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Research article

Stochastic Frontier Analysis of Production Technology: An Application to the Pharmaceutical Manufacturing firms in Ghana

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Abstract

The aim of this study was to find out the level of technical efficiency of pharmaceutical manufacturing firms in Ghana and analyse the factors that determine their efficiency level. A survey based on questionnaire administration was applied to collect data from the entire population of pharmaceutical manufacturing firms numbering 39 across the country. A stochastic frontier analysis based on the Cobb-Douglas production functional form was applied to estimate the technical efficiency of production among firms. Subsequently, the ordinary least square (OLS) was used to determine the factors that influenced technical efficiency levels of firms. The findings show that technical efficiency level among firms range between about 34% and 62% with the mean technical efficiency level of 50%. In addition, the results show that percentage of professionals employed by firms, the ages of firms' plants and the number of maintenance exercises by firms significantly determined their technical efficiency level. Furthermore, capital and skilled labour had greater positive impacts on output levels of capsules and tablets produced. It is recommended that firms invest more in their capital stocks through replacement of old machines with new ones and ensuring regular maintenance of equipment. Firms should also employ more professionals and improve upon the technical know-how of existing workforce through in-service training. These will make them operate closer to their potential frontiers (more technically efficient) so as to be more cost effective and competitive.

Keywords: Technical Efficiency, Pharmaceutical ManufacturingFirms, Cobb-Douglas Production Function, Stochastic Frontier, Determinants, labour, capital

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INTRODUCTION

Classical microeconomic textbooks describe firms to be homogeneous units. Thus, all firms are assumed to operate at the same level of technical efficiency. However, empirical studies frequently show that in the real world some firms are more technically efficient than others (Caves, 1989). Whilst some firms operate at their technological frontier and potentially earn higher profits, others lag considerably behind and are barely able to survive.

It has been identified by experts that technical efficiency at firm-level is one of the major preconditions to industrial and for that matter economic growth and development particularly in developing countries. According to Kalirajan (1990), industrial and economic development in developing countries implies that the prevalence of relatively high technical efficiency levels among firms in such economies tends to approach that of firms in advanced economies like those of the western countries. In this direction, there is a gradual divergence of policies in the developing countries towards the market-oriented models of 'Washington Consensus' development policies that have promoted privatization, competition in the spirit of trade liberalization and foreign direct investment. The implication is that only firms that are near their efficiency frontiers can benefit from these policies and catch up with others as far as competition is concerned.

Thus, it is no gainsaying that technical efficiency at firm-level is very crucial to firms themselves and the country in which they operate. In respect of this, modern firms desire to be technically efficient in order to survive modern competition that has characterised developing countries as a result of waves of globalisation in the world's economy. This compels firms in developing countries to adopt improved production technologies that will enable them optimize the use of their capital equipment and other co-operant inputs to enable them get closer to their potential production frontiers to reduce cost of production and in order to widen their profit margins. This will make it possible for them to compete favourably with their competitors from the external sector and from within (Chow, 1993). Once firms are successful in this direction, they place themselves in an advantageous position to expand their operations and enjoy the associated economies that accompany large scale production hence, they can be assured of survival in business.

Again, Chow argues that the associated gains of firms being technically efficient are not limited to themselves only. Host countries of such firms become the ultimate beneficiaries of the gains thereof. The fact that firms become technically efficient enables them add more value to primary products in developing countries and this has the tendency to increase export revenue earning capacities of their countries of origin for further developmental activities. They are again in the position to increase their contributions to domestic revenue generation to central government through the payments of corporate taxes given the fact that their profit margins would have increased significantly.

A reasonable amount of efforts have been given to the measurement and analysis of productive efficiency in theoretical and empirical studies for many years following Farrell's seminal work (1957). Equally important is the work by Forsund, Lovell and Schnidt (1980) which provides a summary of various approaches to frontier analysis and efficiency measurement.

Analysis of productive efficiency is associated with examining exogenous influences on efficiency. Thus, exogenous variables that characterise the environment in which production occurs have been incorporated into efficiency measurement models in a variety of approaches. Early contributions to literature on this issue include Pitt and lee (1981) and Kalirajan (1981). The adoption of a two-step formulation by these works cannot be overemphasized. Currently, approaches to the incorporation of exogenous influences have been refined and significant improvements in modeling technical inefficiency effects in stochastic frontier models opened new directions for empirical analysis (Kumbhakar and Lovell, 2000).

This paper contributes to the literature on firm level efficiency measurement and explanation using a stochastic frontier production model with technical inefficiency effects for cross-section data. This formulation has the advantages of simultaneously estimating the parameters of the stochastic frontiers and the inefficiency models, given appropriate distributional assumptions associated with the error terms. The stochastic frontier model is applied to the pharmaceutical manufacturing firms in Ghana to provide empirical evidence on the sources of technical inefficiency in the industry. The importance of measuring technical efficiency in the Ghanaian pharmaceutical manufacturing industry is not far fetched.

Firstly, the Ghanaian pharmaceutical manufacturing industry is a force to recon with in terms of investment in the manufacturing industry as a whole. According to the Ghana investment promotion centre (GIPC), between 2000 and 2009 out of 28 investment establishments in the chemical manufacturing industry, 35.7% was made in the pharmaceutical manufacturing business. In the area of employment, it contributed 21% of the total employment in the general manufacturing industry for the same period (GIPC, 2009).Secondly, the implementation of Ghana's trade liberalization policy under the economic reform programme from early 1980s to the late 1990s which led to the elimination of tariffs and other forms of trade barrier, has in no small measure made it imperative for firms to be more efficient technically in order to stand the challenges of unbridled competition from outside the country, in particular, the Asian countries. This has become even more important for the fact that with the introduction of this reform, the market size of the Ghanaian pharmaceutical manufacturing industry is likely to reduce to just 30% (Harper &Ghansah, 2007).Thirdly, for reasons of poor technology pharmaceutical manufacturing firms in Ghana are unable to meet the World Health Organisation's(WHO's) precondition of quality standards, and hence, are not permitted to produce and or export Active Pharmaceutical Ingredients (API_S) :- drugs that are used to treat virus diseases, and TB drugs that address Neglected Tropical Diseases (NTDs) and cardiovascular illnesses. Thus, knowledge in the technical efficiency level in the pharmaceutical manufacturing sub-sector will ultimately prepare the ground for the firms in the industry to be reconsidered by the WHO in this direction. Lastly, a study that actually addresses the issue of technical inefficiency in the pharmaceutical manufacturing industry in Ghana is of great importance because no research work has been done to this effect.

