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Poultry Value Chain Performance Measurement Using Stochastic Frontier Analysis in Mozambique, Maputo Region

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Abstract: Poultry production in Mozambique occupies a prominent place in the agricultural sector, especially because it is attractive for the promotion of entrepreneurship and self-employment. These facts are due to the short cycle and a large increase in the consumption of poultry products. However, despite the opportunities it presents, challenges do exist, namely, the strategic organization of producers and the access to the market, which give producers a weak capacity to compete, and thus favoring imports to the country. To analyze competitiveness, stochastic models were used to determine the efficiency of producers and to define good practices. The results clearly show that producers with a more organized and well-planned structure, producing more than 2000 chickens per cycle of production, tend to be more efficient when compared to those with less organized structures and without commercial agreements that facilitate market access.

Keywords: poultry; evaluation; market; efficiency; stochastic frontier analysis

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1. Introduction

A country's ability to improve its standard of living over time depends almost entirely on its ability to raise its output per a worker (Kuosmanen et al. 2014). Efficiency study is an important area of economic analysis that has attracted the attention of economists, especially in the last three decades (Ajibefun 2008). According to Kuosmanen et al. (2014), efficiency analysis is an important and extensive research area that provides answers to such essential questions as: Who are the best performing firms, and can we learn something from their behavior? What are the sources of efficiency differences across firms? Can efficiency be improved by government policy or better managerial practices? Are there benefits to increasing the scale of operations?

Stochastic frontier analysis has proved to be of great value in analyzing the structure of producers' performance and in investigating the determinants of producers' performance (Kumbhakar et al. 2017). The analysis of efficiency has strong policy relevance, as many of the determinants of producers' performance are subject to government decisions and can be relevant for strategic reforms (Coelli and Battese 1996; Coelli et al. 2005; Erkoc 2013). Among them, value chain analysis is an important tool to achieve sustainable development.

Therefore, the present study aims to understand the performance of different players, identifying the star performers and their practices in a value chain and identifying the determinants of inefficiencies in the poultry production. In turn, using the identified best practices will develop a knowledge sharing framework to meet poultry value chain sustainability in Mozambique.

The results of the study clearly demonstrate that there are factors influencing the efficiency of the poultry in the region. Some influence positively and others negatively. There are four important factors differentiating the best performers from others, namely, the

farm size and its respective production quantity, business registration, and plan. The mortality rate, which makes a considerable difference between the best performers and others operating below the mean efficiency of production units in the Maputo region, combined with commercial agreements, are factors negatively influencing the efficiency of the poultry farmers and being thus important determinants of inefficiencies of production units.

2. Materials and Methods

2.1. Estimation of Cost Efficiency

There are distinct efficiency measurement methodologies that emanate from different concepts of efficiency. Hence, it is crucial to select the most suitable method in line with the available data (Furkova 2013). The selected method must consider economic optimization in relation to market prices and competition (Russell and Young 1983). There are two methods used for studies related to efficiency. The first method is the accounting approach for measuring efficiency, which uses accounting methods of comparing financial ratios linked to costs in measuring firms' efficiency. The second method is a frontier efficiency method, which gives a summary statistic of the firm's performance that adjusts for the differences among firms (Coelli et al. 2005; Furkova 2013). The emergence of frontier efficiency as the preferred method for measuring firm's efficiency has made the traditional accounting approach less used (Asmare and Begashaw 2018). The frontier approach measures the efficiency of a firm as compared to the best practice frontiers that include all other firms in the industry. Frontier methods are over and above traditional methods by providing results that are relevant and reliable (Hughes and Mester 2008). They are helpful for testing economic hypotheses, and guiding regulators and policy makers on suitable responses to problems and developments in a particular industry and in the economy at large (Berger and Mester 1997). Basically, there are two broad categories of frontier efficiency methodologies: parametric and non-parametric methods. The parametric technique is further divided into stochastic frontier analysis (SFA), the thick frontier approach (TFA), and the distribution-free approach (DFA), while non-parametric techniques are divided into data envelopment analysis (DEA) and the free disposable hull (FDH) (Asmare and Begashaw 2018; Maudos et al. 2002).

Efficiency analysis using parametric and non-parametric methods has monopolized the recent literature on efficiency measurement. Parametric methods of efficiency analysis have significant advantages by distinguishing and modelling the random noise from inefficiency. According to Asmare and Begashaw (2018), non-parametric methods have deficiencies because they do not distinguish between the true inefficiency and statistical noise effects.

In accordance with parametric approaches, the efficiency frontier is constructed based on econometric modelling, usually in the form of a Cobb–Douglas (log-linear) production function. Therefore, the production function is defined by the set of explanatory variables (inputs, outputs, and other possible explanatory variables) and the two components of the composite error term (the random error) and the inefficiency term (Coelli et al. 2005; Erkoc 2013). The stochastic frontier approach treats deviations from production function as comprising both random error (noise) and inefficiency. Therefore, SFA assumes a two-sided distribution (usually normal with zero mean) of the error term and one-sided distribution of the non-negative inefficiency term (Erkoc 2013; Furkova 2013; Russell and Young 1983; Henningsen and Kumbhakar 1996; Schmidt and Sickles 1984).

