Production Structure and Technical Efficiency of the Indian Pharmaceutical Industry : A Parametric Analysis

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Abstract

This paper endeavored to examine the production structure and technical efficiency in Indian pharmaceutical industry during 1974-75 to 2011-12. In view of achieving the above objective, data was culled out from the various reports of the *Annual Survey of Industries* and *Handbook of Statistics.* For analysis purpose, the stochastic frontier approach was used to estimate the production function and the time varying technical efficiency in the Indian pharmaceutical industry. The empirical analysis based on the econometric technique showed that the Cobb-Douglas production function with Hicks-neutral technical progress was not appropriate in case of the Indian pharmaceutical industry. Therefore, it was observed that the translog production function with capital using non-neutral technological progress represented the technological relationship in the Indian pharmaceutical industry. Moreover, the time-variant prediction of technical efficiency at constant returns to scale, at varying returns to scale, and scale efficiency in the Indian pharmaceutical industry during the study period revealed that the average technical efficiency at constant returns to scale for the Indian pharmaceutical industry during the entire period turned out be 0.995 and it implied that the Indian pharmaceutical industry had realized about 99.5% of its technical abilities. Thus, there were very less variations in the technical efficiency in the Indian pharmaceutical industry and showed the stable trends throughout the study period.

Keywords: **pharmaceutical industry, technical efficiency, stochastic frontier**

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The Indian pharmaceutical industry is at the front in the science based industries with the diversified capabilities and opportunities in the field of manufacturing of drugs and medicinal products. The Indian pharmaceutical industry has a comparative cost advantage over other countries. The production cost of the Indian pharmaceutical industry is lowest in the world and is estimated to be 70% less than that of USA and Europe. In 2014, the Indian pharmaceutical industry was valued at $26 billion, and its rank was 14th in terms of value and 3rd in terms of the volume, and it is growing at about 13% per annum. The growth of the pharmaceutical sector has been contributed by high quality and competitively priced exports to both the developing countries and high regulated markets of U.S. and EU (India Pharma Summit, 2013-14). The Indian pharmaceutical industry grew at an estimated compound annual growth rate (CAGR) of 13% during 2009-2014 and is also expected to grow at CAGR of 12% during 2012-2020 (National Pharmaceutical Pricing Policy, 2012 & Drugs Price Control Order, 2013). The Drugs and Pharmaceutical sector of India flourished under the process patent regime of 1970 that reigned for more than four decades. The flexible provisions of the Indian Patent Act of 1970 helped the Indian firms to imitate patented products of foreign firms, master the technique of reverse engineering and, in most

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cases, come out with even better process technology for the same products. The comparative advantage of the industry was ,therefore, an outcome of the Patent Act of 1970. It favorably influenced the Indian producers to create a niche for themselves (Kumar, 2006).

The introduction of the Patent Act, 1970 seems to act as silver lining for the Indian pharmaceutical industry. The Patent Act, 1970 has granted only process patent for pharmaceuticals (earlier The Design and Patent Act, 1911 granted both process as well as product patent) and reduced the duration of patent to 7 years (Mazumdar, 2010). Moreover, various government initiatives have been implemented for the growth of the Indian pharmaceutical industry, that is, Drugs Price Control Order, 1970 ; Foreign Exchange Regulation Act, 1973 ; New Drug Policy, 1978, etc. The scenario of the Indian pharmaceutical industry has changed in different transition periods like Indian Patent Act, 1970 and TRIPS agreement under the aegis of WTO. The Indian pharmaceutical industry is going through a transition period by a combination of external forces and internal productivity challenges. On the one hand, the TRIPS agreement of WTO has sought to strengthen the patent protection (both process and product patent) for the pharmaceutical products in countries like India and on the other hand, economic reforms of 1991 and other internal policy changes in India have sought to deregulate and de-license the Indian pharmaceutical industry through lesser price controls to compete with the international standards.