Pharmaceutical manufacturing firms in Ghana face strong competition from their relatively well-endowed counterparts from the Asian and Middle-East countries on the domestic pharmaceutical market. Thus, the sale of more quality and cheaper pharmaceutical products from these countries tends to reduce the market size of the domestic pharmaceutical manufacturing firms making it difficult for them to grow to enjoy the benefits of large scale production (Harper &Ghansah, 2007). According to Harper &Ghansah (2007), concerns have been expressed by the players in the industry with respect to the technical efficiency level of the domestic pharmaceutical manufacturing firms, attributing their inability to compete with their counterparts outside to their low level of technical efficiency.

This situation in the pharmaceutical industry in Ghana has created fertile grounds for generating public perception that there is a problem bothering on technical efficiency among the firms in the industry in the face of the influx of foreign investors in the industry after the introduction of the trade liberilisation policy in the country during the late 1990s (GIPC , 2010). In spite of the indispensable role played by the pharmaceutical manufacturing industry in the country, no work has been done in the existing literature to scientifically examine the technical efficiency level among firms in this industry and the accompanying factors that determine their technical efficiency.

This study seeks to fill this gap by addressing the following pertinent questions. What is the level of technical efficiency of pharmaceutical manufacturing firms in Ghana? What firm-specific characteristic factors influence technical efficiency of pharmaceutical manufacturing firms in Ghana? To what extent do output levels of these firms respond to their capital and labour inputs?

Theoretical Framework

The pioneering work of Farrell (1957) was initially developed based on the deterministic frontier approach which attributed the entire deviation of the actual output of firms from their potential maximum output to inefficiency of the firms. However, the works of Aigner, Lovell and Schmidt (1977) and Meeusen and Van Den Broeck (1977) were first to separately but concurrently identify that the deviation of firms' output from their potential maximum output was not entirely attributable to inefficiency. They established that it was partially attributable to both inefficiency of the firms and statistical noise or randomness associated with econometric model (Kumbhaker& Lovell, 2000).

Kumbhaker and Lovel (2000) noted that this became known as the traditional stochastic frontier model. It uses the non-negative random aspect of the error term (i.e. one with half normal distribution) to produce a measurement of technical inefficiency or the ratio of actual output to the maximum output with the given inputs and the level of. When firms in an industry operate at different levels of inefficiency as a result of poortechnology, inadequate incentives, inappropriate input levels, mismanagement or less than perfectly competitivebehaviour, the level of output could vary. Basically, the traditional stochastic frontier model is stated as:

$$Y_i = f(x_i; \beta) + e_i; \ i = 1,2,\dots, N; \ N = \text{last firm.} \qquad (1)$$

$$e_i = v_i - u_i;$$

Where Y_i represents the output level of the ith sample firm, $f(x_i; \beta)$ is a suitable function such as Cobb-Douglas or Translog production function of vector x_i of inputs for the ith firm and a vector β of unknown parameters. e_i is an error term made up of two components, vi and ui. v_i indicates a random error with zero mean and a constant variance N $(0;\sigma_v^2)$. On the other hand, u_i is a non-negative truncated half normal, independently and identically distributed random variable associated with firm-specific factors, N $(0, \sigma_u^2)$ which leads to the ith firm not attaining maximum efficiency of production.

According to Battese and Rao (2001), the use of the stochastic frontier metaproduction approach, demonstrated how technical efficiency of firms across groups is estimated. They further used a decomposition result to show analysis of regional levels of efficiency and productivity potential. According to them, assuming stochastic frontier model for all different regions or groups in an industry such that for the $_j$th group or region, there are sample data on N_j firms producing one output from the various inputs. The stochastic frontier for each region or group can be stated as;

$$y_{ij} = f(x_i, \beta j)e^{v_i - u_i}. \qquad (2)$$

Where, $_i$ = 1,2,…Nth firm and v_i are random variables independently and identically distributed with zero mean and constant variance as N $(0, \sigma^2)$. That is, random variables are independent of the u_{is} which are defined by the truncation (at zero) of the N (0, σ^2) distributions. Omitting the subscript *j* to simplify the model for the $_j$th group gives;

$$y_i = f(x_{i,}\beta)e^{v_i - u_i} \equiv e^{x_i\beta + V_i - U_i} \quad (3)$$

Therefore, the stochastic frontier metaproduction functional model for all firms in all the regions or groups of the industry is defined as;

$$y_i = f\left(x_{i,}\beta^*\right)e^{v^*_i - u^*_i} \equiv e^{x_i\beta^* + v^*_i - u^*_{i,}} \quad (4)$$

$i = 1, 2,\ldots,$ N and $N = \sum_{j=1}^{R} Nj$

Where, N represents the total number of sample firms in the (R) regions. According to Battese and Rao (2001) the result of the maximum likelihood estimates of parameters of the stochastic frontier metaproduction function cannot be an envelop of the individual production functions of the regions since the satisfaction of the assumption of the regional frontier will not mean that those associated with the stochastic frontier metaproduction function are also satisfied. The authorshowever, conceded that if the estimation of the metaproduction function is constrained, itsestimates under the maximum likelihood approach can envelope the regional functions. They showed that the model for the *j*th group and the stochastic frontier metaproduction function yields the identifying relationship as;

$$1 = \frac{x_i\,\beta}{x_{i\beta^*}} * \frac{e^{v_i}}{e^{v_i{}^*}} * \frac{e^{-u_i}}{e^{-u_i{}^*}},(5)$$

Where, the 3 ratios on the right hand side of equation (5) are called the productivity potential ratio (PPR), the random error ratio (RER) and the technical efficiency ratio (TER) respectively.