Parametric methods of efficiency have the benefit of modelling inefficiency and noise (Johnson et al. 2015). The SFA method is preferable when certain classical assumptions are satisfied regarding the composite error terms, including the contributions from the inefficiency distribution and measurement errors (Katharakis et al. 2014; Huang and Wang 2002; Oh and Hildreth 2016). The method is useful to measure independently the effect of other exogenous factors such as market prices, through using a programming or econometric method to control effects (Huang and Wang 2002). Moreover, Ajibefun (2008) reported that parametric frontier analysis allows the test of hypotheses concerning the goodness of fit

of the model. On the other hand, parametric frontier functions require the definition of a specific functional form for the technology and for the inefficiency error term.

Bauer (2008) compares parametric and non-parametric techniques and states that non-parametric approaches place less emphasis on the formulation of the specification of the frontier. One drawback of non-parametric techniques is that they do not take prices into account. Hence, they account for only technical inefficiency in producing too few outputs from given inputs or using too many inputs to produce given outputs. Furthermore, using non-parametric approaches makes it difficult to compare firms that concentrate on the use of inputs or outputs, because it is impossible to compare one input or output with another without including the relative input or output prices. In this sense, the primary focus of non-parametric techniques is optimization technology rather than economic optimization. Furthermore, non-parametric techniques do not account for random errors in the data. They usually assume that any measurement error is due to luck.

There is no consensus on the most preferred method for efficiency measures. However, parametric approaches have some strong assumptions concerning the functional form of the efficient frontier, which makes them preferred to non-parametric methods (Kumbhakar et al. 2017; Oh and Hildreth 2016).

2.2. Cost Efficiency Analysis

Research studies aimed at measuring the efficiency of different sectors' institutions have increased over the years. The approach used for such efficiency studies has been based on evaluating an efficient frontier of firms and then measuring the differences between observed institutions and those on the efficient frontier. Although many such studies have found a significant difference in cost inefficiencies, there is no general agreement on the sources of the measured differences in efficiency (Berger and Mester 1997).

According to Berger and Mester (1997), degrees of efficiency can be rooted in three broad sources: (i) differences in the efficiency concept used; (ii) differences in various measurement methods used within the different efficiency concepts used, and; (iii) correlations of efficiency such as macroeconomic, regulatory, and specific characteristics, which then explain some of the differences in efficiency after controlling for the efficiency concept used and the method of measurement used.

2.3. Empirical Approach to SFA

Several studies for efficiency assessment have been made using stochastic frontier analysis (SFA). These studies were carried out in a variety of sectors, and very often in the banking or financial sectors. Very few studies of efficiency analysis have targeted the agricultural sector and associated value chains. However, there is a record of a growing number of studies carried out in the sector, with emphasis on the analysis of technical efficiency of production units and its determinants. In this group, we can highlight studies carried out in the rice chain, highlighting the study conducted by Dawson and Lingard (1989) with their attempt to measure rice farms' efficiency considering the time element in The Philippines. The study showed that technical inefficiency is the major reason for deviation from the frontier production function, but in general efficiency has improved during the period. Another study on rice was conducted by Erwidodo (1990) in his doctoral dissertation, when he intended to identify and analyze the determinants of efficiency of rice producers in Indonesia. This study concluded that rice producers in Indonesia were 7% technically inefficient and 14% economically inefficient, and this phenomenon was basically due to the poor adoption of new production technologies, especially new varieties.

More recently, Kea et al. (2016) in Cambodia sought to determine technical efficiency and its determinants. The results indicate that the level of rice production in Cambodia tends to vary, with influence of different levels of investment in agricultural machinery, size of the production area, and levels of technical knowledge in fertilizer application. The study also found that there are possibilities for improving the efficiency of producers, since the average efficiency was 78.4%.

Furthermore, recent studies have been carried out in other agricultural sectors such as the dairy value chain in Brazil, such as the study by Maia et al. (2019) whose objective was to investigate the dynamics and determinants of the efficiency of producers in conditions of climate resilience. The authors concluded that better technologies have a potential impact on improving the productive efficiency of local farmers.

2.4. Stochastic Frontier Model

Stochastic frontier analysis (SFA), which was independently designed by Aigner et al. (1977) and Meeusen and Van Den Broeck (1977), has been a notable contribution to econometric techniques for estimating cost, production, and profit frontiers and for estimating technical and economic efficiency of firms.

One unique feature of stochastic frontier analysis is that it allows for random errors associated with the choice of functional form, which results in a stochastic frontier. This model is often referred to as a decomposed error model, where the part that serves as statistical noise follows a symmetric distribution and the other part, representing inefficiency, follows a specific one-sided distribution. This approach allows for the cost inefficiencies to be estimated using a one-step maximum likelihood estimate (MLE) procedure (Fries and Taci 2004). Below is the model in panel form as specified by Musonda (2008).