The hurdles of regulation that affected the smooth functioning of the Indian pharmaceutical firms in response to market forces have been minimized by the process of economic reforms of 1991 and reforms in the Drugs and Cosmetics Act (1994 and 2002). The various policy measures include the abolition of the industrial licensing requirements for all varieties of drugs, removing the restrictions on import of bulk drugs, allowing firms to import better quality raw-material and technology, scrapping the linkage requirement, limiting the scope of price control and the automatic approval for foreign ownership up to 100% with foreign technology arrangement, introduction of new products and processes, and facing the challenges that might arise due to recognition of Product Patent. It was also experienced that the recognition of product patent and removal of trade restrictions would allow more technological collaboration with foreign multinational enterprises (MNE) which in turn would have a positive spillover effect on the efficiency and productivity of the Indian pharmaceutical industry. Due to the TRIPs obligations, the Indian pharmaceutical industry requires to improve its efficiency and productivity for a sustained long run growth and to become cost effective to compete with the MNCs of the pharmaceutical products. It is a well acknowledged fact that the efficient production of operations and the optimal and productive use of the available resources, given the existing technology, is a pre-requisite to achieve higher productivity levels in input usage and sustained economic growth. If the firms are not making best use of the existing technology, improving their technical efficiency is usually more cost effective than introducing new technology to achieve sustainable output growth. However, if the firms are reasonably technically efficient, then an increase in productivity requires new technology to shift the production function upward (Neogi & Ghosh, 1994).

In order to estimate the underlying technology, one can examine either the cost function and associated production function, which results into the existence of certain regularity conditions for cost and production functions, which are dual to each other. Due to this unique correspondence between production and cost function, one can well see all of the information about the underlying technology is contained in both functions. However, the selection of suitable functional form is required to estimate the production function.

The selection of the functional form lies among the various types of production function like Cobb-Douglas production function, Constant Elasticity of substitution (CES) production function, and Translog production function. The Cobb-Douglas production function exhibits constant returns to scale and it assumes that the elasticity of substitution is equal to unity (=1) ; whereas, the CES production function assumes the elasticity of substitution may differ from unity and it also exhibits constant returns to scale over a period of time. The Translog production function is a flexible functional form imposing relatively few priori restrictions on the properties of the underlying technology, it allows for variable elasticity of substitution, non-neutral technological progress, and variable returns to scale (Christensen, Jorgenson, & Lau, 1973).

In the present analysis, Translog production function has been used to estimate the parameters of production technology in the Indian pharmaceutical industry.

Review of Literature

This section is to review the literature so as to formulate the problem precisely along with its rationale of undertaking. Since it is not possible to review all the literature relating to the study, but the objective is to indicate the type of work done in this direction both at the national and international level. In this context, the review of various studies done in this section provides an overview relating to the Indian pharmaceutical industry.

Researchers have applied various parametric and non-parametric approaches to estimate production structure and technical efficiency of the Indian pharmaceutical industry. The recent studies relating to the present study includes the study of Singh and Singh (2014), who analyzed the technical efficiency and total factor productivity growth of 30 major Indian pharmaceutical firms during the period from 1991 to 2011 using data envelopment analysis. The efficiency analysis revealed that throughout the study period, the average performance of the selected firms was suboptimal, and the inefficiencies were enlarged in the post-TRIPS period. Neogi (2012) measured efficiency of Indian pharmaceutical firms using unit-level ASI data for the period from 2000 - 01 to 2005 - 06 and reported that the firms, with low efficiency, were not able to survive in the business and were compelled to exit or merge with large efficient firms. Pannu (2011) analyzed the relative efficiency and productivity change in the Indian pharmaceutical companies between 1998 and 2007 and found a positive impact of R&D investments and patents on the companies' sales, market share, exports, and their abilities to attract contract manufacturing.

Thus, the present study tried to fill up the existing void in the literature and endeavored to apply the recent methodological developments in the field of evaluating the production structure and technical efficiency of Indian pharmaceutical industry.

