Analysing the efficiency of farms in Burkina Faso

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Abstract

In this article, the stochastic cost frontier approach with inefficiency effects was used to analyse the economic efficiency of farms in Burkina Faso. The findings indicate that the average level of the cost inefficiency of a farm was 35.8%, which corresponds to an average monetary loss of 13 188 CFA francs per hectare. The level of education of the head of household, the loss of labour time due to diseases, access to a good road, ownership of a radio set, access to credit and residence in a high-potential agricultural zone were identified as the main determinants of the level of cost inefficiency. The findings reveal that farms face diseconomies of scale, which implies that small-scale farms were more efficient than large farms. However, farms recorded economies of scope between cereals and cotton, oilseeds and legume production.

Key words: cost inefficiency; economies of scale; economies of scope; stochastic cost frontier

1. Introduction

The capacity of agriculture in Burkina Faso to contribute to economic growth and poverty reduction among farm households depends on the economic efficiency of farms. Agricultural production is mainly extensive and dominated by smallholder farmers with low productivity and average land size, ranging from three to six hectares (Ministère de l'Agriculture, de l'Eau et des Ressources Halieutiques[1] 2004). Most of their land was allocated to food crops until the liberalisation of the agricultural sector in 1992.

Since this policy reform, smallholder farmers have started diversifying their crops toward both food and cash crops in order to improve their living conditions. However, beyond market opportunities and land availability, smallholder farmers' crop diversification decisions depend on their ability to face the additional costs incurred by the adoption of new crops, and this has had an impact on the economic efficiency of farm production.

The concept of economic efficiency of production comprises two dimensions: technical efficiency and allocative efficiency (Farrell 1957). Technical inefficiency is characterised by a shortfall in production in view of what is technically possible with a given level of inputs. Allocative inefficiency is the use of inputs in non-optimal ratios in view of their relative prices. Most studies on smallholder farms focus on technical efficiency (Kalirajan 1990; Audibert 1997; Nuama 2006).

There is a gap in the literature relating to scale economies and scope economies of farms in the context of Burkina Faso. The existing studies on the issue are focused more on the technical and allocative efficiencies of small-scale farms (Savadogo *et al*. 2016). The integrated multi-production nature of most farms in Burkina Faso, which combine both food and cash crops, was not taken into account.

[1] Ministry of Agriculture, Hydraulics and Water Resources

Farmers generally grow several crops on different plots or the same plot, and not considering this aspect in the model may not be enough to understand farmer reactions to policy interventions.

This study used the cost frontier approach to deal with the economic efficiency of farms in Burkina Faso. It is useful for the modelling of the smallholder farmers' productive behaviour in the context of multi-output and to deal with scale and scope economies. The study used survey data collected from households in rural Burkina Faso within the framework of the "Convergence" project, which was collaborative research between the Laboratory of Quantitative Analysis Applied to Development – Sahel (LAQAD-S) of the University of Ouaga 2 and the International Food Policy Research Institute (IFPRI).

The rest of the study is organised into four sections. Section 2 presents the conceptual framework of the cost frontier analysis, while Section 3 focuses on the descriptive analysis of the major characteristics of the farms. The findings of the analysis of farm production efficiency are presented in Section 4. Finally, Section 5 draws conclusions and sets out policy implications.

2. Analytical framework of farms' cost frontier

Economic inefficiency, according to Farrell (1957), is consistent with the neo-classical hypothesis that assumes that a firm minimises costs subject to the level of production (substantive rationality). As a result, the economic inefficiency of a firm can only be accidental or temporal, given uncertainty, anticipation errors and market imperfections. However, Leibenstein (1966) has demonstrated through his concept of X-efficiency that firms are not systematically optimal (limited rationality).

According to Leibenstein (1966), firms are not designed to gather, store and process all the information needed to make the best decisions. They only deal with criteria that meet their own rationality and are therefore structurally inefficient. He elucidated this phenomenon through the existence of an X-input that is different from the production factors, and this shows the quality of the organisation or the management of its resources. Conceptually, X-inefficiency describes the same reality as economic inefficiency from the neo-classical point of view, but the methodological assumption regarding the rationality of the firm differs quite drastically.

The concept of economic efficiency is very difficult to observe in a firm. It is possible to approximate it by referring to the production, cost or profit frontier (Farrell 1957). The cost frontier measures the minimum costs necessary to produce a vector of products, given the technology used and a vector of input prices. It provides a summary of information relating to the type of production technology and helps to analyse the production efficiency of a firm.