It can be written as follows:

$$Y_{it} = X_{it}\,\beta + v_{it} + u_{it}$$

where:

- Y_{it} is the logarithm of the variable that measures outcomes (output) in firm i at observation t,
- X_{it} is the vector of inputs (the required resources for production of poultry) associated with firm i and observation t,
- β is the vector of parameters to be estimated,
- v_{it} is the random component, assumed to be independently identically distributed with a mean of zero and variance σ_v^2,
- and u_{it} is a non-negative random component associated with production inefficiency, assumed to be independently distributed such that u_{it} is obtained by truncation (at zero) of the normal distribution with the mean of $z_{it}\delta$ and variance ${\sigma_u}^2$.

Thus, the inefficiency component is a function of a set of explanatory variables, z_{it}, and a vector of parameters, δ, to be estimated.

The parameters of the production function (β) and those in the inefficiency component (δ) can be simultaneously estimated by maximum likelihood. The production inefficiency for firm i and observation t, can be expressed as:

$$u_{it} = z_{it}\delta + w_{it}$$

where the random variable w_{it} is defined by the truncation of the normal distribution with a zero mean and variance ${\sigma_u}^2$, such that the point of truncation is $-z_{it}\delta$. Thus, parameters δ show how variables z influence the inefficiency term. If a coefficient is positive, then the corresponding variable is contributing to inefficiency, and if negative, then the variable and the inefficiency term are inversely related.

2.5. Variables

Before presenting the econometric model to be used for this study, it is important to specify the various inputs, outputs, and input prices to be used for this study.

The SFA model was constructed by one output variable (production, e.g., number of chicks housed per cycle) and four price of input variables, including feed, day-old chick, labor, and other expenses, which include bills of water, energy, charcoal, vaccines, and medicines used during the cycle, as well as the price of deprecation of the infrastructure

or rent paid. The total is then considered for the determination of efficiency in the model used.

2.5.1. Explaining Variables

We were interested in understanding the determinants of the cost efficiency of the variable total cost. The price of inputs of production provided by our panel data were: (a) price of feed (PFeed in MZN considering the price of a bag of 50 kg); (b) price of hired labor (PLabor, in constant in MZN), taking into account exclusively temporary and permanent labor; (c) price of day-old chick (PDOC, in MZN for the price of a day-old chick), and; (d) price of other expenses (POthers), for the price of all other important costs of poultry production means, such as vaccines and medicines, cost of electricity used during the cycle of production, water supplied during the cycle, transport and communication during the cycle, as well as the renting or even the depreciation of the infrastructure, was considered as part of the price of other inputs) and the output of production (ProdR, units of housing chicks per cycle).

These variables are viewed as prices of inputs of the cost function because they are believed to directly related to the total cost of producing poultry and hence have a direct influence on the production of poultry in each firm. Therefore, the total cost is directly influenced by these variables, which also include the production in number of chicks reared per cycle.

2.5.2. Determinants of Efficiency

According to Musonda (2008) and Asefa (2011), there are different factors that account for the level of efficiency in any industry. Some factors such as skill levels, managerial expertise, and experience of workers may be inherent in the internal organizational structure of the firm. On the other hand, there are external factors that can be responsible for the level of efficiency or inefficiency of a firm. These external factors include regulatory constraints, real business cycles, macroeconomic shocks, labor disputes, and the market structure in which the firm operates. While the internal factors are specific to each firm and within the control of the firm, the external factors are outside the control of the firm. It is therefore pertinent that the so-called efficiency correlates are included in stochastic frontier analysis. These variables, which are neither input nor output variables, usually affect the distribution of inefficiency. Furthermore, they can affect the productivity performance of firms and they have been included in efficiency studies in a variety of ways, including: (i) they may scale the frontier function and/or the inefficiency distribution; (ii) they may shift the frontier function and/or the inefficiency distribution, and; (iii) they may both scale and shift the frontier function and/or the inefficiency distribution (Belotti et al. 2012).

There are many of these variables that may affect the performance of a firm operating in the poultry industry. Hence, to analyze the determinants of poultry efficiency in the Maputo region, this study adopts the following explanatory variables: production arrangement system, sales agreement, farming experience and age of the producer, farm size, business plan, business registration, and manager level of education, as well as farmer association membership and access to extension services.

Explaining the variables which may influence the production frontier and are considered the component of inefficiency (z) are:

- **Commercial agreements** with the following indicator questions: input agreement (Yes or No), sales agreement (Yes or No), and production arrangement systems (Independent or Integrated).
- **Organizational structure**, basically considering the following questions on: registration of the farm or unit of production (Yes or No), farm or unit of production size (the capacity of the unit to rear the chickens per cycle), membership of associations (Affiliated or Not), as well as the planning instrument in place, i.e., business plan (Yes or No).

- **Management of firms or units**, basically concentrated on perceiving the background of managers by bringing their age, experience, and education, as well as understanding access to technical assistance to improve their production unit's quality and sustainability.

