \qquad SRV\Pi(\mathbf{w}^v, \mathbf{p}, \bar{\mathbf{x}}^f) = \sup_{x^v,y}\{\mathbf{p}.\mathbf{y} - \mathbf{w}^v.\mathbf{x}^v; (\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y}) \in T\}.$$

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

It is rather straightforward to establish duality between the short-run directional distance function (3) and the short-run variable profit function (8).[7]

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

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

(b) $SRD(\mathbf{x^v}, \bar{\mathbf{x}}^\mathbf{f}, \mathbf{y}; \mathbf{g}) = \inf_{\mathbf{w},\mathbf{p}\geq 0}\{(SRV\Pi(\mathbf{w}^v, \mathbf{p}, \bar{\mathbf{x}}^\mathbf{f}) - (\mathbf{p}.\mathbf{y} - \mathbf{w}^v.\mathbf{x}^v))/(\mathbf{p}.\mathbf{g}_o + \mathbf{w}^v.\mathbf{g}_i^v); (\mathbf{w}, \mathbf{p}) \neq 0\}$.

Proof: See Appendix.

To take account of credit constraints when optimizing profits, the long-run expenditure-constrained profit function is defined as:

$$(6) \qquad EC\Pi(\mathbf{w}, \mathbf{p}, E_L) = \sup\{\mathbf{p}.\mathbf{y} - \mathbf{w}.\mathbf{x}; (\mathbf{x}, \mathbf{y}) \in T^{E_L}\}$$

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

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

where E_S is the amount of outlays one can spend on variable inputs solely.[8]

Integrating Credit Constraints into Profit Efficiency Decompositions

Having defined all basic elements for gauging performance, we now define a suitable efficiency decomposition. First, we repeat the basic additive decomposition of profit efficiency developed in Chambers, Chung, and Färe (1998); 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 cases.

The overall efficiency index (*OE*) is defined as the quantity:

$$(8) \qquad OE(\mathbf{x}, \mathbf{y}, \mathbf{p}, \mathbf{w}) = (\Pi(\mathbf{w}, \mathbf{p}) - (\mathbf{p}.\mathbf{y} - \mathbf{w}.\mathbf{x}))/(\mathbf{p}.\mathbf{g}_o + \mathbf{w}.\mathbf{g}_i).$$

Thus, $OE(\mathbf{x}, \mathbf{y}, \mathbf{p}, \mathbf{w})$ is the ratio between (*a*) the difference between maximum profit and observed profit for the observation evaluated and (*b*) the normalized value of the direction vector $\mathbf{g} = (\mathbf{g}_i, \mathbf{g}_o)$ for given output and input prices $(\mathbf{p}, \mathbf{w})$. Then, we characterize a *TE* index ($TE(\mathbf{x}, \mathbf{y})$) as the quantity: $TE(\mathbf{x}, \mathbf{y}) = D(\mathbf{x}, \mathbf{y}; \mathbf{g})$. Finally, the *AE* index is defined as the quantity: $AE(\mathbf{x}, \mathbf{y}, \mathbf{w}, \mathbf{p}) = OE(\mathbf{x}, \mathbf{y}, \mathbf{w}, \mathbf{p}) - D(\mathbf{x}, \mathbf{y}; \mathbf{g})$. The notion of *OE* ensures that both *TE* and *AE* are realized simultaneously. The following additive decomposition identity holds: $OE(\mathbf{x}, \mathbf{y}, \mathbf{w}, \mathbf{p}) = AE(\mathbf{x}, \mathbf{y}, \mathbf{w}, \mathbf{p}) + TE(\mathbf{x}, \mathbf{y})$. All three

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.

[7] 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 (4) and the short-run directional distance function (2), since the fixed cost terms cancel out. However, in a ratio-based approach, such duality result could not be maintained, while the former (between (2) and (5)) can. Therefore, we focus on the former duality result.

[8] Both of these expenditure-constrained profit functions are dual to long run, respectively, short-run expenditure-constrained directional distance functions mentioned in footnote 6. For reasons of space, we refrain from formally establishing these duality results.

components are semi-positive, with zero indicating efficiency. This implies that increases in efficiency are reflected in decreasing scores.