$$\text{i.e. PPR} \equiv \frac{e^{x_i\beta}}{e^{x_i\beta^*}} \equiv e^{-x(\beta^* - \beta)} \quad (6)$$

$$RER_i \equiv \frac{e^{v_i}}{e^{v_{i^*}}} \equiv e^{v_{i} - v_{i^*}} \ (7)$$

$$TER_i \equiv \frac{e^{-u_i}}{e^{-u^*}} \equiv \frac{TE_i}{TEi^*} (8)$$

Desli, Ray and Kumbhakar (2003) used the firm specific intercept to examine efficiency change which takes place over time as a first order auto-regression process (AR_1)in a panel data framework. Their model is based on the fact that human beings tend to learn from their past mistakes in a gradual process. With this, an individual firm tends to correct its inefficiency and attempts to be efficient other things being equal in the subsequent period. Their model is specified as;

$$Y_{it} = \propto_i + \emptyset y_{it-1} + x_{it-1}\emptyset\beta + W_{it}\gamma + \varepsilon_{it\,,}(9)$$

Where, $\varepsilon_{it} = (v_{it} - \emptyset v_{it-1}) - u_{it;} u_{it} \geq 0$. W_{it} shows factors that might persistently influence the firm's productivity and the position of its frontier over time. They also defined the composed error term (ε) as having one component $(v_{it} - \emptyset v_{i,t-1})$ which follows an MA (1) process which is two-sided (-∞ + ∞), while the other component (u_{it}) is one-sided (0, + ∞). According to them technical efficiency of firm *i* at time t is measured by;

$u_{it} = y^{f}_{it}$ - Y_{it}, (10)

Where $u_{it}$is the technical efficiency, y^{f}_{it} is the possible maximum output level of the firm and, Y_{it} is the actual output level of the firm at the time. Thus;

$y^{f}_{it} = \propto_i + \emptyset y_{it-1} + x_{it}\beta - x_{it-1}\emptyset\beta + W_{it}\gamma$.(11)

Therefore, the technical efficiency (TE) of the firm is measured by;

TE = $e^{y_{it} - y^{f}_{it}} = e^{-u_{it}}$(12)

According to Desli et al. (2003), a firm's history of inefficiency tends to affect its present output level. With the model being dynamic, the lagged value of y appears in the function as a regressor. Again, there is the separation of technical inefficiency from time-invariant firm effect (α_i). Furthermore, if time is used as a regressor in the model through w_{it}, there is the feasibility of the exogenous estimation of technical change from $\partial y/\partial t$ and thus, technical change can be separated from technical efficiency as $TE_{it} - TE_{it-1}$.

Production Function

A production function shows the functional relationship between the quantity of a specific product that can be produced within a time and a set of inputs used, given the existing technology in a socio-cultural environment (Ferguson, 1978).Production function could be applied as a barometer for finding out what magnitude of increase in output over time is attributable to increases in the inputs of production, the existence of returns to scale and technical progress. The traditional theory of production function of the firm expresses output as a function of typically two inputs, thus; capital (K) and labour (L) in the forms of the Cob-Douglas and Translog functions as;

Q = Q (K, L(13)

Cobb-Douglas Production Function

The traditional Cobb-Douglas production functional form with two factor inputs is stated as follows;
$Q_{=}$ AO $L^{\alpha}{}_{t}$ $K^{\beta}{}_{t}$(14)

Or
lnQ = lnA_O+αlnL+ βlnk(15)

WhereAo is a scale parameter,Q is the level of output,α is the elasticity of output with respect to labour and β is the elasticity of output with respect to capital.The sum of α and β (α + β) gives the magnitude of homogeneity of the function which is also an indicator of returns to scale parameter. If the sum of the two is greater than unity, the function is said to be exhibiting increasing returns to scale. If it is however, less than unity it exhibits decreasing returns to scale and if it is just equal to unity it shows constant returns to scale. Originally, Cobb and Douglas assumed returns to scale to be constant which means the sum of the elasticities is always equal to unity. The Cobb-Douglas production function is based on the assumption that the elasticity of substitution of labour for capital is equal to one in the production of all commodities. This is seen as a major weakness of the model since it tends to restrain the model from measuring the existence of factor intensity reversal. However, in spite of the inherent weakness associated with the Cobb-Douglas model, it has been intensively applied in quite a number of empirical research works such as one by Chirwa (2007) on health services efficiency in the United Kingdom (UK) and Griliches (1967) on the United States of America's census of manufacturing.

Translog production function

The transcendental logarithmic production function also called the Translog production function was developed by Christensen, Jorgensen and Lau (1973). They approximated the logarithm of output by a quadratic form in the logarithm of two inputs as;

$lnQ = b_O + b_K lnK + b_L lnL + 1/2b_{kk}(lnK)^2 + 1/2b_{LL}(lnL)^2 + b_{LK}lnKlnL$ (16)

Where Q is the gross manufacturing output, K is real stock of capital input, L is labour input, bo is the intercept or the constant term, b_L and b_k are first order derivatives, b_{LL} and b_{kk} are own second order derivatives and b_{Lk} is a cross second order derivative. According to Christensen et al.(1973), the advantage of this production function is that it is easily estimated as compared to the Cobb-Douglas production function. As a Taylor second-order approximation to any production function, it can be used for the verification of whether or not the coefficient of the elasticity of substitution of factor inputs is variable. In the case of a three-factor inputs situation; capital (K), labour (L) and material (M), equation (16) can be reformulated as follows;

$lnQ = b_o + b_k lnK + b_L lnL + b_M lnM + 1/2b_{kk}(lnK)^2 + 1/2b_{LL}(lnL)^2 + 1/2b_{MM}(lnM)^2 + b_{LK}lnKlnL + b_{LM}lnMlnL + b_{kM}lnKlnM$(17)

Where, variables are as defined before with bMM being own second order derivative and b_{LM} and bKMbeingcross second order derivatives. This function is relatively a more flexible form of production function which takes account of the shortcomings of the Cobb-Douglas production function by permitting the partial elasticities of substitution between inputs to vary. The elasticity of scale can vary with output and factor proportions, permitting its long run average cost curve to take the traditional U-shape. The properties of this production function make it superior over that of the Cob-Douglas and others. For a two-factor (K, L) situation, the output elasticity with respect to labour would be stated as;

$e = \frac{\partial lnQ}{\partial lnL} = b_L + b_{LL}lnL + b_{LK}lnK$(18)

In the case of a three-factor situation focusing on labour combining with K and raw materials (M) we have;

$e = \frac{\partial lnQ}{\partial lnL} = b_L + b_{LL}lnL + b_{LK}lnK + b_{LM}lnM$(19)

Analysis of Factors that Influence Technical Efficiency

The existing theoretical literature indicates that there are two methodologies used in analyzing factors that influence technical efficiency of production units (firms). These involve the ordinary least square (OLS) and the Tobit regression model. In each of the two approaches efficiency scores are obtained first from the stochastic frontier production function. Then the scores are used as dependent variables to run a regression over some explanatory variables (socio-economic factors of firms) with the use of the OLS or the Tobit model also called the censored regression model (Chirwa, 2007).