Commercial Agreements

Commercial agreements are common to several production chains. In Maputo and in the poultry value chain, three types of agreements are frequent. These agreements are normally established between the actors in the chain. Therefore, it was considered important to understand how the establishment of these agreements could affect the efficiency of the producers in the region. The agreements in the value chain are viewed as means to promote and facilitate the operations of the players as well as the procedures and forms to ensure coordination of governance and uniformity of principles along the value chain, thus securing the sustainable development of the value chain (Cafaggi and Iamiceli 2020; Hastings et al. 2016). Based on this assumption, it is intended to understand the established agreements between farmers and other relevant actors in the chain, such as: (a) supply of inputs, usually an agreement that can be established between the suppliers of different inputs to production units and the producers, and usually including great benefits such as discounted prices, exclusivity, and technical assistance, and; (b) sales contracts, established between producers and buyers, which may be retailers, slaughterhouses, and catering companies and other organizations with interests in the consumption of products, processing, and marketing. Finally, a type of agreement refers to the type of production arrangement established and is mentioned by authors such as da Conceição Nicolau et al. (2011) and Oppewal et al. (2016). There are two systems in the region, namely, those that have a signed agreement and those who have no agreement signed. The first are said to be integrated and the others are said to be on an independent arrangement system. Usually, integrated producers have agreements for the supply of inputs and sale of their production to the integrating company. However, there are records of production units in the region that, although not integrated, have separate agreements with a single or even several companies.

Structural Organization of the Production Unit

Some management indicators have to do with the planning, organization, and structure of the companies/production units. In this respect, planning indicators, such as the existence or not of a business plan, can indicate the level of planning of the companies and, therefore, we wanted to know in the study how this could affect the operations of companies and, consequently, their efficiency. Likewise, for the issue of company's structure, the legality was questioned to assess their official capacity, to indicate which structures would be created to fully respond to market dynamics. The registration of a company or farm can represent its organizational level, since each structure must meet appropriate organizational models. According to the Mozambican commercial code, the registration of entities will be linked to their own organizational requirements, such as partners, fiscal concepts, type of accounting, and others, including the need for environmental licensing. Therefore, registration provides an indication of different types of business structures and, given the complexity of defining business structures, we refer only to registration. Registration makes the business formal and with obligations to adapt to the formal operationalization of its activities, including the following structural aspects: accounting structure type, operating facilities, professional managers, and often well-defined operating plans. In addition, the need for a well-structured business plan is most of the time linked to the size of the business, assuming that, the bigger is the company or production unit, the likelier is the existence of business registration. Therefore, the other important factor to be considered to test the structural organization influence on the efficiency will be the size of the production unit since we do not have data on the investment size of the producers in the study.

> *"The lack of registration is pointed out by several studies as one of the major obstacles faced by Mozambican companies to get access to financing, mainly in the agricultural sector and particularly in the livestock sector. Therefore, the lack of officialization of these businesses makes it difficult even to define more appropriate lines since there are no reliable statistics on real needs." This fact will affect the growth of small businesses in the sector, which become increasingly less efficient"*

The size of the production unit provides an illustration of the organizational structure needed to face the typical challenges of investment capacity, given that the investment size is directly proportional to business strategies and different responses to market dynamics. Therefore, and because it would be difficult to obtain an estimate of the real size of investments, very often the investment is made without sound estimates of the amounts to be invested, but rather based on the size of the production unit, which usually gives us an idea about the expenses incurred either in the construction of infrastructure, as well as in the acquisition of materials needed for production. Likewise, the size can provide a clear indication of the operational costs, which makes us believe that they could somehow influence the variability of the inefficiency of the poultry farms analyzed in this study.

Another parameter considered to analyze the organizational structure of companies was the membership in existing associations in the region. In fact, associations perform functions that can promote the activities of their members which make a difference between those who are affiliated and those who are not affiliated with an association. Among the various functions of the associations is the presence of members in a discussion forum on the constraints and needs for reforms to improve the activities of partners in the region. Other actions of associations promote access to consumer markets and protect the producer through the establishment of clear pricing strategies that show positive relationship to income generation and profit (Bachke 2009).

Management of Production Units

To understand the influence of unit's management on efficiency, four important factors were indicated, which are the age of the unit manager (in years), the unit manager's educational level (in number of years in school, to define different levels), experience of the firm manager (in number of years of practical experience in poultry production), and technical assistance to the unit (present or absent).

Thus, 12 variables are considered as determinants of efficiency of the study units of poultry production in the region.

- **Age**: measures the age of the managers of the firms included in the study.
- **ED**: accounts for the education of the respondents to the questionnaire or interviews conducted in the firms. It represents only the managers of the visited units.
- **ProdSis**: represents the different arrangements system of the poultry producers in the value chain, considering the existence of two arrangement systems as indicated, independent, and integrated.
- **SalesAg**: represents the sales agreement established with a buyer which may influence the production of a certain unit.
- **FExperience**: farming experience, which may influence the technical expertise of the producer and shifting thus the frontier line.
- **FSize**: farm size is another important factor which may differentiate producers in the business environment and hence influence the production frontier.
- **BPlan**: a business plan is directly related to management of the unit and may have direct influence on the production process and sales.
- **BRegist**: business registration is another important managerial aspect to consider which may influence the production process and sales.

2.5.3. Data and Descriptive Statistics

The analysis was based on a balanced panel with data for 25 poultry farmers in the region from September 2020 and March 2021 (seven cycles of production for each

production unit, thus making 175 total observations) as presented in the Table 1. The selected farmers are representative of the poultry production structure in Maputo, having producers in different arrangement systems (integrated and independent). Currently, two main production arrangement systems are identified in the Maputo region: the independent production arrangement system, and the integrated production arrangement system. The producers considered for the study were also selected from different sizes (INE 2019), considering two important categories. The small-scale producers' facilities do not comply with technical recommendations such as orientation, inclination, and use of footbaths at the entrance to the production unit, which is reflected in low production performance in their facilities. Large producers normally produce under acceptable technological conditions and with substantial investments in the activity. In general, well-structured companies with organized accounting participate in this category, and most resort to financing at the start of their business.