Using the short-run variable profit function, similar short-run overall efficiency (*SROE*) components can be defined. Setting fixed inputs in the directional vector equal to zero ($\mathbf{g}_i^f = 0$), *SROE* is the quantity:

$$\text{(9)} \quad SROE(\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y}, \mathbf{w}, \mathbf{p}) = (SRV\Pi(\mathbf{w}, \mathbf{p}, \bar{\mathbf{x}}^f) - (\mathbf{p}.\mathbf{y} - \mathbf{w}^v.\mathbf{x}^v))/ \left(\mathbf{p}.\mathbf{g}_o + \mathbf{w}^v.\mathbf{g}_i^v\right).$$

Short-run technical efficiency (*SRTE*) corresponds to the short-run directional distance function ($SRTE(\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y}) = SRD(\mathbf{x}, \mathbf{y}; \mathbf{g})$). A short-run allocative efficiency index (*SRAE*) again bridges the gap: $SRAE(\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y}, \mathbf{w}, \mathbf{p}) = SROE(\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y}, \mathbf{w}, \mathbf{p}) - SRTE(\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y})$. Since in the empirical section we cannot separate the latter components, we ignore this distinction between *TE* and *AE* in the developments that follow.

FGL distinguish between actual and financial short-run efficiency. Actual efficiency (*ACE*) is defined as the ratio between observed profits and a short-run expenditure-constrained profit function. *FE* is measured as the short-run expenditure-constrained profit function divided by the short-run profit function. The challenge is now to transform this ratio-based FGL decomposition, such that it is compatible with the additive decomposition outlined above. Furthermore, this FGL decomposition needs adaptation, since lagged expenditure constraints are to be included in our empirical analysis, representing the separation of planning and production in agriculture. This adds a planning efficiency (*PE*) component to the FGL decomposition. We first develop the extended decomposition from a long-run perspective. Then, we switch to a short-run viewpoint taking account of input fixity.

First, long-run *ACE* is defined as the difference between the long-run expenditure-constrained profit function and observed profits, normalized by the value of the directional vector:

$$\text{(10)} \quad ACE\left(\mathbf{x}, \mathbf{y}, \mathbf{w}, \mathbf{p}, E_L^t\right) = \left(EC\Pi\left(\mathbf{w}, \mathbf{p}, E_L^t\right) - (\mathbf{p}.\mathbf{y} - \mathbf{w}.\mathbf{x})\right)/ (\mathbf{p}.\mathbf{g}_o + \mathbf{w}.\mathbf{g}_i).$$

Next, long-run *PE* can be characterized as the difference between long-run *ACE* with lagged and current expenditure constraints:

$$\begin{aligned} \text{(11)} \quad PE\left(\mathbf{x}, \mathbf{y}, \mathbf{w}, \mathbf{p}, E_L^t, E_L^{t-1}\right) &= ACE\left(\mathbf{x}, \mathbf{y}, \mathbf{w}, \mathbf{p}, E_L^{t-1}\right) - ACE\left(\mathbf{x}, \mathbf{y}, \mathbf{w}, \mathbf{p}, E_L^t\right) \\ &= \left(EC\Pi\left(\mathbf{w}, \mathbf{p}, E_L^{t-1}\right) - EC\Pi\left(\mathbf{w}, \mathbf{p}, E_L^t\right)\right)/(\mathbf{p}.\mathbf{g}_o + \mathbf{w}.\mathbf{g}_i). \end{aligned}$$

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

Finally, long-run *FE* is defined as the difference between *OE* (without expenditure constraint) and *ACE* with a lagged expenditure constraint:

$$\begin{aligned} \text{(12)} \quad FE\left(\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y}, \mathbf{w}, \mathbf{p}, E_L^{t-1}\right) &= OE(\mathbf{x}, \mathbf{y}, \mathbf{w}, \mathbf{p}) - ACE\left(\mathbf{x}, \mathbf{y}, \mathbf{w}, \mathbf{p}, E_L^{t-1}\right) \\ &= \left(\Pi(\mathbf{w}, \mathbf{p}) - EC\Pi\left(\mathbf{w}, \mathbf{p}, E_L^{t-1}\right)\right)/ (\mathbf{pg}_o + \mathbf{wg}_i). \end{aligned}$$

FE is positive whenever the lagged expenditure constraint is binding in the long-run expenditure-constrained profit function. This component indicates the loss of profits due to the expenditure constraint, and thereby reveals any eventual difficulties farmers encounter when financing their investments.