The use of the OLS and the Tobit model in analyzing the factors that influence technical efficiency is criticized on the grounds that the firm's knowledge of its level of technical efficiency affects its input factor choices hence, efficiency may be dependent on the firm's inputs other than the socio-economic factors (Rahmah&Abidin, 2009). Rahmah and Abidinargue that the use of the Tobit model is more complex and is appropriate for relatively large sample sizes of respondents.

Previous Findings

Previous works attribute technical efficiency of firms to different socio-economic factors termed as the determinants of efficiency of such firms. Carlsson (1972) after studying some Swedish industries concluded that technical efficiency suffers from various protectionist policies against competition. Beeson and Husted (1989) in a cross-state study for the United State of America found that a considerable part of the variation in efficiency could be attributed to regional differences of labour force characteristics, levels of urbanization and industrial structure. Alvarez and Crespi (2003) in analyzing micro, small and medium sized Chilean manufacturing firms found that efficiency is positively associated with the experience of the workers, modernization of physical capital and product innovation activity. They argued that other variables such as outward orientation, educational level of the owner and participatory support programmes did not affect the efficiency of the firms.

Methodology

A two-staged procedure of theoretical framework is used for this study. The first one deals with finding the mean technical efficiency levels for firms using their production parameters. The second stage uses the obtained levels of mean technical efficiency for the firms to estimate their firm-specific characteristic (socio-economic) factorsreferred to as determinants that influence their technical efficiency level.

The stochastic frontier production function developed by Aigner et al. (1977) and Meeusen et al. (1977) as used by Battese and Coelli (1995) is adopted study to find technical efficiency level for the firms. We assume that the frontier production function is of Cobb-Douglas or translog form as given in equations(15) and (16). Two main reasons account for the adoption of this approach instead of the data envelopment analysis (DEA). First, it has the ability to consider both factors beyond the control of the firm and the technical inefficiency hence, it is closer to reality. Second, it separates the random variation of the frontier across firms as well as the effects of measurement error and other random shocks from the effect of inefficiency. With the use of a frontier production functional form, the methodology of the stochastic frontier approach is developed as in equation (20).

$$y = f(x;\beta). \qquad (20)$$

Equation (20) defines the technological link between inputs (x) and the resulting output (y) under the assumption that production is considered in an efficient manner and β represents unknown parameters to be estimated. Due to some degree of inefficiency, a firm potentially produces less than it might and as a result, its production function is stated in equation (21).

$$y = f(x_i;\beta) * TE_i. \qquad (21)$$

The firm's technical efficiency (TE_i) represents the ratio of observed output to maximum feasible output and lies between 0 and 1. TE_i is considered to be non-negative since the firm's output is assumed to be positive. If TE_i is equal to 1, then the firms employ all of their inputs efficiently and achieve an optimal output. If it is less than 1, the firms experience a degree of inefficiency in their production. It is assumed that technical efficiency is a stochastic variable with a distribution common to all firms and can be written as in equation (22).

$$TE_i = \exp(-u_i). \qquad (22)$$

But $0 \leq TE_i \leq 1$, therefore, $u_i \geq 0$. Again, the firm's output level is subject to various random shocks that include anything from bad weather to unexpected luck and these effects are denoted as exp (v_i). Thus, the production function is further expanded to equation (23).

$y_i = f(x_i;\beta) \cdot \exp(-u_i) \cdot \exp(v_i)$.   (23)

After taking the natural log of both sides equation (24) is obtained.

$$\ln y = \beta_0 + \sum_{j=1}^{K} \beta_i \ln x_i + v_i - u_i, (24)$$

Where *j* refers to all firms from the first to the last (k).In this general specification, v_i is a pure noise component and a two-sided normally distributed variable, while ui is the non-negative technical inefficiency component. Both terms form a compound error term with an apriori unknown distribution. The model is estimated by maximum likelihood assuming a log-quadratic production function that encompasses either the Cobb-Douglas or the translog specification.

Apart from the input variables, exogenous variables that characterise the environment in which firms operate and firm-specific characteristics also influence their technical efficiency. In identifyingsuch factors influencingtechnical efficiency, many empirical studies have involved the estimation of stochastic frontiers, prediction of firm level technical efficiencies and identification of reasons for the potential and actual outputs (Kalirajan, 1981).

Thus, having obtained the parameters of the production function for the firms, Battese and Coelli (1995) used them to obtain the technical efficiency score of firms by expressing the actual output level as a percentage or fraction of the potential maximum output after which a mean technical efficiency is obtained. The technical efficiency is calculated as indicated in equation (25).

$$TE_i = \frac{y_i}{y_i^*} = \frac{y_i}{\exp(x_{i,}\beta)} = \exp(-u_i), (25)^*$$

Where y_i is the actual mean output level of firms, $y_i^* = \exp(x_{i,}\beta)^*$ is the potential mean maximum output level of the firms and (–u) is as defined before. After finding the mean technical efficiency level, the next stage is to find the firm-specific characteristic (socio-economic) determinants that might have influenced the technical efficiency level of the firms. The ordinary least squares (OLS) regression model is employed in this case. This method is chosen against the Tobit model because as literature indicates, the Tobit model is ideal for large numbers of sample sizes since the observations of the dependent variable are censored. Given the size of the population of 39 firms for this study, and the fact that the observations of the dependent variable (mean technical efficiency level) is not censored, the OLS is more appropriate for analyzing the firm-specific characteristic factors that influenced technical efficiency levels of firms (Rhamah&Abidin, 2009). The OLS is thus stated in equation (26).

$$Y_i = \alpha x_i + e_i, \quad (26)$$
$$u_i \sim iidN(0, \sigma^2)$$

Where, Y_i represents the dependent variable which is the obtained technical efficiency score for the firms, α and x_i are the vectors of unknown parameters and explanatory variables respectively and e_i is the random error term.