Consider the case where a farm produces a vector of outputs, $y \in R_+^m$, with a particular vector of quasi-fixed inputs, $z \in R_+^Q$, while facing a particular vector of variable input prices, $\omega \in R_+^n$. The objective of the farm is to minimise its variable costs, ωx, required to produce y, given the technology used. Its cost frontier is defined as:

$$c(y, z, \omega) = \omega x * CE$$

This cost frontier must be homogeneous of degree 1, concave, continuous and not decreasing with respect to farm input prices. The cost efficiency (CE) is measured by the relationship between the minimum cost, $c(y, z, \omega)$, and the observed cost, ωx, as follows:

$$CE = \frac{c(y, z, \omega)}{\omega x} \qquad where\ \ 0 \le CE \le 1$$

If $CE = 1$, the minimum production cost of the farm product vector is equal to the observed cost and the farm is then cost efficient. The cost efficiency provides information about the difference between the observed total cost and the minimum production cost of each farm without distinguishing allocative inefficiency from technical inefficiency. Thus, the cost inefficiency accounts for the economic efficiency according to Farrell (1957), or the X-inefficiency according to Leibenstein (1966).

Let us assume that $TC = \omega x$, the observed total cost for the farm.

This implies that $TC = c(y, z, \omega) * exp(u)$

with $exp(u) = \frac{1}{CE}$

where $exp(u)$ is the inverse of the cost efficiency and u the random error term associated with the cost inefficiency.

The econometric model of the cost frontier can be expressed as follows:

$$TC = c(y, z, \omega) * exp(u + v)$$

where v represents the random error term including measurements, and specification errors and exogenous shocks.

We will then obtain a stochastic cost frontier model which will assess the random error and the cost inefficiency specific to each farm (Aigner *et al*. 1977; Meeusen & Van den Broeck 1977; Jondrow *et al*. 1982). For the cost frontier to be defined properly, the functional form adopted must allow the imposition of properties of symmetry and homogeneity of degree 1 with respect to input prices. Therefore, the translog function becomes more convenient and is the most utilised function in the literature due to its flexibility (Coelli & Perelman 2000). For a sample of $i = 1, \ldots, N$ farms, the multi-output translog cost frontier is specified as follows:

$$\begin{aligned} lnTC_i = {} & \alpha_0 + \sum_{j=1}^{m} \alpha_j lny_{ji} + \sum_{k=1}^{o} \beta_k \, lnz_{ki} + \sum_{l=1}^{n} \delta_l ln\omega_{li} \\ & + \frac{1}{2}\sum_{j=1}^{m}\sum_{j'=1}^{m} \alpha_{jj'} lny_{ji} lny_{j'i} + \frac{1}{2}\sum_{k=1}^{o}\sum_{k'=1}^{o} \beta_{kk'} lnz_{ki} lnz_{k'i} \\ & + \frac{1}{2}\sum_{l=1}^{n}\sum_{l'=1}^{n} \delta_{ll'} ln\omega_{li} ln\omega_{l'i} + \frac{1}{2}\sum_{j=1}^{m}\sum_{k=1}^{o} \mu_{jk} lny_{ji} lnz_{ki} \\ & + \frac{1}{2}\sum_{j=1}^{m}\sum_{l=1}^{n} \pi_{jl} lny_{ji} ln\omega_{li} + \frac{1}{2}\sum_{k=1}^{o}\sum_{l=1}^{n} \tau_{kl} lnz_{ki} ln\omega_{li} + v_i + u_i \end{aligned}$$

To be "well behaved", the translog cost frontier must comply with the following constraints:

- Symmetry:
$\alpha_{jj'} = \alpha_{j'j},\ \beta_{kk'} = \beta_{k'k},\ \delta_{ll'} = \delta_{l'l},\ \mu_{jk} = \mu_{kj}, \pi_{jl} = \pi_{lj}, \tau_{kl} = \tau_{lk},$
$\forall\, j, k, l, j', k', l'$

- Homogeneity:
$$\sum_{l=1}^{n} \delta_l = 1, \sum_{l'=1}^{n} \delta_{ll'} = 0\ \forall\, l, \sum_{l=1}^{n} \pi_{jl} = 0\ \forall\, j, \sum_{l=1}^{n} \tau_{kl} = 0\ \forall\, k$$

The homogeneity constraint is taken into account by the normalisation of the total cost and input prices by the price ω_r of one of the inputs as reference. The choice of reference factor has no influence on the outcomes, since the estimators are obtained through the maximum-likelihood method. The translog cost frontier can be rewritten as follows:

$$ln\left(\frac{TC_i}{\omega_{ri}}\right) = \alpha_0 + \sum_{j=1}^{m} \alpha_j lny_{ji} + \sum_{k=1}^{o} \beta_k \, lnz_{ki} + \sum_{l=1}^{n} \delta_l ln\left(\frac{\omega_{li}}{\omega_{ri}}\right)$$
$$+\frac{1}{2}\sum_{j=1}^{m}\sum_{j'=1}^{m} \alpha_{jj'} lny_{ji} lny_{j'i} + \frac{1}{2}\sum_{k=1}^{o}\sum_{k'=1}^{o} \beta_{kk'} lnz_{ki} lnz_{k'i} + \frac{1}{2}\sum_{l=1}^{n}\sum_{l'=1}^{n} \delta_{ll'} ln\left(\frac{\omega_{li}}{\omega_{ri}}\right) ln\left(\frac{\omega_{l'i}}{\omega_{ri}}\right) + \frac{1}{2}\sum_{j=1}^{m}\sum_{k=1}^{o} \mu_{jk} lny_{ji} lnz_{ki}$$
$$+\frac{1}{2}\sum_{j=1}^{m}\sum_{l=1}^{n} \pi_{jl} lny_{ji} ln\left(\frac{\omega_{li}}{\omega_{ri}}\right) + \frac{1}{2}\sum_{k=1}^{o}\sum_{l=1}^{n} \tau_{kl} lnz_{ki} ln\left(\frac{\omega_{li}}{\omega_{ri}}\right) + v_i + u_i$$

Symmetry and homogeneity constraints help to significantly reduce the number of parameters to be estimated. The stochastic cost frontier approach, in addition to the estimation of the cost efficiency of each farm, helps to identify their explanatory factors. In order to avoid the pitfalls of a two-stage approach, this study used the single-stage estimation method proposed by Battese and Coelli (1995). This approach simultaneously estimates the stochastic cost frontier, the explanatory variables of the cost inefficiency and the cost efficiency scores. The econometric model of the explanatory factors of cost inefficiency is defined as follows:

$$u_i = s_i\theta + \omega_i$$

where s_i is a vector of explanatory factors of the cost inefficiency, θ is the vector of parameters, and ω_i is a vector of random variables representing the estimation errors.

Assumptions on the errors of the stochastic cost frontier model with inefficiency effects are:

(i) the random errors, v_i, are normally distributed, $N(0, \sigma_v^2)$, and are independent from the random errors associated with cost inefficiencies u_i;

(ii) the random errors associated with cost inefficiencies, u_i, are independently and normally distributed, $N(s_i\theta, \sigma_u^2)$, and truncated at zero ($u_i \geq 0$) ;

(iii) the random errors, ω_i, are normally distributed, $N(0, \sigma_w^2)$, and truncated at $-s_i\theta$ $(\omega_i \geq -s_i\theta)$.

Under such assumptions, the stochastic cost frontier parameters with inefficiency effects and the scores of cost efficiency can be estimated by the method of maximum likelihood, using the Frontier 4.1 program (Coelli 1996). In the parameter-estimation process, the variances of the error terms are given by:

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \quad \text{and} \quad \gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$$

The γ parameter takes a value ranging from 0 to 1. If the assumption $\gamma = 0$ is not statistically rejected, then $\sigma_u^2 = 0$; this means that the agricultural farms are cost efficient.

Using the parameters estimated from the stochastic cost frontier, it is possible to develop indicators for analysis of scale economies ($ScaleE$) and scope economies ($ScopeE$). Scale economies are assessed by the scale elasticity, which is obtained by summing up all the cost elasticities with respect to the outputs:

$$ScaleE = \sum_{j=1}^{m} \frac{\partial ln(TC/\omega_r)}{\partial ln y_j}$$

Based on the cost translog frontier developed, the scale economies are therefore assessed by the following formula:

$$ScaleE = \sum_{j=1}^{m} \left[\alpha_j + \sum_{j'=1}^{m} \alpha_{jj'} ln y_{j'i} + \sum_{k=1}^{o} \mu_{jk} ln z_{ki} + \sum_{l=1}^{n} \pi_{jl} ln \left(\frac{\omega_{li}}{\omega_{ri}} \right) \right]$$

Economies of scale thus vary on the basis of the level of outputs, quasi-fixed inputs and the relative prices of the inputs.

If $ScaleE < 1$, farms achieve scale economies

If $ScaleE > 1$, farms achieve diseconomies of scale

Scope economies are said to exist if a particular farm can produce outputs at a lower cost than separate farms specialised in the production of each output. Economies of scope are difficult to calculate, as it is not possible to objectively break down the production costs per output type. Baumol *et al*. (1982) proposed an alternative method based on the principle that an adequate condition of the existence of economies of scope is the complementarity of the outputs. According to Deller *et al*. (1988), economies of scope exist between outputs y_j and y_k if

$$ScopeE_{y_j,y_k} = \frac{\partial \left[\partial (TC/\omega_r)/\partial y_j \right]}{\partial y_k} < 0$$

that is

$$ScopeE_{y_j,y_k} = \frac{\partial^2 (TC/\omega_r)}{\partial y_j \partial y_k} < 0$$

$$\forall\, j \neq k, \;\; j,k = 1, \dots, m$$

The rationale behind this measure is that the production of an extra unit of output, y_k, reduces the marginal cost of producing an extra unit of output, y_i, implying cost complementarities, or economies of scope.