Table 1. Descriptive statistics of the collected variables.

Variables	N	Mean	Standard Deviation	Min	Median	Max
CT (Total costs)	175	1,563,284.00	2019.39	94,800.00	490,640.00	11,196,000.00
Sales	175	1,924,886.86	2610.03	91,200.00	561,600.00	15,360,000.00
ProdR (Total production)	175	10,236.05	13,865.00	480.00	2910.00	76,800.00
PF (price of feed)	175	1962.59	147.63	1740.00	1897.50	2247.50
PDOC (price of day-old chick)	175	38.87	2.20	27.33	39.00	43.00
PLabor (price of labor)	175	4716.57	649.87	3500.00	4750.00	6000.00
POthers (price of others)	175	16.88	1.18	15.00	17.00	19.00
Age	175	48.84	10.02	28.00	47.00	69.00
ED	175	11.08	3.08	7.00	12.00	17.00
FExperience	175	10.88	4.09	3.00	10.00	18.00
FSize	175	16,020.00	21,939.47	1000.00	3000.00	80,000.00
MortRate	175	3.40%	0.90%	2.00%	3.00%	6.00%

Source: Computed by the author from the farm survey (September 2020 to March 2021).

The interviews were carried out with managers of the production units targeting the cost of production and the income statement and other relevant information regarding input and output prices. To reduce the errors in the data provided, available production and financial reports were also considered for the cost and price of input extraction and used for the estimations.

- CT (Total costs), sales, PF (price of feed), PDOC (price of day-old chick), PLabor (price of labor), and POthers (price of other expenses) are all presented in MZN, the Mozambique currency.
- ProdR (total production) is presented in number of chickens.
- Age is presented in years.
- ED (education) is presented in number of grades or years at school.
- FExperience (farmer experience) is presented in number of years at the poultry activity.
- FSize (farm size) is presented as the potential number of chicks lodged per cycle of production (capacity of the farmer to lodge a certain number of chickens per cycle).
- MortRate (mortality rate) is presented as the number of chicks dying per cycle and is given in percentage format.

2.5.4. Data Analysis

The R package frontier was used to implement the models. This package allows consideration of two of the four possible distributions previously mentioned: half- and

truncated normal for the inefficiency error component u_{it}. Therefore, the analysis was restricted only to these two distributions. This routine follows the approach detailed in Coelli (1995) and can be summarized in the following steps:

- Firstly, OLS estimates of the function $f(X,\ \beta)$ are obtained and all β estimators except for the intercept (β_0) are unbiased.
- A two-phase grid search of $\gamma = \frac{\sigma_u^2}{\sigma^2}$ is conducted, with the β parameters set to the OLS values. Possible values of γ vary from 0.1 to 0.9, with increments of 0.1. The β_0 and $\sigma^2 = \sigma_u^2 + \sigma_v^2$ parameters are adjusted according to the corrected ordinary least squares formula. At this phase, other parameters such as μ or δ are set to zero.
- Finally, the values resulting from the grid search are used as starting values in an iterative maximization procedure.

The Davidon–Fletcher–Powell (DFP) method has been successfully used in a wide range of econometric applications and was also recommended for the estimation of the stochastic frontier production function (Coelli 1996).

Estimation of the Stochastic Frontier Model

This study uses the form of the stochastic cost frontier model similar to that suggested by Battese and Coelli (1995). Using the selected model for the data and model specification, the study adopts the following model:

$$\ln(TC_{it}) = \beta_0 + \beta_1(lnPFeed_{it}) + \beta_2(lnPDOC_{it}) + \beta_3(\ln ProdR_{it}) + \beta_4(\ln Others_{it}) + \beta_5(\ln Labor_{it}) + V_{it} + U_{it}$$
$$i = 1, 2, 3 \ldots,\ 25\ t = 1, 2, 3\ \ldots\ ,\ 7$$

where:

- TC_{it}—observed total costs of the ith production unit in a cycle t.
- $PFeed_{it}$—feed price vector of the ith production unit in a cycle t.
- $PDOC_{it}$—day-old-chick price vector of the ith production unit in a cycle t.
- $ProdR_{it}$—a vector of production of the ith production unit in a cycle t.
- $POthers_{it}$—other input price vector of the ith production unit in a cycle t.
- $PLabor_{it}$—labor price vector of the ith production unit in a cycle t.
- V_{it}—random variables of the ith production unit in a cycle t, reflecting effects of statistical noise.
- U_{it}—time-varying cost inefficiency

Furthermore,

$$U_{it} = \delta_1(ProdSis)_i + \delta_2(SalesAg)_i + \delta_3 \ln(ED)_i + \delta_4 \ln(FExperience)_i + \delta_5 \ln(FSize)_i + \delta_6(BPlan)_i$$
$$+\delta_7(BRegist)_i + \delta_8 \ln(Age)_i + \delta_9(ExtServices)_i + \delta_{10}(AssMember)_i + w_{it}$$

3. Results and Discussion

The stochastic frontier cost function was estimated with all continuous variables in logarithmic form, except for the variables that are expressed in names considering the nominal uses as they appear in the datasheet (production arrangement system (ProdSis), business plan (BPlan), sales agreement (SalesAg), input agreement (InputsAg), business registration (BRegist), extension services (ExtServices), and association membership (AssMember)). This enables us to interpret the marginal effects of the prices of inputs on production and the marginal effects of the explanatory variables in the inefficiency component as elasticities. The estimation results are shown in Table 2.