Database

For the analysis purpose, the data has been extracted from the various reports of summary results of *Annual Survey of Industries*, a publication of Central Statistical Organization (CSO), Government of India. The present study has used the ASI data because it covers all the factories under Indian Factories Act, 1948, which refer to the factories which employ 10 or more workers and using power also and the factories which are not using power but employing 20 or more workers or more workers on any preceding 12 months have been used for the analysis. The analysis of production structure and technical efficiency in Indian pharmaceutical industry is confined to the period from 1974 - 75 to 2011 - 12 because of the availability of the required data. In the present study, two inputs (gross fixed capital at constant prices and number of employees) and one output (gross value added at constant prices) have been taken into account. All the monetary data have been deflated using appropriate price deflators with 2004 - 05 as the base year. The detailed definitions of these inputs and outputs have been given in ASI as follows :

(1) Gross Value Added : In the present study, gross value added has been used as a measure of output, because depreciation charges in the Indian industries are known to be highly arbitrary fixed by the income tax authorities and seldom represent true/actual capital consumption (Goldar, 1985). The *Annual Survey of Industries* publishes the series by using the following relation :

$$GVA = TO - TI \qquad (1)$$

where, *GVA* means gross value added, *TO* and *TI* represent total output and total input, respectively.

(2) Labour Input : The *Annual Survey of Industries* provide three distinct measures of the labour input; a) man-hours worked, b) number of workers, and c) number of employees (which include both workers and persons other than workers such as supervisors, technicians, etc.). The present study has used a number of employees consisting of both non-production and production workers as a measure of labour input. As per the definition provided by ASI, the production workers relate to all persons employed directly or through agency whether for wages or not and engaged in any manufacturing process or in cleaning any part of the machinery or premises used for manufacturing process come under the production workers. However, persons holding the positions of supervisor, or management, or employed in administrative office, store keeping section and welfare section, engaged in the purchase of raw material, etc. are included in the non-production workers.

(3) Capital Input : In the present study, we have used the gross fixed capital stock as a measure of capital input. The standard practice of perpetual inventory method has been followed here to generate the series of gross fixed capital stock at constant prices. This requires a gross investment series, an asset price deflator, a depreciation rate, and a benchmark capital stock. We followed the procedure adopted by Martin and Warr (1990) and Austria and Martin (1995) for getting an estimate of initial value of capital stock. This procedure involves the following steps:

Step 1 : The gross real investment (I_t) has been obtained by using relationship :

$$I_t = (B_t - B_{t-1} + D_t) / P_t \qquad (2)$$

where,
B_t = Book value of fixed capital in the year t ;
D_t = Value of depreciation of fixed assets in the year t ; and
P_t = Price index of machinery and machine tools in the year t.

Step 2: The logarithm of gross real investment was first regressed against a time trend to obtain its average growth rate ω and a trend value of investment at the beginning of the same, that is, I_0.

Step 3 : Making the conventional assumption that the capital stock grows at a steady state at time t_0 , the value of capital stock for initial year (K_0) has been then estimated as :

$$K_0 = \frac{I_0}{\omega + \delta} \qquad (3)$$

where,
K_0 = gross value of initial capital stock ;
ω = estimated growth rate of investment ; and
δ = annual rate of discarding of capital.

In the present analysis, we have taken annual rate of discarding of capital equal to 5%.

Step 4 : After obtaining the estimate of fixed capital for the benchmark year, the following equation has been used for the measurement of gross fixed capital series at 2004-05 prices :

$$K_t = K_{t-1} + I_t - \delta K_{t-1} \qquad (4)$$

where,
K_t = Gross fixed capital at 2004 - 05 prices by the end of year t ;
I_t = Gross real investment in fixed capital during the year t ; and
δ = Annual rate of discarding of capital.

All the above variables have been deflated at 2004 - 05 prices using appropriate price deflators. After obtaining gross value added at constant prices, gross fixed capital at constant prices, and total employees, we followed Ray (2002) and Kumar (2003) and divided these variables by the total number of factories in the Indian pharmaceutical industry. This step provides us GVA at constant prices as per factory gross fixed capital at constant prices per factory, and total persons engaged per factory in the Indian pharmaceutical industry (Kumar, 2003).