Based on the cost translog frontier developed, the economies of scope are assessed by the following formula:

$$ScopeE_{y_j,y_k} = \frac{(TC/\omega_r)}{y_j} \frac{\alpha_{jj'}}{y_k}$$

3. Variables in the empirical model and data

This section presents the variables in the empirical econometric model and describes the data used for the estimation and analysis.

3.1 Definition of the variables in the empirical econometric model

The theoretical model of the cost frontier with inefficiency effects developed in this study uses two types of variables, the cost frontier variables and the cost inefficiencies variables.

i) Factors explaining the cost frontier

The cost frontier of agricultural production depends on the level of agricultural products, the quasi-fixed inputs and the prices of variable inputs.

Cost of production. The cost of production accounts for the overall operational costs incurred by the agricultural production process.

Agricultural products. The agricultural products refer to the total value of harvest from major crops, expressed in CFA francs using the farm-gate price. The agricultural products include cereals, cotton, oilseeds and legumes. Cereals include millet, sorghum, maize, fonio and rice. Oilseeds include groundnuts and sesame, while legumes include vandzou and beans. The agricultural products are expected to have a positive impact on the total cost of production.

Quasi-fixed inputs. The quasi-fixed inputs include family labour and farm size. Family labour is estimated as the amount of labour measured in man-days that family members spent working on the farm. Farm size is the cultivated land in hectares for a growing season. A positive effect of fixed inputs on total production cost is expected.

The price of variable inputs. The main variable inputs include seeds, fertilisers and manure. The price of seeds is measured by the average weighted price per kilogramme of the different seeds used. The price of fertiliser is captured by the average weighted price of a kilogramme of NPK and urea. The price of manure is approximated by the average price of a cartload of manure. It is expected that the price of the inputs will have a positive effect on the total production cost.

ii) Explanatory factors of cost inefficiencies

Cost inefficiencies in farming may be related to the managerial and organisational capabilities of the staff in charge of the management of productive resources (Leibenstein 1966). In the light of this, human capital contributions may explain the levels of cost efficiency. Moreover, cost inefficiency in farming may be influenced by households' demographic and socio-economic characteristics.

Education. The level of education of the head of household is important for the accumulation of human capital that could influence cost efficiency in production. It is measured by the number of years of formal education received by the household head. The education of the household head is likely to have a negative effect on cost inefficiency.

Time lost due to a disease. Good health stimulates workers to participate more actively in agricultural production. But illness affects cost efficiency by reducing the overall labour capability, as it prevents workers from carrying out their tasks correctly. Health status is assessed by the number of days lost by the workers in the household due to illness. Under normal circumstances, time lost due to a disease should have a positive impact on cost inefficiency.

Social assistance. Social assistance is a binary variable that takes the value of 1 if the farm has received a subsidy on agricultural inputs, and 0 otherwise. It is expected that there will be a negative effect of social assistance on cost inefficiency.

Experience of workers in agriculture. Household head education does not take into account other factors that may contribute to the high productive capacities of the workforce. Therefore, experience may be considered as an important factor for human resource development. Experience helps to quickly grasp concepts during training as a result of practical exposure accumulated over the years. Worker's experience in agricultural production is measured by the number of years of practice in the field. This is determined by subtracting the schooling age (six years) and the number of years spent at school from the worker's age. As the situation stands, the experience of staff is likely to have a negative effect on cost inefficiency.

Access to a good road. Rural roads help to reduce transaction costs related to access to agricultural inputs. Access to a good road is measured by the distance from the farm to a good road. This factor should have a negative impact on cost inefficiency.

Ownership of a radio set. Agricultural information helps farmers to make better decisions and take advantage of the opportunities that the sector offers them. It is approximated by a binary variable that takes a value of 1 if a radio is available in the household, and 0 otherwise. This factor is likely to have a negative effect on cost inefficiency.

Access to credit. Credit helps farmers to purchase modern inputs and allows a better allocation of the factors of production. It is determined by the amount of credits used for farming activities. Credit is likely to have a negative effect on cost inefficiency.

High potential agricultural zone. The agricultural potentialities of the residential area of the household are represented by a binary variable that takes the value 1 if the farm household resides in a region with high agricultural potentialities, and 0 otherwise. A negative effect of agricultural potentialities of the area of residence of the household is expected on cost inefficiency.

Dependency ratio. Pressure from family responsibilities may stimulate workers to invest more energy and manage their farms better. This is determined by the rate of dependency per household. This factor is expected to have a negative effect on cost inefficiency.

3.2 Data collection method

The data used for this study was collected within the framework of the "Convergence" project. The objective of the project was to conduct research on "Maximising the impact of social service expenditures on agricultural labour productivity and incomes in African countries". The survey was conducted from January to February 2011 by the Laboratory of Quantitative Analysis Applied to Development – Sahel (LAQAD-S), in the context of collaborative research with the International Food Policy Research Institute (IFPRI).