Data

The survey design which was chosen for this study applied the primary-sourced cross-sectional survey data from the pharmaceutical manufacturing firms in Ghana covering the year, 2009. The main strength of this research design is that it encourages direct communication between the researcher and the targeted respondents in the course of data collection. Compared to other forms of design, it has the advantage of solving several problems relating to estimation and aggregation of data collected from the primary sources (Rahmah&Abidin, 2009).

All the 39 pharmaceutical manufacturing firms in Ghana were used as respondents for the study. This became imperative because using a portion of the population as a sample for the study would not produce any statistically meaningful and reliable result considering the size of the population. Thus, the use of the entire population would be more reliable and realistic.

The fact that pharmaceutical manufacturing firms characteristically produce a wide range of varied finished products made it necessary to classify the products into three major descriptions namely tables, capsules and syrups. This made the handling of such a situation more feasible for the study. Tablets included all forms of pills for oral dosage or otherwise. All forms of liquid, ointments and suspensions were classified as syrups whilst all forms of shelled powder were classified as capsules. Thus, the data used each firm's output levels for these products in 2009. Tablets and capsules were measured in packs whilst syrups were measured in litres. From a factory definition, a pack is made up of 100 sachets of 100 milligrams of tablets or capsules particularly packed in a box. A litre of syrup is the equivalent of 1 000 millilitres of that syrup. Inputs used by firms included labour, capital and raw materials. Labour is made up of skilled and unskilled expressed in man-hour units. Skilled labour included highly trained workers called technicians at the factories and the management teams of the firms. Unskilled labour refers to workers with no specific training like cleaners and porters. Capital used by firms was mainly made up of engine powered equipments (plants) which are in some varied forms depending on the sizes of the respective firms. The current cost of a plant of a firm was considered for use in the data instead of the physical unit of the plant. The main plant considered for the study was the 'crush plant' which was seen as the plant that partially influenced the final output of a firm in all the three products and not the finished peripheral small plants which were used for product branding.

Raw materials used by the firms were predominantly imported with a few ones obtained domestically. The major imported raw materials included chemicals of different varieties and volumes whilst the domestic ones included paper curtains, labels, bottles and water. The local materials were substantially less expensive as compared to the imported ones. Once again, the expenditures made on the raw materials (in Ghana cedis) were considered for the estimation and not their physical units.

Model specification

With reference to equation (24) a specification of a production functional form upon which the stochastic frontier analysis will be based is constructed. This will lead to the estimation of the parameters of variables with the application of the Frontier version 4.1 software developed by Coelli (1996). In practice, both the Translog and the Cobb-Douglas production forms are usually adopted. The Translog form is more flexible in permitting substitution effects among inputs, and is claimed to be a relatively dependable approximation to reality (Christensen, Jorgensen & Lau, 1973). The Cobb-Douglas form on the other hand, is simple and commonly used but imposes severe restrictions on technology by restricting the production elasticities to be constant and the elasticities of input substitution to be unity.

Appropriate production functional form

In determining whether the stochastic frontier production function was of Cobb-Douglas or translog form in order to ensure statistical consistency in the estimation, two steps of testing were applied. First, a regression for firms' data was run separately with the two functional forms. It was conclusively observed that the Cobb-Douglas production function was a better option. This is because it produced a normal production curve for the data. The Translog production function was rejected because it produced a non-concave production curve indicating that it was not appropriate for the data. It also meant that there were no interactive terms among the input factors of the data hence, the choice of the Cobb-Douglas form. After this, the Cobb-Douglas production function was restricted and subjected to log-likelihood test as has been used in literature by several researchers like Rhamah and Abidin (2009) and Alorvor and Anatu (2003). This test is done with the null hypothesis that the frontier production function is not of Cobb-Douglas form. The test is explained on Table 1.

Log likelihood test

As revealed by empirical literature, the commonest statistical test in substantiating the use of the Cobb-Douglas production form is the log likelihood test. Therefore the data are subjected to the log likelihood test to justify the appropriateness of the use of the Cobb-Douglas production form to estimate the parameters of the model. This is notwithstanding the fact that the data showed a normal production curve when used to run the OLS regression as explained earlier.

Table 1: Log likelihood test for model

Null hypothesis	Log likelihood value	df	P value	Decision
(Tablets)				
$H_0: \beta_0 = \beta_1 = \beta_K = 0$	15.6656	5	0.0000	Reject
(Capsules)				
$H_0: \beta_0 = \beta_1 = \beta_K = 0$	15.6827	5	0.0000	Reject
(Syrups)				
$H_0: \beta_0 = \beta_1 = \beta_K = 0$	19.1814	5	0.0000	Reject

Test statistic: ($\chi^2_{5,0.95}$) = 0.7107

Table (1) shows the log likelihood test for justifying the use of the Cobb-Douglas production functional form for the model of the firms. The null hypothesis, Ho is a restriction that the frontier production function is not of Cobb-Douglas form, hence, $H_0: \beta_0 = \beta_1 = \beta_K = 0$ indicates that all the parameters will be equal to zero if applied. With 5 degrees of freedom, the chi-square distribution on Table (1) at 95% is 0.7107. All the log likelihood estimates from the stochastic frontier production function for the three products of the firms fall outside this critical value. Thus, the log likelihood values are significant given their respective probability values as significantly less than one percent (i.e. 0.0000). We therefore, fail to accept the null hypothesis that the frontier production function is not of Cobb-Douglas form. The Cobb-Douglas production form is thus, used for the estimation using the variables from the observed data as shown with equation (27).