Table 2 shows that the input prices and output are positive and significant at the usual significance levels. An increase in input prices or in output increases the costs. All the estimated coefficients have the expected signs, which is a positive relation between the input prices and output to cost efficiency. Therefore, bigger outputs and high input prices generate increased costs. The elasticities of the input prices and output ranged from 0.989 for the output to 0.0166 for the price of labor using the frontier estimates.

Table 2. Estimates of stochastic cost frontier for poultry farmers in the Maputo region.

Variable	Estimate	Std. Error
Intercept	−1.753 *	0.395
ln (PFeed)	0.471 *	0.043
ln (PDOC)	0.833 *	0.047
ln (PLabor)	0.016	0.021
ln (POthers)	0.038	0.043
ln (ProdR)	0.989 *	0.004
gamma (ϒ)	0.674 *	0.177
SigmaSqU	0.005 *	0.000
SigmaSqV	0.000 *	0.000
log likelihood value = 365.993		

* means significant at 1% level. Source: Computed by the author from frontier 4.1c using R statistical software package estimates.

The coefficient estimates of the feed price and day-old chicks were significantly different from zero, while the rest of the variables were usually non-significant. The results that were significant indicate that high feed and day-old-chick price resulted in higher production costs. However, the study reveals that there was no significant relationship between price of labor and the output, hence not significantly contributing to the increasing costs of production.

3.1. Determinants of Efficiency in Poultry Production in Maputo

3.1.1. Organizational Structure

All factors show signs as expected. The coefficients are all positive, with the majority being significant at the 5% significance level. This reveals that the organizational structure of companies is directly related to their efficiency, that is, the more the production unit is structurally organized, the more efficiently it operationalizes its activities. For the present study, the following factors were considered for the organizational structure: registration of the entity (officialization of the business), existence of a business plan, the size of the firm or production unit, and adherence to local associations. Among these, the officialization of the business, design of the business plan, and the size of the production unit were significant, indicating the existence of a positive effect on the efficiency of the production unit with the existence of the plan, registration, and larger size of the production unit, i.e., a larger, properly registered unit with an up-to-date business plan uses its resources more efficiently and therefore more cost-effectively. Thus, the levels of inefficiency tend to be reduced with an increase in the size of the production unit and the existence of a business plan for a duly officialized production unit. This is explained by the fact that strategically planned companies are the most efficient when compared to those that do not plan (Cornelisse and Hyde 2002). As expected, the business plan would allow for a more informed decision since the managers are more knowledgeable of the business and its surrounding environment. The business plan represents an instrument for rationalizing the use of resources and operational improvement, as illustrated by Cornelisse and Hyde (2002) when discussing agribusiness planning, specifically on providing directions for agricultural firms. The registration of production units is also considered a key to success. Among other advantages, it allows companies to access financing and other opportunities that are only possible with legally recognized entities. One of the challenges for the agribusiness sector is the non-officialization of actors, thus hindering access to important statistical data for the development of priorities of various development support entities, including access to finance and other initiatives to promote development of the sector, as demonstrated by

Bottasso and Sembenelli (2004) when analyzing the influence of business ownership on efficiency.

The adherence to associations was considered an important factor to explain the effect on the efficiency of the production units included in this study. Although the factor indicated the existence of a positive relation, it was not significant, which can be explained by the fact that the associations of this particular sector are not fully performing the roles they are expected to do. Currently, they are limited to representing their members in a forum that aims to discuss the problems of members and in some cases to offer selected training to its members, when in fact they would have a greater impact if they entered the discussion of prices and fixing them in clear defense of the interests of sector operators (Bachke 2009; Foong 2005). Some point out that sector associations have also been involved in supporting their members in the negotiation of input prices, benefiting from discounts on their acquisition. In addition, they seem to be engaged in operationalizing community slaughterhouses, which would absorb production of its members who spend several days searching for the market to place their products, often resulting in increased costs.