The national scope of the study led to the subdivision of the whole rural area of Burkina Faso into six strata based on the quality of social characteristics of the population (health, education, nutrition and access to drinking water) and the concentration of non-governmental organisations within the area. Thus, 36 villages were randomly selected according to the weight of each stratum and agricultural potentialities of the area. In each village, 15 households were selected randomly, making a total sample size of 540 households surveyed.

Data was collected on demographic and socio-economic characteristics, food and cash crops and farm expenditure for each household.

3.3 Smallholder household demographic and socio-economic characteristics

In Burkina Faso, farms are production and consumption units generally organised around a household and managed by a head of household who is responsible for making decisions on the management and allocation of productive resources. Farming activities and family life are virtually inseparable. Tables 1 and 2 present the demographic and socio-economic characteristics of the households and farms.

Household characteristics. The analysis of standard deviation and confidence intervals at the 5% level of significance shows that households' characteristics are rather similar (Table 1). In farm households, the source of labour is generally the family. On average, a farm is made up of eight members, four of whom are workers. The dependency ratio shows that each farm worker is responsible for the welfare of at least one inactive person. This means that the individual workers are obliged to work harder to produce more for their households.

Workers within a household have at least 25 years of experience in agricultural production. This reveals their level of maturity in farming. However, a head of household received, on average, less than one year of formal education (0.6 years). This low level of formal education of the household heads shows that the technical know-how of workers depends essentially on their practical experience.

Farmers' ability to work is often marred by health problems affecting members of the household. Workers in a household lose about seven working days due to illnesses. Sickness can therefore have a serious effect on agricultural productivity by compelling workers to stay at home, either because they are sick, or because they need to take care of a sick member of the family.

Table 1: Household characteristics

	Average	Standard deviation	Confidence interval at the threshold of 95%	
Household size	8.1	0.2	7.8	8.4
Worker population size	3.9	0.1	3.7	4.1
Dependency ratio	1.2	0.0	1.2	1.3
Workers' experience (in years)	25.5	0.3	24.9	26.0
Education of the head of household (in years)	0.6	0.1	0.4	0.7
Time lost due to a disease (days)	6.7	0.6	5.4	7.9

Source: Calculations from Convergence / Burkina data, 2011

Farm characteristics. The analysis of standard deviation and confidence intervals at a 5% level of significance shows that the characteristics of the system of production are quite stable (Table 2). The agricultural production is generally dominated by small multi-output farms that spend, on average, 102 695 CFA francs on inputs in order to cultivate an average farm size of 3.6 hectares and harvest a total output value of 352 368 CFA francs. Farms therefore record a gross margin of 249 673 CFA francs. Although these farms are market oriented, their agricultural products are dominated by food crops.

Most farms in Burkina Faso are involved in cereals production. On average, a farm produces cereals valued at 240 164 CFA francs per farming season, representing 68.2% of the value of its total production. To respond to the financial needs of households, part of the harvest is often sold on the market. Cereals are generally made up of sorghum, millet, maize, fonio and rice across the agricultural potentialities of the area of residence of the household.

Oilseeds, cotton and legumes are the major cash crops produced in Burkina Faso. On average, a farm produces oilseeds valued at 59 489 CFA francs, representing about 17% of the total value of its outputs. In addition to cotton, which represents about 10.3% of total production value, oilseeds are mostly grown in regions that have high agricultural potentialities. However, the average legume production stands at 16 341 CFA francs, representing 4.6% of the value of production for a farm. Legumes are generally grown in regions with low agricultural potentialities.

Table 2: Farm characteristics

	Average	Standard deviation	Confidence interval at the threshold of 95%	
Value of production (FCFA)	352 368	22 589	307 995	396 741
Cereals	240 164	16 746	207 268	273 061
Cotton	36 373	6 198	24 198	48 549
Oilseeds	59 489	10 944	37 991	80 988
Legumes	16 341	1 488	13 418	19 264
Cost of production (FCFA)	102 695	7 700	87 569	117 821
Agricultural gross margin (FCFA)	249 673	18 731	212 877	286 469
Farm size (ha)	3.6	0.1	3.4	3.8

Source: Calculations from Convergence / Burkina data, 2011

4. Analysis of the efficiency of farms

The analysis of farms production highlights the degrees of cost efficiency. It also indicates factors that are likely to improve cost efficiency. Taking into account economies of scale and scope economies allows an understanding of the effects of size and diversification on the cost efficiency of farms.

4.1 Econometric estimations of cost stochastic frontier with inefficiency effects

The parameters of the model and cost efficiency scores per farm were estimated with the maximum likelihood method, using Frontier 4.1 software (Coelli 1996). With the nine explanatory variables, the translog cost frontier that takes into account symmetry means there are 55 parameters to be estimated. However, when applying the homogenous property to the cost frontier with the price of seeds as the reference variable, one would be left with only 45 parameters to be estimated. The results from the stochastic cost frontier with inefficiency effects estimations are presented in Table 3.