Cobb-Douglas function

$$\ln Y_{gi} = \beta_{0g} + \beta_{1g}\ln sl_{gi} + \beta_{2g}\ln ul_{gi} + \beta_{3g}\ln k_{gi} + \beta_{4g}\ln M_{gi} + v_{gi} + u_{i.} \quad (27)$$

Where, *ln* is natural logarithm (that is log to base *e*, where e = 2.718). Y represents the mean output level for the firms for each of the three products in 2009. Output is defined in terms of (a) tablets; for all forms of tablets produced by firms in 2009; (b) capsules; for all forms of shelled powdered chemical product produced by firms in 2009; and (c) syrups; for all forms of powdered and liquid chemical product produced during 2009, *gi* denotes the i^{th}firm and *sl* denotes skilled labour used by firms in terms of man-hours, *ul* denotes unskilled labour used by firms in terms of man-hours, kdenotes values of physical capital used by firms, M denotes other inputs (raw materials) used in production in 2009 by firms,*v*is a two-sided error term assumed to be identically and independently distributed, u is a non-negative technical inefficiency component of the error term and *βs* are parameters to be estimated. Having obtained the production parameters for each product by firms using equation (27), the technical efficiency level for firms is predicted with equation 28. After this, the mean technical efficiency level for firms is obtained.

$$TE_{gi} = \frac{Y_i}{e^{\beta_{0g} + \beta_{1g}\ln sl_{gi} + \beta_{2g}\ln ul_{gi} + \beta_{3g}\ln k_{gi} + \beta_{4g}\ln M_{gi} + v_{gi} + u_{gi}}} = e^{-u_{gi}} \qquad (28)$$

Now, using the composed error term (u_i) of the stochastic frontier production function model as in equation 28, the variation in actual output from the frontier output level is partially attributed to technical inefficiency defined by:

$$\sigma^2 = (\sigma_u^2 + \sigma_v^2) \qquad (29a)$$

$$\gamma = \sigma_u^2/(\sigma_u^2 + \sigma_v^2) = \sigma_u^2/\sigma^2 (29b)$$

That is, the parameter $\gamma = \sigma_u^2/\sigma^2$ is the proportion of the variance of technical inefficiency in the entire error variance. Where, σ^2 is as defined before and γ is the measure of technical inefficiency for firms. We next find the determinants of technical efficiency of the firms using some socio-economic factors.

Specified model for determinants

The next stage deals with finding the determinants of technical efficiency of the firms. Referring to equation (26) the mean technical efficiency level obtained from equation28 is used to find the parameters of firm-specific characteristic factors (determinants) that influenced technical efficiency of the firms. The OLS method is specified in equation (30).

$$Yi = \beta_{10} + \beta_{11}Ppe_i + \beta_{12}Ag_i + \beta_{13}Aps_i + \beta_{14}D_i + \beta_{15}Nm_i + e_i (30)$$

Apriori restrictions: $\beta_{11}, \beta_{13}, \beta_{15} > 0$; $\beta_{12} < 0; \beta_{14} < or > 0$.

Where, $Y_i$is the mean technical efficiency score obtained for firms from equation (28), βs are unknown parameters to be estimated, Ppe_i represents the percentage of professionals employed by the i^{th}firm, Ag_i represents the average age of plants used by firms, Aps_i shows the average period of schooling of employees of firms, $D_{i,}$ dummy variables such that 1 represents firms that have their own distribution channels and 0 otherwise and Nm_i represents the number of plant maintenance exercises conducted by firms during 2009. Firms were asked to provide the average period of schooling of only employees whose job descriptions directly impacted on output of firms. These included management personnel and other skilled employees like technicians at the factory.

Data analysis

Descriptive statistics

Basic statistics of the various values used in the computation of scores for technical efficiency of firms are considered on Table (2) illustrating the mean and standard deviation values of firms to find out the behaviours of the variables for the study. From Table (2) it is observed that the mean output level of capsules by the firms is slightly greater than that of syrups with tablet production for the year being the highest of 12,110,000. Also, investment made in raw materials by the firms during the period was a little less than one-third of the value of capital totaling GH¢6 100 000.00.

Table 2: Average Values of Variables

Variable	Description	Mean	St. Deviation
Ln(Y)	1.Tablets in packs ('0 000)	12 110	6 174
	2. Capsules in packs ('0 000)	11 360	6 02 5
	3. Syrups in litres ('0 000)	11 229	6005
ln (K)	Capital ('0 000)	6 100	3 978
ln (SL)	Skilled labour in man-hours	301 160	219 710
ln(UL)	Unskilled labour (in man-hours)	88 340	71 210
ln (M)	Raw materials used in 2009 ('0 000)	1 591	1 274
Efficiency model			
Ppe	Percentage of professionals employed	42.46	8.91
Ag	Age of plant used	13.31	7.18
Aps	Average schooling period of employees (in years)	16.28	4.59
Dm	Dummy 1: if firm has its own distribution channel	0.45	0.96
Nm	Number of maintenance of plants in a year	3.13	1.24

Source: Survey data, 2009

Firms employed more skilled labour totaling 301 160 man-hours than they did in the case of unskilled labour notwithstanding the fact that the percentage of unskilled workers was greater; - about only 43% of labour force in the industry was skilled.

Estimation of stochastic frontier production models

The parameters of input coefficients and the associated variances obtained from the maximum likelihood estimation using the Cobb-Douglas stochastic frontier production model are presented in Table 3.They indicate the magnitude of the parameters and their significance in firms' application of inputs during the period under consideration.

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Table 3: Estimation of stochastic frontier production models for products by firms

Variable	Parameters	Tablets	Capsules	Syrups
Constant	β_0	0.4390*	0.6706**	0.6248***
		(0.5385)	(0.1208)	(0.4311)
ln K	β_1	0.7621**	0.8726**	0.6380*
		(0.4422)	(0.3055)	(0.4120)
ln(SL)	β_2	0.8202***	0.7610**	0.6764***
		(0.0290)	(0.1024)	(0.0340)
ln(UL)	β_3	-0.2122	-0.1322	0.0521
		(0.0112)	(0.0133)	(0.0156)
ln M	β_4	0.8557***	0.9799*	0.7884**
		(0.3720)	(0.2248)	(0.0539)
Variance parameters				
Lambda ($\frac{\sigma_u}{\sigma_v}$)	λ	1.5323	1.5679	1.4233
Sigma	σ	0.8642	0.9682	0.9424
		(0.1452)	(0.2541)	(0.2570)
Sigma-squared (u)	σ_u^2	0.7488	0.9374	0.8881
		(0.1822)	(0.5124)	(0.3251)
Sigma-squared		0.1836	0.1922	0.1871
(v)	σ_V^2	(0.3982)	(0.7512)	(0.9654)
Log likelihood		14.4450	14.7166	10.9044
Gamma (γ)	$\sigma_u^2/(\sigma_u^2 + \sigma_V^2)$	0.8031	0.8297	0.5301
		(0.1822)	(0.5632	(0.9512)