Methodology

(1) Production Structure - Concept and Measurement : A production function is a mathematical statement which describes the technological relationship between inputs and output in physical terms or it is the functional relationship which presents the transformation of physical inputs into physical output. It also presents the quantitative relationship between quantity of inputs and output. The production function is the name given to the relationship between the rates of input of productive services and the rate of output of product. It is an economist's summary of technological knowledge. More precisely, the production function states the maximum quantity of output that can be produced from any given amount of various inputs per period of time or it states that the minimum quantity of various inputs that are required to yield a given quantity of output per period of time, technology being assumed to be remain constant. It is important to note that when a change in technology occurs such as introduction of a new technology or the substitution of skilled labour for unskilled labour, then we will get a new production function. Algebraically, a production function is written as:

$$Q = f(L, K) \qquad (5)$$

where, Q stands for the quantity of output, L and K stand for quantity of labour input and capital input, respectively.

Moreover, the present study attempts to estimate different components and parameters of the technical change with the use of the production function approach. A production function captures the relationship between the outputs obtainable from a given set of inputs at a specified stage of technical change. The present study restricts itself to use the translog production function. In algebraically form, the production function can be represented as :

$$Q = f(K,L) \qquad (6)$$

where, Q is the output of the industry, K is the quantity of the capital employed, and L is the quantity of labour employed.

(2) Transcendental Logarithmic (Translog) Production Function : The production structure in the Indian pharmaceutical industry has been analyzed with the help of translog production function. The term "translog production function" is abridged from " transcendental logarithmic production function" which was proposed by Christensen, Jorgenson, and Lau in their two papers published in 1971 and 1973, which dealt with the problems of strong separability (additivity) and homogeneity of Cobb-Douglas and CES production functions and their implications for the production frontier. Therefore, the translog production function has been developed by

Christensen, Jorgenson, and Lau (1973). The translog production function is conceptually simple and imposes no a- priori restrictions on elasticities of substitution and returns to scale ; hence, it is widely used in empirical analysis. The translog production function has been used to examine input substitution, separability and aggregation, technical change and productivity growth, and productive efficiency (Greene, 1997). The translog production function specification is a flexible functional form imposing relatively few a-priori restrictions on the properties of the underlying technology. It allows for variable elasticity of substitution (VES), variable scale elasticity and non-neutral technological progress. Homotheticity, separability, and CRTS can be imposed by testable restrictions on the parameters, and the form reduces to the multiple input Cobb-Douglas specification as a special case (Kumar, 2003).

The translog production function with n inputs and general factor-augmenting technical progress takes the form:

$$LnY = \beta_0 + \beta_1 t + \beta_K LnK + \beta_L LnL + \left(\frac{1}{2}\right)\beta_{KK}(lnK)^2 + \beta_{KL}\, knK.lnL + \beta_{Kt}\, t.LnK + \ + \beta_{Lt}\, t.LnL + \beta_{tt}\,(t)^2$$

$$LnY = \beta_0 + \beta_1 t + \beta_{tt} t^2 + \sum_{k=1}^{m} \beta_k LnX_k + \frac{1}{2}\sum_{k=1}^{m}\sum_{j=1}^{m} \beta_{kj} LnX_k LnX_j + \sum_{k=1}^{m} \beta_{kt}(Ln.X_K)\, t + \mu_t - \upsilon_t \qquad (7)$$

where,

Y is index of output, 'X_k' represents the 'k^{th}' input, t is time variable allowing non-neutral technological change, and β's are the parameters of the production function. 'μ_t' is assumed to be independently and identically distributed normal, random errors, having zero means and unknown variance, and 'υ_t' is technical inefficiency. Also, it does not assume a Hicks-neutral or a constant rate of technological change and the elasticity of substitution between inputs is allowed to vary with the level of inputs (Kumar, 2003). Moreover, in the specification of Translog production function, the elasticity of output with respect to inputs and capital are not constant as in Cobb-Douglas production function and the change depends on the levels of input and time. The elasticity of output of each variable input is :

$$\frac{\delta \ln Y}{\delta \ln L} = \beta_L + \beta_{LL}.\ \ln L + \beta_{LK}.\ \mathrm{In} K + \beta_{Lt}.\ t \qquad (8)$$

$$\frac{\delta \ln Y}{\delta \ln K} = \beta_K + \beta_{KK}.\ \ln K + \beta_{LK}.\ \mathrm{In} L + \beta_{Kt}.\ t \qquad (9)$$

$$\frac{\delta \ln Y}{\delta \ln X_K} = \beta_k + \Sigma_k \beta_{kj}\, \mathrm{Log} X_j + \beta_{kt}\, t \qquad (10)$$