Clearly, the complete decomposition now reads:

$$\begin{aligned} \text{(13)} \quad OE(\mathbf{x}, \mathbf{y}, \mathbf{w}, \mathbf{p}) = {} & FE\left(\mathbf{x}, \mathbf{y}, \mathbf{w}, \mathbf{p}, E_L^{t-1}\right) \\ & + PE\left(\mathbf{x}, \mathbf{y}, \mathbf{w}, \mathbf{p}, E_L^t, E_L^{t-1}\right) \\ & + ACE\left(\mathbf{x}, \mathbf{y}, \mathbf{w}, \mathbf{p}, E_L^t\right). \end{aligned}$$

Basically, this is just the difference-based equivalent of the ratio-based efficiency decomposition of FGL, extended with a long-run

PE component, because of the presence of a lagged expenditure constraint.[9]

Turning to a short-run perspective, a series of similar components can be defined with exactly the same interpretation as in the long-run case. Therefore, we briefly define these components, but abstain from repeating their interpretation. The short-run actual efficiency (*SRACE*) is defined as the difference between the short-run expenditure-constrained variable profit function and observed variable profits, normalized by the value of the directional vector:

$$(14)\quad SRACE(\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y}, \mathbf{w}, \mathbf{p}, E_S^t) = \big(SRVEC\Pi(\mathbf{w}, \mathbf{p}, \bar{\mathbf{x}}^f, E_S^t) - (\mathbf{p}.\mathbf{y} - \mathbf{w}^v.\mathbf{x}^v)\big)/(\mathbf{p}.\mathbf{g}_o + \mathbf{w}^v.\mathbf{g}_i^v).$$

Then, short-run planning efficiency (*SRPE*) can be characterized as the difference between short-run *ACE*s with lagged and current expenditure constraints:

$$(15)\quad SRPE(\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y}, \mathbf{w}, \mathbf{p}, E_S^t, E_S^{t-1}) = SRACE(\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y}, \mathbf{w}, \mathbf{p}, E_S^{t-1}) - SRACE(\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y}, \mathbf{w}, \mathbf{p}, E_S^t) = \big(SRVEC\Pi(\mathbf{w}, \mathbf{p}, \bar{\mathbf{x}}^f, E_S^{t-1}) - SRVEC\Pi(\mathbf{w}, \mathbf{p}, \bar{\mathbf{x}}^f, E_S^t)\big)/(\mathbf{p}.\mathbf{g}_o + \mathbf{w}^v.\mathbf{g}_i^v).$$

Finally, one defines short-run financial efficiency (*SRFE*) as the difference between *OE* and *ACE* with a lagged expenditure constraint:

$$(16)\quad SRFE(\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y}, \mathbf{w}, \mathbf{p}, E_S^{t-1}) = SROE(\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y}, \mathbf{w}, \mathbf{p}) - SRACE(\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y}, \mathbf{w}, \mathbf{p}, E_S^{t-1}) = \big(SRV\Pi(\mathbf{w}, \mathbf{p}, \bar{\mathbf{x}}^f) - SRVEC\Pi(\mathbf{w}, \mathbf{p}, \bar{\mathbf{x}}^f, E_S^{t-1})\big)/(\mathbf{p}.\mathbf{g}_o + \mathbf{w}^v.\mathbf{g}_i^v).$$

The complete short-run decomposition now reads:

$$(17)\quad SROE(\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y}, \mathbf{w}, \mathbf{p}) = SRFE(\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y}, \mathbf{w}, \mathbf{p}, E_s^{t-1}) + SRPE(\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y}, \mathbf{w}, \mathbf{p}, E_S^t, E_S^{t-1}) + SRACE(\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y}, \mathbf{w}, \mathbf{p}, E_S^t).$$

Description of the Sample and Empirical Results

Sample: Description and Details on Model Specifications

The sample from Centre d'Economie Rurale du Pas-de-Calais (CER) contains 178 French farms in the Nord-Pas-de-Calais, observed from 1994 to 2001. The farms in this balanced panel specialize in cash crops (grain, sugar beets, etc.). Livestock is of little or no importance for them. One French bank (Crédit Agricole) has a near monopoly on agricultural financing (Benjamin and Phimister, 2002). Its position is reinforced by the fact that it is also an agent for government policies (e.g., subsidized credit).