Source: computed from survey data, 2009

Note: ***, ** and * denote significance at 1%, 5% and 10% respectively

In line with literature, and as explained in the empirical framework, variables used in the model include capital, labour (skilled and unskilled), and raw materials used by firms. Compared to labour, capital is more productive than skilled and unskilled labour in capsules production. This is supported by the finding of Doms and Jensen (1998) which concluded that foreign-owned firms in the US were more productive with capital having greater impact on output. On the other hand, the parameters for skilled labour are 0.8202, 0.7610 and 0.6764 significant at 1%, 5% and 1% levels respectfully in the productions of tablets, capsules and syrups respectively. This shows that skilled labour is more productive than capital in syrup production which is reminiscent of the finding by Globerman, Ries and Vertinsky (1994) in their study in Canada which concluded that foreign-owned firms enjoyed higher output response to labour than with capital. The implication of the parameters is that, if capital stock increases by 10%, outputs in tablets, capsules and syrup will increase by about 8%, 9% and 6% respectively. In the same vein, if 10% more of skilled labour is employed, outputs in the products will positively respond by 8%, 8% and 7% increases in the same order.

In contrast to the other inputs, parameters of unskilled labour in the production of tablets, capsules and syrups are-0.2122, -0.1322 and 0.0521 respectively which are relatively low. Thus, if more units of unskilled labour are employed, outputs in tablets and capsules will decrease implying that there is over-deepening of unskilled labour employment in the production of the two products, hence, their output levels will increase if there is a fall in the level of employment of unskilled labour.

The estimated parameters for raw materials are 0.8557, 0.9799 and 0.7884 significant at 1%, 10% and 5% respectively in the production of tablets, capsules and syrups respectively. Output responses in both capsules and syrup to raw materials are understandably the highest recording about 10% and 8% respectively if 10% more of raw materials are employed by the firms. This makes raw materials the most important input compared to the other inputs.

Furthermore, it is observed from Table (3) that the values of lambda (λ) and sigma(σ) in each estimate of the three products are large and significantly greater than zero. Thus, the correctness of the specified distribution assumption of the study (i.e., $e_i = v_i + u_i$) is approved. Given the values of lambda for the three products as 1.5203, 1.5579 and 1.4301 respectively, it indicates that the one-sided error term 'u' dominates the symmetric error term 'v' hence, the variations in actual outputs are attributed to differences in firms' practices rather than random variability. Again, gamma $(\gamma) = \sigma_u^2/(\sigma_u^2 + \sigma_V^2)$ is also a measure of level of inefficiency in the variance parameter ranging between 0 and 1. For tablets, gamma is estimated at 0.8031. This implies that about 80% of random variation in tablets production is explained by inefficiency among firms in the pharmaceutical manufacturing industry in Ghana. With respect to capsules and syrups productions, gamma values are 0.8297 and 0.5301 implying that about 83% and 53% of random variations are respectively explained by inefficiency among firms.

Technical efficiency level of firms

To estimate the technical efficiency level of firms, the production parameters obtained from the stochastic frontier Cob-Douglas production functional form are first expressed as a fraction of the potential output levels of the firms. They are subsequently used to predict the technical efficiency score for each product using the conditional expectation of equation 28. As noted in the methodology section, the technical efficiency score of the firms for a product is between 0 and 1. Secondly, the maximum and minimum technical scores are estimated for firms in producing the three products.

The meantechnical efficiency score for the three products by the firms is then obtained and multiplied by 100 for conversion into percentage and is shown on Table (4)

Table4: Technical efficiency level of firms

No. of Firms	Mean (%)	St. Dev (%)	Minimum (%)	Maximum (%)
39	50.17	23.56	33.67	61.83
t-ratio for testing of mean	2.7**			

Source: Computed from survey data, 2009

** shows statistic significance at five percent level (one tail test)

It can be observed from Table (4) that the mean technical efficiency score for firms in producing the three products ranges between about 34% and 62% indicating the scores for the least and most technically efficient firms respectively. Specifically, the mean technical efficiency score for firms is 50% significant at 5% level (one-tail test). Thus, the pharmaceutical manufacturing firms in Ghana for the period under consideration operated at the efficiency level of 50%.The implication is that output of firms was just half way from their frontier (potential output level) during the period under consideration. This differs from the findings of Alorvor and Anatu (2003). In their study involving firms from different industries in Ghana, the mean efficiency level of domestic firms was 74% whilst that of foreign firms was 45%.

Analyzing determinants

As described in the methodology section, the firm-specific characteristic factors or determinants that are likely to influence technical efficiency of firms are determined. This is done by using their respective predicted technical efficiency mean score as dependent variable to run OLS regression over such factors as independent variables. Firm-specific characteristic factors used in this study included percentage of professional workers of a firm (Ppe), age of firm's plant (Ag), average period of schooling by workers (Aps), a dummy variable (Dm) with 1 showing that a firm has its owndistribution channel and 0 showing otherwise and the number of plant maintenance exercise undertaken by firms during the period under consideration (Nm).The results are shown in Table 5.

Table (5) shows that the statistics obtained do not indicate any problem of estimation. The obtained R^2 of 0.5965 means that the estimated regression line explains about 60 percentof the variation in the mean technical efficiency levels of firms. The F statistic, which is significant at less than 1% significance level, has a value of 11.42 and falls outside the Table value of 2.52. This shows that we fail to accept the null hypothesis that the parameters do not explain the dependent variable (mean technical efficiency score). The implication is that the egressors jointly explain variations in the mean technical efficiency of firms. It can also be observed that Ppe and Nm have positive impact on technical efficiency with regressor coefficient values of 0.730 and 0.565 which are significant at 5%each respectively.