Before interpreting the results of the cost stochastic frontier with inefficiency effects, it is necessary to carry out various specification tests to be sure of the quality of the model. Table 3 shows that the estimate for the variance parameter, γ, was different from 0 and less than 1 at the 5% level of significance. Therefore, the null hypothesis, which specifies that the inefficiency effects are not stochastic, was rejected. Individual tests show that most coefficients of the cost frontier with inefficiency effects were significant.

Table 3: Estimates of the stochastic cost frontier parameters with inefficiency effects[2]

	Parameters	Standard errors		Parameters	Standard errors
Constant	*** 4.5738	1.5492	ln(oilseeds)ln(labour)	0.0088	0.0086
ln(cereals)	* -0.5140	0.2699	ln(oilseeds)ln(fertiliser price)	* 0.0239	0.0131
ln(cotton)	*** 0.3672	0.1319	ln(oilseeds)ln(manure price)	*** -0.0197	0.0071
ln(oilseeds)	0.0167	0.0750	ln(legumes)ln(farm size)	0.0098	0.0086
ln(legumes)	** 0.1601	0.0739	ln(legumes)ln(labour)	-0.0107	0.0081
ln(farm size)	1.1383	0.8772	ln(legumes)ln(fertiliser price)	** -0.0272	0.0123
ln(labour)	-0.2274	0.5443	ln(legumes)ln(manure price)	-0.0030	0.0064
ln(fertiliser price)	-0.2599	0.9708	ln(farm size)ln(labour)	0.0138	0.1195
ln(manure price)	* -1.2613	0.6863	ln(farm size)ln(fertiliser price)	0.1047	0.1504
ln(cereals) ²	*** 0.0345	0.0125	ln(farm size)ln(manure price)	-0.0072	0.1046
ln(cotton) ²	0.0075	0.0139	ln(labour)ln(fertiliser price)	-0.1537	0.1514
ln(oilseeds) ²	** 0.0135	0.0054	ln(labour)ln(manure price)	0.0739	0.0860
ln(legumes) ²	** 0.0198	0.0077	ln(fertiliser price)ln(manure price)	-0.1031	0.1251
ln(farm size) ²	0.0770	0.1668	**Factors explaining the cost inefficiencies**		
ln(labour) ²	-0.0353	0.1598	Constant	0.1312	0.2177
ln(fertiliser price) ²	*** 1.0011	0.3076	Education	** -0.1011	0.045
ln(manure price) ²	0.1194	0.1055	Education ²	** 0.0081	0.0039
ln(cereals)ln(cotton)	* -0.0216	0.0118	Time lost due to a disease	*** 0.0102	0.0019
ln(cereals)ln(oilseeds)	-0.0051	0.0068	Social assistance	-0.0282	0.1533
ln(cereals)ln(legumes)	-0.0099	0.0071	Experience	-0.0006	0.0075
ln(cereals)ln(farm size)	-0.0973	0.0612	Access to a good road	*** 0.0160	0.003
ln(cereals)ln(labour)	0.0527	0.0465	Ownership of radio set	*** -0.2842	0.1047
ln(cereals)ln(fertiliser price)	0.1164	0.0972	Access to credit	* -0.0014	0.0008
ln(cereals)ln(manure price)	0.0846	0.0612	High potential agricultural zone	*** -0.8510	0.1787
ln(cotton)ln(oilseeds)	-0.0012	0.0010	Dependency ratio	-0.047	0.0645
ln(cotton)ln(legumes)	-0.0009	0.0009			
ln(cotton)ln(farm size)	0.0193	0.0189	**Variance parameters**		
ln(cotton)ln(labour)	-0.0133	0.0132	σ^2	*** 0.6351	0.0450
ln(cotton)ln(fertiliser price)	** 0.0352	0.0155	γ	** 0.2963	0.1194
ln(cotton)ln(manure price)	*** -0.0271	0.0102	Log likelihood	-645.301	
ln(oilseeds)ln(legumes)	** -0.0014	0.0006	LR test	62.294	
ln(oilseeds)ln(farm size)	0.0014	0.0103	Number of observations	540.000	

Source: Calculations from Convergence / Burkina data, 2011
*** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level

A generalised likelihood ratio was used to test the significance of a number of hypotheses (Table 4). The first null hypothesis, which specifies that the model is not a cost frontier with inefficiency effects,

[2] Costs of production and input prices have been divided by the price of seeds, which was used as reference price in the implementation of the homogeneity property to the cost frontier.

was rejected at the 5% level of significance. The second null hypothesis, which specifies that the translog functional form is not suitable to represent the cost frontier, was rejected at the 5% level of significance. The third null hypothesis, which specifies that the cost inefficiency effects are not a linear function, was also rejected at the 5% level of significance.