Monetary data are deflated using their price indices and expressed in constant Euros of 1994, to neutralize strong price variations over time (especially for the outputs). Turning to the specification of technology, output is measured by total sales (*SALES*). We define two variable inputs and three fixed inputs. Variable inputs are: (*a*) materials and operational expenses (seeds, fertilizers, pesticides, energy, gas, water, etc.) (*OPERATIONAL EXPENSES*), (*b*) taxes and salaries of hired labor (*EMPLOYEES*) expressed as full time equivalent (FTE) farm employees (i.e., 2,400 working hours/year). The three fixed inputs are as follows: (*a*) An annual depreciation (over a period of fifteen years) of building and capital equipment services (*IMMOBILIZATIONS*). (*b*) The cost of land is computed by applying rental rates to both hired and owned land. 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.[10] (*c*) The cost of family labor is the sum of minimum wages and the social security taxes paid by employers (*FAMILY LABOR*). One unit of

[9] Long-run actual efficiency can be decomposed into technical and allocative efficiencies. The same remark applies to the short-run equivalent expression developed below. The basic mathematical programs are available in FGL.

[10] Unfortunately, there is no agronomical fertility index available for individual farms. Note that the analysis has also been performed without correcting for yield differences: results are very similar.

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

Variables	Average	Standard Deviation	Coefficient of Variation	Minimum	Maximum
Family labor (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 (€)[a]	51,350.73	31,438.88	0.61	6,162.90	185,931.52
Immobilizations (€)[a]	38,863.54	30,100.25	0.77	1,612.66	268,997.05
Sales (€)[a]	225,343.04	138,343.95	0.61	24,678.06	937,601.64

[a]Constant 1994 prices.

family labor in FTE equals 2,400 hours per year. Their wage is the minimum (defined by the French SMIC) plus social security contributions by employer.

Descriptive statistics for this sample are 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 labor. The real annual growth rates are (*a*) total labor 0.73%, (*b*) surface area 1.11%, (*c*) operational expenses 2.04%, (*d*) immobilizations 4.97%, and (*e*) sales 2.59%.

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 farms face identical prices each year is plausible, because most output prices are regulated by the CAP, and most inputs are procured within the same regional markets where prices between firms differ little. Assuming identical prices, FGL (page 577) show that all profit functions defined above can be estimated using revenue and cost categories, since the resulting optimal profits are identical. This 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 (1991).

With respect to the panel nature of the sample, we opted to estimate nonparametric production technology frontiers for each year separately, imposing minimal assumptions (i.e., strong input and output disposability, convexity, and variable returns to scale (see Färe and Primont (1995) for details)). 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 stronger hypotheses. For example, one can estimate an intertemporal frontier by including all observations in the reference technology while disregarding the time dimension. While this presupposes the absence of technological change, it enhances 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 Tauer and Stefanides (1998), this can be done using the technological change component of recent productivity indices/indicators (e.g., Malmquist or Luenberger (Chambers, 2002)) that essentially compare observations relative to two production technologies, each representing a given year. In this case, the time dimension in the second stage tobit panel estimation is only supposed to capture variations in *TE*.[11]

Empirical Results: The Extent of Credit Rationing among French Farmers

Because of the introduction of a one-year lagged expenditure constraint in some models, short-run expenditure-constrained and expenditure-unconstrained profits were estimated using an annual profit frontier over 1995–2001. Table 2 lists average efficiency

[11] Results for the other two specifications of technology (i.e., intertemporal frontier with and without correcting for technological change) are also computed. The first stage efficiency results are slightly different in that higher inefficiency levels are detected, but all qualitative interpretations stay unaltered (e.g., the relative importance of actual, financial, and planning efficiencies is about the same). Moreover, conclusions of the second stage tobit analysis remain unaffected.

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

Efficiency Components	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%

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

Time Horizon	Binding Credit Constraint	Nonbinding Credit Constraint
Short run	67.2%[a]	32.8%
	1.60	n.a[b]
Long run	99.7%	0.3%
	1.35	n.a.