Since elasticity of output as well as factor shares vary with input levels in the translog production function, the elasticity of substitution is also a function of input levels and is not a constant. The expression for the rate of technical progress in a translog production function is given as :

$$\frac{\delta \ln Y}{\delta\, t} = \beta_t + \beta_{tt}.\ t + \beta_{Kt}.\ \mathrm{In} K + \beta_{Lt}.\ \mathrm{In} L \qquad (11)$$

where, β_t is the rate of autonomous technical progress *(TFPG)*, β_{tt} is the rate of change in technical progress and β_{Lt} and β_{Kt} define the bias in technical progress. If both β_{Lt} and β_{Kt} are zero, then the technical progress is the Hicks-neutral type. If β_{Kt} is positive, then the share of capital increases and there is capital using bias.

In translog production function, where atleast one $\beta_{kj} \neq 0$, where k and j refer to the inputs, there exist configuration of inputs such that neither monotonicity nor concavity is satisfied, following simply the quadratic nature of the translog production function, the concavity can be assured if constant returns to scale are imposed and their own share elasticities are non-positive. If translog production function is well behaved, it is possible to explore its characteristics with respect to homotheticity and constant return to scale. However, it is also possible to impose homotheticity and constant return to scale by testable restrictions on the parameters. The homotheticity implies that marginal rate of substitution between labour and capital is constant at constant capital-labor ratio. Therefore, the optimal factor proportions are independent of scale. In translog production function, the condition for homotheticity is given as:

$$\beta_{LL}+\beta_{LK}=0 \quad \text{and} \quad \beta_{KK}+\beta_{LK}=0$$
$$\Sigma_K \beta_{Kj}=0 \tag{12}$$

In addition to the restriction of homotheticity, the translog production function also requires the restriction of constant return to scale, which is given as :

$$\beta_K+\beta_L=1$$
$$\Sigma\beta_K=1 \tag{13}$$

The translog production function reduces to Cobb-Douglas production function if :

$$\beta_{kj}=0 \text{ for all } k \text{ and } j \tag{14}$$

(3) Technical Efficiency - Conceptual Framework and Measurement : The technical efficiency of the firm is their capacity and willingness to produce maximum output with given technology and inputs (Neogi & Ghosh, 1994). The efficiency as the ratio of observed output to the maximum potential output that can be attained from given inputs and efficiency comprises of technical efficiency, scale efficiency, and allocative efficiency (Farell, 1957). Technical efficiency is defined as relative productivity over time or space, or both. In general, a technically efficient firm would be one that produces the maximum possible output(s) from a given set of inputs or one that produces a certain level of output(s) with the minimum amount of inputs (Bhullar & Singh, 2017). Thus, technical efficiency refers to a firm's ability to transform physical inputs to output(s) relative to the best-practice frontier.

Consider the production frontier of the i^{th} firm, producing a single output with multiple inputs following the best practice techniques which can be defined as:

$$Y^*_i=f(x_{i1},x_{i2},\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots,x_{im})/A \tag{15}$$

where x_{ik}s and Y^*_i are the k th input and frontier output of the i^{th} firm, respectively, and A is the given technology that is common to all firms in the sample.

Consider the situation where the firm is not producing its maximum possible output owing to some slackness in production induced by various non-price and socioeconomic organizational factors. The production function of the firm can be written as:

$$Y^*_i=f(x_{i1},x_{i2},\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots,x_{im})\exp(u_i) \tag{16}$$

Here, u_i represents the combined efforts of various non-price and socioeconomic organizational factors which constrain the firm from obtaining its maximum possible output. In other words, u_i , which is firm-specific, reflects the firm's ability to produce at its present level, which is otherwise called the firm's technical efficiency. When the firm is fully technically efficient, then u takes the value of 0 and when the firm faces constraints, u takes a value less than 0. The value of u reflects the extent to which the firm is affected by the constraints.