Table 4: Hypothesis tests on the parameters of the cost frontier with inefficiency effects

Null hypothesis	**Likelihood ratio** (LR)[3]	**Chi-square value (95%)**	**Decision**
H_0: $\alpha_j = \beta_k = \delta_l = \alpha_{jj'} = \beta_{kk'} = \delta_{ll'} = \mu_{jk} = \pi_{jl} = \tau_{kl} = \theta_m = 0$, $j, j', k, k', l, l' = 1, \dots, 8$ and $m = 1, \dots, 10$	533.8	75.9	Reject H_0 (No cost frontier with inefficiency . effects)
H_0: $\alpha_{jj'} = \beta_{kk'} = \delta_{ll'} = \mu_{jk} = \pi_{jl} = \tau_{kl} = 0$, $j, j', k, k', l, l' = 1, \dots, 8$	133.2	53.9	Reject H_0 (Cobb-Douglas)
H_0: $\theta_m = 0$, $m = 1, \dots, 10$	62.3	18.3	Reject H_0 (No inefficiency . effects)

Source: Calculations from Convergence / Burkina data, 2011

Regarding the results of the tests, we can conclude that the model is consistent and can be used for the analysis.

4.2 Cost inefficiency of farms

This section examines the distribution of cost inefficiency scores and the effects of their explanatory factors.

4.2.1 Distribution of cost inefficiency scores and associated financial losses

The results from Table 5 show that Burkinabe farms are cost inefficient. The level of the cost inefficiency scores reveals that the farms were about 35.8% inefficient, with a confidence interval of 95% ranging between 33.8% and 37.8%. This implies that a cost-efficient farm could save up to 35.8% of current production cost to reach the same levels of production.

An analysis of cost inefficiency scores according to farm size helps to understand the effects of farm size on cost inefficiency. To do that, this study categorised farm size greater than the average farm size (3.6 ha) as large-sized farms and the rest as small farms. The comparison test of the average levels of cost inefficiency between the two categories showed a remarkable difference at the 1% level of significance (Table 5). Large farms (45.6%) had a higher level of cost inefficiency than smaller farms (30.5%).

Table 5: Test of the levels of cost inefficiency scores

	Observations	**Cost inefficiency (%)**	**Standard deviation**	**Confidence interval at the level of 95%**	
All farms	540.0	35.8	23.3	33.8	37.8
Small farms	350.0	30.5	19.0	28.5	32.5
Large farms	190.0	45.6	27.0	41.7	49.5
Difference (diff)	-	-15.1	2.0	-19.1	-11.2
Test	Ho: diff = 0	Ha: diff < 0		Pr (T < t) = 0.0000	

Source: Calculations from Convergence / Burkina, 2011

[3] $LR = -2(\log l_0 - \log l_1)$, where $\log l_0$ and $\log l_1$ represent the log likelihood function for the null hypothesis and the alternative hypothesis respectively. When the empirical value of the likelihood ratio is higher than the Chi-square theoretical value at the 95% level of significance, the null hypothesis is rejected.

Cost inefficiency causes financial losses for Burkinabe farms. Table 6 shows that a farm lost on average 13 188 CFA francs per hectare and per season due to cost inefficiency. Farm size analysis indicates that large farms lost on average 15 110 CFA francs per hectare, against 12 144 CFA francs per hectare for small farms.

Table 6: Comparison test on average financial losses per hectare

	Observations	Financial losses	Standard deviation	Confidence interval at the threshold of 95%	
All farms	540	13 188	22 803	11 260	15 116
Small farms	350	12 144	23 856	9 636	14 652
Large farms	190	15 110	20 646	12 156	18 065
Difference	-	-2 966	-	-6 998	1 066
Test	Ho: diff = 0	Ha: diff < 0		Pr (T < t) = 0.0745	

Source: Calculations from Convergence / Burkina data, 2011

To reduce financial losses caused by cost inefficiency, it is necessary to highlight the major factors that explain the cost-inefficiency scores of farms.

4.2.2 Factors explaining cost inefficiency of farms

Estimates of the effects of factors explaining the cost inefficiency of the farms are presented in Table 3. A negative and significant sign shows a negative impact of the variable considered on cost-inefficiency scores. The results show that education of the head of household, labour time lost due to diseases, access to a good road, ownership of a radio set, access to credit and the agricultural potentialities of the area of residence of the household were the major factors explaining the levels of cost inefficiency.

The results reveal that formal education had a negative impact on the cost inefficiency of farms at the 5% level of significance. However, its quadratic effect shows that, beyond 6.2 years, formal education had a positive effect on cost inefficiency. This result was consistent with the findings of Fleming and Lummani (2001) for cocoa smallholders in Papua New Guinea, which showed that a higher education is often associated with more off-farm employment that limits the time and attention given to agricultural activities. The results are also partially in line with those found by Sharada (1999) in Ethiopia, which showed that education had beneficial effects on agricultural efficiency when the farmer had at least four years of education.