[a] % with respect to sample size.
[b] n.a. = not applicable.

scores for various components at the sample level. On an average, *OE* is 30.24% and 76.59%, respectively, in the short- and the long-run. This implies that farms could improve their normalized profits by about 30% and 76%. In the short run, *OE* is explained by *ACE* at 23%, *FE* at 8%, and *PE* at −1.5%. A battery of nonparametric test statistics confirm that these efficiency scores, except the planning component, are significantly different from zero.[12] Thus, while mismanagement and technical problems explain most of the gap between observed and maximal profits, the short-run financial constraints also have undeniable effects.

In the long run, financial constraints become the main source of ill functioning. Limited access to financial resources explains 49% of *OE*. Actual inefficiencies remain substantial, but are secondary in importance, while *PE* is again around zero. *PE* is close to zero on an average in both perspectives, clearly confirming the interpretation about farmers aligning initial and planned budgets when needed.

FGL focused on a sample of 82 farms producing rice in 1984 and estimated the loss of profit due to credit constraints at 8%. Using a parametric approach, Bhattacharyya, Bhattacharyya, and Kumbhakar (1996) estimate the efficiency loss 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.

Table 3 reports whether the credit constraint is binding or not in the short- and long-run, as well as the average shadow prices. 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 larger, apparently resulting in easier access to credit. Of course, also their small sample size may well have an influence. Whittaker and Morehart (1991), in another study analyzing 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 simultaneously financially constrained in the short- and long-run. Again, their focus on large farms may partly explain the differences with our results.

The average shadow price of the credit constraint reveals that a unit relaxation adds almost 1.60 to short-run profit, while it adds more than 1.35 to long-run profit. These average shadow interest rates are far above market interest rates. This divergence is evidence of credit rationing and the mark-up quantifies its severity. Clearly, both the short- and long-run development of these farms is seriously jeopardized by a lack of access to credit.

One plausible mechanism behind the overwhelming presence of binding credit constraints is that most farms face 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.

Summarizing the empirical results so far, *FE* 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. 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

[12] Since distributions of efficiency scores are nonnormal, traditional parametric tests are inappropriate. Details are suppressed for reasons of space.

Europe. Also, notice that we only identify potentially credit-constrained farms, a superset of the effectively credit-constrained farms. This implies an upward bias in our estimates of credit constraints, which may partly explain the pervasive nature of credit rationing and the high value of shadow prices.

Empirical Results: A Tobit Model of Factors Influencing FE

In this subsection, we estimate a tobit model to explain the observed heterogeneity in measured *FE* scores. The variables that explain financial inefficiency are likely similar to the variables used in agricultural credit scoring models. Credit scoring models evaluate 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, 1992).

First, variables representing the financial structure of the farm should play a role under capital market imperfections. Therefore, following Bierlen and Featherstone (1998), we include a 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 financing cost (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 *FE*.

Second, the structural characteristics of farm production may well affect *FE*. Relative to other specializations, cash crops farms are more land intensive and their total (own and hired) land size represents the highest share of all tangible assets.[13] 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, we also add the explicit returns to scale indicators discussed previously, i.e., dummy variables representing constant (*DCRS*) and increasing (*DIRS*) returns to scale. Furthermore, within the context of our specialized farms focusing mainly on cereals and sugar beets, the ratio of value added over sales (variable *Rate value added*) can only improve by cultivating at least also some higher value-added crops (endives, 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 select a suitable scale of operations and that economies of scope are substantial, but seem to diminish with size (Chavas, 2001). Finally, the ratio of own capital to value added (variable *Own capital/value added*) is included as a measure of own capital intensity.

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 area* as a proxy of the average yield. 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, 1998).

We report in table 4, the estimates of a multivariate panel regression of *FE* against the above explanatory variables.[14] Given the relative nature of frontier benchmarking (i.e., efficiency measures depend on the sample considered), efficiency scores are bounded below by zero to indicate relative efficiency. Therefore, negative signs indicate improvements of *FE*, while positive signs indicate the reverse. Furthermore, to account for this censoring of efficiency scores, a random effects tobit regression estimator is used. The low p-values for the Wald test in table 4 indicate that the independent variables help explaining the variation of *FE*s. The value of ρ 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 privilege the random effect estimator.

Focusing first on the effects common to both short- and long-run, table 4 indicates that lower financial inefficiency goes hand-in-hand with: (*a*) a bigger size in terms of surface area and

[13] 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.

[14] 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.