3.1.2. Commercial Agreements

Surprisingly, the signs of the coefficients are all negative, although not significant, which may indicate that there are no effects of commercial agreements on the efficiency of production units. It would be expected that companies with established commercial agreements would be more efficient when compared to those that operate independently in the market. Apart from other possibilities, some advantages for such agreements include: exclusivity and priority in the acquisition of inputs, and in some cases at discounted prices which may vary up to 5% of the market price; technical assistance provided by the entities with which commercial agreements are established, and; the ease of distribution of products, that is, a guaranteed market for the placement of production through sales contracts as part of the commercial agreements. However, it is also known that these companies tend to be very dependent on agreements and not strong enough to negotiate prices, especially for the sale of their products in the case of agreements including sales, and integration with a large company. However, often they price takers, which places them in a disadvantaged position when compared to producers operating independently. This situation was also illustrated by Oppewal et al. (2016), who found that integrated companies tend to be less profitable, the main reason being that the contracts make them very dependent and price takers, while independent producers usually negotiate for the setting of prices. The survey carried out for the study showed that almost all independent producers negotiate the marketing price with their customers, usually retailers. Regarding input purchase prices, some independent producers, despite the smaller size of their operations, also benefit from discounts arising from contracts established for large buyers and/or other modalities that offer benefits. Independent producers, because they are not committed to the agreement, have a greater capacity for negotiation as they can freely choose the input supplier, and often they make a careful comparative analysis of the increasingly growing input prices in supply market. Regarding the sale of products, they usually score the best prices on the market, as demonstrated by Karnani and McKague (2014) when describing the producer in the poultry value chain in Mozambique. On the other hand, being free, they can sell their products to various interested parties, even to end consumers, at much more attractive prices (Foong 2005).

Commercial agreements directly affect cost. Therefore, the signing of agreements for the supply of inputs, technical assistance, exclusivity, and marketing of their products may increase variability in inefficiency, thus negatively affecting the efficiency of companies with active agreements in the poultry value chain in the Maputo region.

3.1.3. Management Capabilities

Looking at the factors indicated in Table 3, and regarding the management capacity of the production units' managers, two factors have negative coefficients and the other three

have positive coefficients. Three of the five factors are significantly related to the efficiency of production units. The mortality rate is inversely related to the efficiency of production units, that is, the higher the mortality rate, the greater the variability in the inefficiency, and the lower will be the efficiency of the firm. Therefore, companies with higher mortality rates tend to be less efficient in general. The level of education and professional experience in the sector of the units' managers are directly related to the efficiency of the firm. The more years of experience and education of managers, the lower the level of inefficiency of production units, which is not surprising. Therefore, companies or poultry production units managed by people with more years of experience and higher levels of education tend to be more efficient. Similar results were achieved by Maliranta and Nurmi (2019) in the study of the influence of the owners and employees in the business performance.

Table 3. Determinants of efficiency.

Factors	Estimates	Standard Error	Factors Dimensions
z_Intercept	−0.0439	0.2024	
z_ln (FSize)	0.0301 *	0.0168	Organizational structure
z_BPlan	0.0797 *	0.0287	
Z_BRegist	0.0147 *	0.0190	
z_Associationship	0.0359	0.0281	
z_ProdSystem	−0.0639	0.0963	Commercial agreements
z_SalesAgreement	−0.0134	0.0915	
z_InputsAgreement	−0.0193	0.0215	
z_ln (MortRate)	−0.0961 *	0.0139	Management capabilities
z_Extension	0.0391	0.0306	
z_ln (Age)	−0.0226	0.0407	
z_ln (ED)	0.0651 *	0.0217	
z_ln (Experience)	0.0653 *	0.0238	
Gamma	0.6790	0.1540	*
SigmaSqU	0.0009	0.0003	*
SigmaSqV	0.0004	0.0001	*

Source: Computed by the author from frontier 4.1c using R Statistical software package estimates. * Significance at 5% level.

For age and access to extension services, while they were related to companies' efficiency, their coefficients were not significant. This fact may be due to the age factor not being a determinant for the necessary experience in the sector and the level of education of the managers, which would take away its significance. One could expect age to be inversely related to efficiency despite the non-significant coefficient, because it is well-known that older age does not favor the process of adopting new technologies (Czaja et al. 2006). On the other hand, extension, although positively related to efficiency, is not significant, which can be explained by the fact that it is not possible to measure its quality, but only access to it, since quality is what could dictate and differentiate the influence on efficiency.

3.2. Star Performer Identification in the Poultry Value Chain in Maputo

From Table 4 below, one can compute the average of the mean efficiencies of the 25 firms in all seven cycles (the mean of the seven cycles averages being 0.949, i.e., 94.9%).

Table 4. Ranking of efficiency producers.