The results indicate that labour time lost due to diseases had a positive effect on cost inefficiency at the 1% level of significance. This means that diseases in households greatly affect the cost efficiency of their farms. These results are consistent with those reported by Ajani and Ugwu (2008) in Nigeria, which showed that the improvement of a farmer's health status led to an increase in efficiency.

The amount of credit used related to farm operations had a negative effect on cost inefficiency at the 10% level of significance, suggesting that the compulsion to repay leads to greater productivity. This result is consistent with the findings obtained by Hazarika and Alwang (2003), who highlighted a significant impact of credit on cost efficiency among smallholder tobacco farmers in Malawi. However, credit may have no effect on agricultural performance if it is used for other purposes (Nyemeck *et al*. 2004).

Access to a good road and ownership of a radio set had negative impacts on cost inefficiency at the 1% level of significance, suggesting that the reduction of transaction costs leads to greater productivity of farms. The results also support the view that farms operating in regions with high agricultural potentialities were significantly more cost efficient at the 1% level of confidence than those operating in regions with low agricultural potentialities.

4.3 Scale efficiency and economies of scope

The cost efficiency of farms depends on their size and the diversification of activity on the farm. Scale and scope economies help to measure the role of farm size and agricultural diversification in the reduction of the total cost of production.

4.3.1 Cost elasticities and economies of scale

Parameters estimated from the cost frontier allow cost elasticities for each agricultural product and scale economies at the mean of the observations to be computed (Table 7). The cost elasticities show that the cost of each agricultural product was inelastic. The results show that an increase in the total cost of production was mostly due to cereals (0.76%), rather than to cotton (0.21%), oilseeds (0.10%) and legumes (0.13%).

The results in Table 7 show that the scale elasticity was higher than one (1.20). A one per cent (1%) increase in the all agricultural products leads to an increase in the overall cost of production by 1.20%. This highlights the presence of diseconomies of scale in the production of the Burkinabe farms. Therefore, producing crops on a small scale reduces the total cost of production, implying that smallholder farms are more cost efficient than large farms.

Table 7: Cost elasticities and economies of scale

	Values
Cost elasticity – Cereals	0.76
Cost elasticity – Cotton	0.21
Cost elasticity – Oilseeds	0.10
Cost elasticity – Legumes	0.13
Economies of scale	**1.20**

Source: Calculations from Convergence / Burkina data, 2011

4.3.2 Economies of scope

Economies of scope depend on the existence of cost complementarity between the different farm products. This complementary relationship has to do with the common use of inputs for the same farming activities. The analysis of the results in Table 8 helps to identify pairs of crops which, when cultivated together, are the most efficient.

The results revealed a cost complementarity between cereals and cotton on the same farmland at the 10% level of significance. This means that it is less expensive to produce cereals and cotton together than growing them on separate farms. These results confirm those observed in Burkina Faso, where the biggest large-scale producers of cotton are also the biggest producers of cereals. The crop rotation practice between these two crops on the same farmlands makes the cereals benefit from fertilisers applied to cotton without any additional cost.

Table 8 also shows economies of scope in the production of oilseeds and legumes at the 5% level of significance. As a result, it is more advisable to grow these two crops on the same farmland than on two different pieces of land. This cost complementarity is obviously due to the fact that these different crops do not only share the same inputs, but also require just about the same care and chemical fertilisers. This synergy between them reduces the production cost.

The data in Table 8 reveal an absence of scope economies between cereals and oilseeds, cereals and legumes, cotton and oilseeds, and cotton and legumes. This implies that each pair of crops can be produced on separate farms without any loss of efficiency.

Table 8: Economies of scope

Products	Values
Cereals & Cotton	*-8 434.5
Cereals & Oilseeds	-.004575
Cereals & Legumes	-3 882.5
Cotton & Oilseeds	-156 223.6
Cotton & Legumes	-145 659
Oilseeds & Legumes	**-165 755.2

Source: Calculations from Convergence / Burkina data, 2011
** Significant at the 5% level, * Significant at the 10% level

5. Conclusions and policy implications

This study examined the efficiency of farms in Burkina Faso, using the stochastic cost frontier approach. The empirical results show that the average cost inefficiency was about 35.8%. Efficient use of resources reduced current costs of production on a farm by 35.8%, representing 13 188 CFA francs per hectare of cultivated land, while maintaining the same levels of production.

The results also show that good health, access to a good road, ownership of a radio set, farming credit and residing in a zone with high agricultural potentiality significantly reduced cost inefficiency. However, beyond 6.2 years of education, an additional year of education of the household head became a handicap to cost efficiency in farming. The results reveal that farmers face diseconomies of scale and achieve scope economies between cereals and cotton, and oilseeds and legumes.

In terms of policy implications to improve the cost efficiency of farms, decision makers should promote farm households' access to basic formal education, health facilities, good rural roads, input credits and agricultural information, and ensure the establishment of farms in areas with high agricultural potentialities. Small-scale production, as well as joint production of cereals and cotton, and oilseeds and legumes should also be promoted.

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