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	0.04333	−0.05047
	(0.180)[a]	(0.057)
Rate of debt charges	−0.00002	0.00016
	(0.867)	(0.061)
Surface area	−0.00088	−0.00313
	(0.000)	(0.000)
DIRS	−0.01215	0.01137
	(0.216)	(0.091)
DCRS	−0.05856	0.03135
	(0.000)	(0.001)
Rate of value added	0.65914	0.15964
	(0.000)	(0.002)
Own capital/value added	0.02256	−0.01136
	(0.005)	(0.101)
Sales/surface area	−0.00005	−0.00008
	(0.000)	(0.000)
D1995	0.00725	−0.20514
	(0.527)	(0.000)
D1996	−0.03779	−0.18339
	(0.001)	(0.000)
D1997	−0.07633	−0.13498
	(0.000)	(0.000)
D1998	−0.07770	−0.10875
	(0.000)	(0.000)
D1999	−0.12025	−0.10584
	(0.000)	(0.000)
D2000	−0.04719	−0.05028
	(0.000)	(0.000)
Age	−0.00304	0.00072
	(0.000)	(0.268)
Constant	−0.10449	0.98175
	(0.214)	(0.000)
Log-likelihood	478.168	1387.824
Wald test (χ^2)	385.02	3549.54
	(0.000)	(0.000)
ρ	0.302	0.526

[a] *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 χ^2, with $y_{it} = x_{it}\text{B} + u_i + e_{it}$ (H_0: $\text{B}_j = a$ versus H_1: $\text{B}_j \neq a$).

(*b*) higher productive performance, defined in terms of sales per surface area. By contrast, higher value added increases financial inefficiency in the short- as well as in the long-run. A plausible explanation is that producing with a high rate of value added requires specialization and such a specialization strategy requires major investments. Furthermore, compared to the reference year 2001, short- and long-run *FE*s improved, respectively, in the years 1996–2000 and 1995–2000, as can be inferred from the year dummies *D1995* to *D2000*.

There is an opposite effect in the short-run versus the long-run concerning the impact of producing at constant returns to scale. While producing at optimal scale enhances *SRFE*, in the long run it contributes to financial inefficiency. Furthermore, there are some variables that are only significant in either short run or long run. This is notably the case for the farmer's age that improves the *SRFE*, but yields no significant impact on long-run *FE*. According to the farm life-cycle model, liquidity shortages (savings, cash, ...) are likely a problem for young farmers in the short run. Similar effects concerning the age of farmers have been reported by, for example, Tauer and Kaiser (1988). Moreover, a higher rate of debts, identified using the ratio of total debts to assets, improves long-run *FE*, but exerts no significant effect in the short run. The ratio own capital to value added damages *SRFE* only. Finally, the rate of debt charges generate no significant impact on the short run, but it does affect the long-run *FE* 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 collateral. Since they have easier access to credit, they are more capable to adapt their technologies when needed. 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, Chavas and Aliber (1993) identify a positive relation between the debt to asset ratio and *TE* for Wisconsin farms in 1987. Their results support the free cash flow hypothesis suggesting that indebted farmers are motivated to improve their efficiency to ensure their repayment capabilities.

In the literature, a few other effects have also been reported. For instance, Whittaker and Morehart (1991) report that debt-constrained farms owe their debt predominantly to federally subsidized institutions. Since the latter are lenders of last resort, this may well indicate that these farms suffer serious financial difficulties. In our sample, we have no information on these characteristics.

Conclusions

This article studied credit constraints on a panel of French farmers in the Nord-Pas-de-Calais region. The credit-constrained profit maximization model of FGL is extended in three ways. First, the model is rephrased in terms of directional distance functions and a duality relationship between short-run directional distance function and short-run profit function is formulated. Second, the presence of credit constraints in the short run and investment constraints in the long run is modeled using short- and 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. While in the short run there are important actual inefficiencies linked to a poor management, 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. In the long run, almost all farms seem to suffer from credit constraints for financing their investments.

Though it would be good to see some additional work corroborating these results, it is probably evident that the European CAP should pay more attention to credit rationing and that facilitating access to short- and long-run credit is a valuable policy instrument. It could improve the regulation of agriculture and complete the recent policies aimed at direct revenue support. For instance, a system of public sector financial guarantees similar to certain existing private initiatives, mostly at a cooperative level, may alleviate problems of collateral. Furthermore, an additional source of external financing could be loans with annuities varying over the agricultural business cycle. Finally, making leasing more attractive by extending its fiscal deductibility could free internal financial resources. These proposals may merit attention in a European context (especially given the EU enlargement). Policy experience in other developed countries is an additional source of inspiration for these matters (Barry and Robison, 2001).