Table 5: Results of factors influencing technical efficiency levels among firms

Model	Coefficient	St Error	t –values
Constant	0.733**	-0.464	-2.180
Ppe	0.730**	0.258	3.062
Ag	-0.642*	-0.240	2.501
Aps	0.785	0.160	0.332
Dm	0.453	0.166	1.257
Nm	0.565**	0.948	2.872
R^2	0.5965		

F stat.	11.42
Critical value	2.44
Prob. value	0.000

Source: computed from survey data, 2009

Note: ***, **, * denote significance at 1%, 5% and 10% levels, respectively.

This implies that a rise in any of these factors tends to improve on the level of technical efficiency of firms. For instance, if the number of professional workers of a firm increases by 10% the technical efficiency of the firm will increase by about 7%. In the same way, if the number of its maintenance exercises increases by10% firms will have a 5% improvement on their technical efficiency level. However, the Ag significantly influences the technical efficiency level of firms negatively. With a regressor coefficient of -0.642, a 10% increase in the age of a firm's plant will decrease its technical efficiency level by about 6%. Thus, the older a firm's plant becomes, the less technically efficient that firm becomes other things being equal. The work of Bigsten et al (2000) in four African countries of Cameroun, Ghana, Kenya and Zimbabwe came out with similar conclusion that the firm-level technical efficiency levels among firms in these countries were influenced by the ages of plants used by the firms. The regressor coefficients of Dm and Aps are not significant and therefore do not influences the mean technical efficiency level of firms.

Conclusions

Technical efficiency of firms is seen as a precondition to the survival of modern firms in the developing countries in the face of unbridled competition from external producers resulting from globalisation. It is also regarded as a key to developing countries' industrial advancement and economic growth and development. The purpose of this study was to investigate the perceived disparity between the frontier and actual output levels of pharmaceutical firms leading to the discovery of their technical efficiency status in their quest to compete favourably in the domestic market. Considering the total number of pharmaceutical firms in Ghana, the entire population of firms in the industry numbering 39 was used in the study. The questionnaire was used for data collection. Data on firms' inputs for production and firm-specific characteristic (socio-economic) factors of individual firms were collected for the study.

A two-staged procedure was used in analysing the data: stage one employed the Cobb-Douglas stochastic frontier production functional form to find the parameters of the inputs used by firms in producing tablets, capsules and syrups. The obtained parameters were used to predict the mean technical efficiency levels for the firms. The second stage used the technical efficiency levels as the dependent variables to run an OLS over the socio-economic factors to determine the factors that influenced technical efficiency level of the firms.

With reference to the finding of the study, the following conclusions are drawn. Firstly, the mean technical efficiency level for firms was predicted with their respective input parameters. It was observed that the technical efficiency levels of firms in the industry ranged between about 34% and 62% with average technical efficiency level of 50%. It could be concluded that pharmaceutical manufacturing firms in Ghana in 2009 were less technically efficient compared to firms from different industries in Ghana as indicated by the work of Alorvor and Anatu (2003). It was also observed that the gap or the level of disparity between the frontier (potential) and actual output levels was quite great and could largely be attributed to firms' inefficiency in their production activities given the normal distribution error gap. This is in agreement with literature finding that firms' output deviations from their frontier outputs are not only due to the econometric error term associated with the applied specified model in estimation but also to their inherent inefficiency.

Secondly, it was found that percentage of professionals employed by firms, the ages of firms' plants and the number of maintenance exercises undertaken by firms were the firm-specific characteristic factors that significantly influenced their technical efficiency levels. Thus, the more a firm employs professionals and undertakes frequent maintenance exercises, the more technically efficient it would be, and vice versa, other things being equal. However, the older a firm's plant becomes, the less technically efficient it would be other things being equal. The implication is that firms that employ relatively newer plants are more likely to be more technically efficient than those that use relatively older plants.

Thirdly, it was observed that inputs used by firms had varied degrees of impacts on outputs with reference to all the three products: tablets, capsules and syrups. Capital was observed to be more productive in capsules production compared to both skilled and unskilled labour whilst skilled labour was more productive than capital in syrups production. There was over-deepening of unskilled labour employment in the production of tablets and capsules and that a reduction in the level of employment of this input will lead to a rise in outputs of these products.

Again, plant age, frequent maintenance of plant and the size of professional workforce employed tend to influence technical efficiency levels of firms in the pharmaceutical manufacturing industry. It can be concluded from the results that pharmaceutical manufacturing firms that engage in frequent maintenance exercises and employment of skilled professional labour force are likely to be more technically efficient. The findings of this study actually support the perception that the inability of Ghanaian pharmaceutical manufacturing firms to compete with the external producers on the local market could be blamed on their technical inefficiency in production.

Recommendations

With inspirations from the findings of the study, recommendations are made to the relevant institutions and managements of pharmaceutical manufacturing firms in Ghana.

It is recommended to the management of pharmaceutical manufacturing firms to invest more in their capital stocks by replacing relatively old equipment with new ones. This will have the tendency to increase contributions of their capital to output particularly in capsules and tablet production and also make it possible for their firms to operate closer to their frontiers. Again, they should employ more professionals in production processes or alternatively, give the necessary in-service training to the existing workers to improve upon their professional capacities and make them more productive on the job in syrup and tablet production. By so doing, they would be in a better position to improve upon their levels of technical efficiency, be more cost effective to improve upon their product pricing and be able to compete with their foreign counterparts on the local market. Policy makers should also play a complementary role by moderating duties put on imported machinery to make them more affordable to investors in the business. Thus, technical efficiency in the industry could be improved upon to pave the way for domestic firms to compete with their counterparts abroad.

It is also recommended to managements of firms in the industry to take regular maintenance of machinery seriously especially with relatively aged ones. When this is done effectively, firms will not only be more technically efficient but will also be more cost effective in their operations to increase their chances of making more profits. Further more, employment of skilled labour should be given a priority over unskilled labour in the production of tablets and capsules but in the case of syrups production, unskilled labour employment is a better choice to increase output levels in the respective situations.

The pharmaceutical manufacturing association of Ghana (PMAG) should encourage joint venture business among its members to pool resources together to be able to install relatively larger plants with bigger capacities rather than the use of individual smaller plants. This will put them in a better position to improve upon their capacity utilization to reduce cost.

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