Cycles	I	II	III	IV	V	VI	VII	Firms Means	Ranking
Means	0.930	0.939	0.972	0.953	0.946	0.952	0.948	0.949	-
F01	0.943	0.917	0.993	0.983	0.970	0.961	0.995	0.966	13
F02	0.980	0.987	0.992	0.988	0.983	0.981	0.960	0.982	10
F03	0.908	0.878	0.975	0.950	0.947	0.954	0.940	0.936	17
F04	0.834	0.853	0.927	0.892	0.906	0.903	0.869	0.883	23
F05	0.786	0.777	0.905	0.777	0.765	0.883	0.852	0.821	25
F06	0.988	0.990	0.994	0.987	0.987	0.986	0.987	0.988	5
F07	0.905	0.904	0.980	0.959	0.963	0.919	0.928	0.937	16
F08	0.990	0.990	0.993	0.985	0.984	0.981	0.981	0.986	7
F09	0.993	0.992	0.994	0.992	0.991	0.991	0.991	0.992	3
F10	0.879	0.897	0.889	0.887	0.886	0.884	0.884	0.886	22
F11	0.995	0.995	0.996	0.995	0.994	0.994	0.994	0.995	1
F12	0.979	0.979	0.977	0.977	0.976	0.972	0.972	0.976	12
F13	0.817	0.917	0.942	0.959	0.949	0.955	0.964	0.929	18
F14	0.979	0.968	0.985	0.962	0.954	0.955	0.945	0.964	14
F15	0.964	0.983	0.994	0.988	0.987	0.983	0.993	0.985	8
F16	0.890	0.919	0.988	0.979	0.901	0.983	0.976	0.948	15
F17	0.985	0.983	0.991	0.993	0.982	0.978	0.979	0.984	9
F18	0.878	0.876	0.946	0.874	0.862	0.861	0.884	0.883	24
F19	0.983	0.992	0.995	0.986	0.972	0.969	0.978	0.982	11
F20	0.995	0.995	0.996	0.994	0.992	0.991	0.984	0.992	4
F21	0.985	0.989	0.993	0.989	0.982	0.989	0.982	0.987	6
F22	0.904	0.885	0.930	0.931	0.934	0.906	0.872	0.909	20
F23	0.935	0.944	0.969	0.900	0.883	0.921	0.914	0.924	19
F24	0.881	0.880	0.953	0.912	0.899	0.910	0.888	0.903	21
F25	0.992	0.992	0.996	0.995	0.991	0.990	0.990	0.993	2

Source: Computed by the author from efficiency estimation on the R frontier package.

Considering star performers, those scoring above the average, we conclude that 14 firms are star performers, while the remaining 11 are below the average efficiency line, thus having 44% of firms or production units operating below the mean efficiency, which represents a problem for competitivity of the value chain in the region. Possible causes for this situation can be explained through the determinants of efficiency as shown in Table 5, where the explanatory variables are expressed by their average numbers or in terms of percentage of farmers.

In Table 5, main differentiation elements can be identified. Farm size (FSize) and consequently the number of chickens produced (ProdR) tend to be directly proportional to efficiency. These two elements show a big difference between the two groups of producers, above or below the average efficiency estimated at 94.92%. While producers who are best performers have an average production of 2571 chickens, the others have only an average value of 1773. This seems to indicate that, for a farm to be efficient, it must have a minimum production of 2600 chickens per cycle. In addition to production and the size of the production units, the registration of the business (BReg) and production planning (BPlan) were also found as elements of differentiation among the groups. Producers

with below-average efficiency do not have business plans and only one-third have their businesses registered. Therefore, these elements can be decisive regarding the structural and management aspects of the production units. Another factor of great importance in differentiating the two groups is undoubtedly the mortality rate (Mort), in which the best performers have an average mortality rate of 3.3%, 0.3% less than producers with below-average efficiency. This fact is rather important since the level of the mortality rate is crucial to the efficiency of productive units.

Table 5. Differentiation elements from the best performers and others.

Scores	Factors											
	Prod	**FSize**	**Age**	**Ed**	**Exper**	**BPlan**	**BReg**	**Sag**	**Iag**	**Exte**	**Ass**	**Mort**
Above average efficiency	17,839	27,215	48.57	11.57	10.43	42%	50%	14%	15%	95%	100%	3.3%
Below average efficiency	1177	1773	49.18	10.91	10.81	0%	37%	10%	10%	95%	100%	3.6%
Min	720	1000	28	7	3	0%	0%	0%	0%	0%	0%	3%
Max	57,142	80,000	69	17	18	100%	100%	100%	100%	100%	100%	6%

Source: Computed by the author from the farm survey (September 2020 to March 2021).

4. Conclusions

This study analyzed poultry producers' cost efficiency in the Maputo region with a sample of 25 producers between September 2020 and March 2021, encompassing seven production cycles. The analysis of the cost efficiency was carried out through an SFA model. As we see it, it is important to know the way in which the efficiency of the producers has evolved, and its determinants. To reach this objective, we have included in the model variables that characterize the producer's structural organization, the managerial capabilities of the producers, and commercial agreements, as they would indicate the relationships and coordination in the value chain. Furthermore, through cost efficiency, the study identified the best performers and differences in efficiency between the producers in the region and the specific characteristics determining that efficiency. The results revealed important conclusions.

The influence of the organizational structure of the production units indicates that a high organizational structure of the units, right farm size, business registration, and planning would be key to development of the sector as it secures the efficiency of the producers. Surprisingly, commercial agreements such as integrated firms, having a sales contract, and input supply agreements showed negative influence on the efficiency of the units. However, it must be said that the coefficients representing this effect were not statistically different from zero.

The production units with more experienced managers are more efficient in comparison with the producers with less experience, and fewer education years. Producers registering a higher mortality rate are more inefficient than those who manage to achieve a lower mortality rate. Then, it is only natural that producers using proper extension services and are qualified managers are more efficient.

Analyzing the determinants of efficiency of the poultry producers in the region, four important factors differentiate the best performers from others, namely, the farm size and its respective production quantity, business registration and plan, and finally the mortality rate, which makes a considerable difference between the best performers and others operating below the mean efficiency of production units in the Maputo region.

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