[Received June 2003; accepted July 2005.]

References

Ball, V., J.-C. Bureau, K. Eakin, and A. Somwaru. 1997. "CAP Reform: Modelling Supply Response Subject to the Land Set-Aside." *Agricultural Economics* 17:277–88.

Barry, P.J., and L.J. Robison. 2001. "Agricultural Finance: Credit, Credit Constraints, and Consequences." In B. Gardner and G. Rausser, eds. *Handbook of Agricultural Economics*, vol. 1a. Amsterdam: Elsevier, pp. 513–71.

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

Benjamin, C., and E. Phimister. 2002. "Does Capital Market Structure Affect Farm Investment? A Comparison Using French and British Farm-Level Panel Data." *American Journal of Agricultural Economics* 84:1115–29.

——. 1997. "Transaction Costs, Farm Finance and Investment." *European Review of Agricultural Economics* 24:453–66.

Bhattacharyya, A., A. Bhattacharyya, and S. Kumbhakar. 1996. "Governmental Interventions, Market Imperfections, and Technical Inefficiency in a Mixed Economy: A Case Study of Indian Agriculture." *Journal of Comparative Economics* 22:219–41.

Bierlen, R., and A.M. Featherstone. 1998. "Fundamental q, Cash Flow, and Investment: Evidence from Farm Panel Data." *Review of Economics and Statistics* 80:427–35.

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

Chambers, R.G. 2002. "Exact Nonradial Input, Output, and Productivity Measurement." *Economic Theory* 20:751–65.

Chambers, R.G., Y. Chung, and R. Färe. 1998. "Profit, Directional Distance Functions, and Nerlovian Efficiency." *Journal of Optimization Theory and Applications* 98:351–64.

Chavas, J.-P. 2001. "Structural Change in Agricultural Production: Economics, Technology and Policy." In B. Gardner and G. Rausser, eds. *Handbook of Agricultural Economics*, vol. 1a. Amsterdam: Elsevier, pp. 263–85.

Chavas, J.-P., and M. Aliber. 1993. "An Analysis of Economic Efficiency in Agriculture: A Nonparametric Approach." *Journal of Agricultural and Resource Economics* 18:1–16.

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

De Meza, D., and D. Webb. 1987. "Too Much Investment: A Problem of Asymmetric Information." *Quarterly Journal of Economics* 102:281–92.

Ellinger, P., N. Splett, and P. Barry. 1992. "Consistency of Credit Evaluations at Agricultural Banks." *Agribusiness* 8:517–36.

Färe, R., S. Grosskopf, and H. Lee. 1990. "A Nonparametric Approach to Expenditure-Constrained Profit Maximization." *American*

Journal of Agricultural Economics 72:574–81.

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

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

Hughes, J.P., W.W. Lang, L.J. Mester, and C.-G. Moon. 1996. "Efficient Banking under Interstate Branching." *Journal of Money, Credit, and Banking* 28:1045–71.

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

Lee, H., and R.G. Chambers. 1986. "Expenditure-Constraints and Profit Maximization in U.S. Agriculture." *American Journal of Agricultural Economics* 68:857–65.

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

——. 1992. "New Optimality Principles for Economic Efficiency and Equilibrium." *Journal of Optimization Theory and Applications* 75:221–64.

Petrick, M. 2005. "Empirical Measurement of Credit Rationing in Agriculture: A Methodological Survey." *Agricultural Economics* 33:191–203.

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

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

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

Tauer, L.W., and Z. Stefanides. 1998. "Success in Maximizing Profits and Reasons for Profit Deviation on Dairy Farms." *Applied Economics* 30:151–56.

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

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

Appendix

Proof of Proposition 1: (a) First, consider the subset defined by $H(\bar{\mathbf{x}}^f) = \{(\mathbf{x}^v, \mathbf{x}^f, \mathbf{y}) \in \Re^{n+m}; \mathbf{x}^f = \bar{\mathbf{x}}^f\}$. By definition, we have $\{(\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y}) \in T\} = T \cap H(\bar{\mathbf{x}}^f)$. Since $\mathbf{g}_i^f = 0$, we have $SRD(\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y}; \mathbf{g}) \geq 0 \Leftrightarrow (\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y}) \in T \cap H(\bar{\mathbf{x}}^f)$ and the result is immediate. (b) The set $\{(\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y}) \in T\} = T \cap \{(\mathbf{x}^v, \mathbf{x}^f, \mathbf{y}) \in \Re^{n+m}; \mathbf{x}^f = \bar{\mathbf{x}}^f\}$ is convex and using a usual dual characterization, we obtain:

$$\begin{aligned}
&T \cap H(\mathbf{x}^f)\\
&= \bigcap_{w,p\geq 0} \Big\{(\mathbf{x}^v, \bar{\mathbf{x}}^f, \mathbf{y}) \in \Re_+^{n+m}; \mathbf{p}.\mathbf{y} - \mathbf{w}^v.\mathbf{x}^v - \mathbf{w}^f.\bar{\mathbf{x}}^f\\
&\qquad \leq \sup_{(\mathbf{x}^v, \mathbf{x}^f, \mathbf{y}) \in H(\bar{\mathbf{x}}^f)} \{\mathbf{p}.\mathbf{y} - \mathbf{w}^v.\mathbf{x}^v - \mathbf{w}^f.\bar{\mathbf{x}}^f\}\Big\}\\
&= \Re_+^{n+m} \cap \bigcap_{w,p\geq 0} M(\mathbf{w}, \mathbf{p}, \bar{\mathbf{x}}^f)
\end{aligned}$$

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

$$\begin{aligned}
&SRD(\mathbf{w}, \mathbf{p}, \bar{\mathbf{x}}^f; \mathbf{g})\\
&\quad = \inf_{\delta \in R} \{\delta; (\mathbf{x}^v - \delta \mathbf{g}_i^v, 0, \mathbf{y} + \delta \mathbf{g}_o) \notin T \cap H(\bar{\mathbf{x}}^f)\}\\
&\quad = \inf_{\delta \in R} \Big\{\delta; (\mathbf{x}^v - \delta \mathbf{g}_i^v, 0, \mathbf{y} + \delta \mathbf{g}_o)\\
&\qquad \notin \bigcap_{w,p\geq 0} M(\mathbf{w}, \mathbf{p}, \bar{\mathbf{x}}^f)\Big\}\\
&\quad = \inf_{\delta \in R} \Big\{\delta; (\mathbf{x}^v - \delta \mathbf{g}_i^v, 0, \mathbf{y} + \delta \mathbf{g}_o)\\
&\qquad \in \bigcup_{w,p\geq 0} \Re^{n+m}/M(\mathbf{w}, \mathbf{p}, \bar{\mathbf{x}}^f)\Big\}\\
&\quad = \inf_{\mathbf{w},\mathbf{p}\geq 0} \inf_{\delta \in R} \{\delta; (\mathbf{x}^v - \delta \mathbf{g}_i^v, 0, \mathbf{y} + \delta \mathbf{g}_o)\\
&\qquad \in \Re^{n+m}/M(\mathbf{w}, \mathbf{p}, \bar{\mathbf{x}}^f)\}\\
&\quad = \inf_{\mathbf{w},\mathbf{p}\geq 0} \inf_{\delta \in R} \{\delta; \mathbf{p}.(\mathbf{y} + \delta \mathbf{g}_o) - \mathbf{w}^v.(\mathbf{x}^v - \delta \mathbf{g}_i^v)\\
&\qquad - \mathbf{w}^f.\bar{\mathbf{x}}^f > SR\Pi(\mathbf{w}, \mathbf{p}, \bar{\mathbf{x}}^f)\}\\
&\quad = \inf_{\mathbf{w},\mathbf{p}\geq 0} \{(SR\Pi(\mathbf{w}, \mathbf{p}, \bar{\mathbf{x}}^f) - \mathbf{p}.\mathbf{y} + \mathbf{w}^v.\mathbf{x}^v\\
&\qquad + \mathbf{w}^f.\bar{\mathbf{x}}^f)/(\mathbf{p}.\mathbf{g}_o + \mathbf{w}^v.\mathbf{g}_i^v); (\mathbf{w}, \mathbf{p}) \neq 0\}
\end{aligned}$$

and, utilizing expression (5), the fixed costs terms cancel out and the result is obtained. ■