A measure of technical efficiency of the firm can be defined as :

$$\exp(u_i) = Y_i / Y^*_i = \text{Actual output/ Maximum possible output} \quad (17)$$

where, the actual or realized output is observed output for a given set of inputs and the potential output is the technologically feasible maximum output for the same set of inputs under the production environment faced by firms .

The present study has basic objectives to analyze the technical efficiency of Indian pharmaceutical industry at aggregate levels. For this purpose, stochastic frontier analysis (SFA), a parametric approach has been used to analyze the technical efficiency of the Indian pharmaceutical industry at aggregate level (industry as a unit) over the period of 1974-75 to 2011-12.

(4) Stochastic Frontier Analysis (SFA) - A Parametric Technique : The parametric estimation of frontier also known as stochastic frontier analysis (SFA) was developed by Aigner, Lovell, and Schmidt (1977). SFA uses econometrics techniques to estimate a stochastic non-deterministic production frontier. The basic idea of this approach is that deviation from the frontier could be partly out of the control of the firm under analysis and thus, leaving a room for random noise. SFA explicitly allows the frontier to move up or down because of random shocks (Ray, 2002). This approach allows the decomposition of error terms into two components: (a) inefficiency term and (b) white noise error term. In order to perform this decomposition, it is necessary to assume some distribution for both components of the error term (Gandhimathy, 2013).

To estimate technical efficiency, the parametric approach specifies a particular functional form for the production function. In present study, only stochastic frontier models based on the estimate of the frontier production function has been considered. The frontier production function is an extension of the familiar regression model based on the microeconomic premise that a production function represents some sort of ideal, the maximum output attainable given a set of inputs (Greene, 1997). In practice, the frontier production function is a regression where the estimation of the production function is implemented with the recognition of the theoretical constraint that all observations lie below it, and it is generally a means to another end, the analysis of efficiency. A measure of efficiency emerges naturally after the computation of the frontier production function, since it corresponds to the distance between an observation and the empirical estimate of the theoretical ideal. The estimated models provide a means of comparing individual agents, either with the ideal production frontier or with each other, and also provide point estimates of environmental variables' effect on efficiency. SFA uses econometrics techniques to estimate a stochastic non-deterministic production frontier. The basic idea of this approach is that deviation from the frontier could be partly out of the control of the firm under analysis and thus, leaving a room for random noise.

The general stochastic frontier production function for the industry can be written as :

$$Y_t = f(X_{it}\,;\beta)\, exp\,(\mu_t - \upsilon_t) \quad (18)$$

where,

X_{it} is the input vector of the industry during period t,

Y_t represents the output of the industry during period $'t'$ ($t = 1,2,3,4,.........T$),

$f(X_{it}\,;\beta)$ is the deterministic component of the production function (Translog), where β is a vector of technology parameters, which is to be estimated and associated with the explanatory variables in the production function.

μ_ts are independent and identical distributed random errors which are assumed to be normally distributed with zero mean and $\sigma^2 u$ variance, which intends to capture the effects of statistical noise or white noise.

υ_ts are non - negative unobservable random variables associated with the technical inefficiency in the output, that is, the actual output of the industry falls short of the potential output of the industry with the given level of technology. Therefore, υ_t is known as the technical inefficiency effect.

Technical efficiency is defined by the ratio of the actual output *(Y_t)* to the corresponding frontier output or potential output defined by the zero inefficiency effect (Y_t*). Given the specification of stochastic frontier production function model (18), technical efficiency of the industry for t^{th} period is given as :

$$TE_t = \frac{Y_t}{Y^*_t} = \frac{f(X_{it}\,;\,\beta)e^{(\mu_t-\upsilon_t)}}{f(X_{it}\,;\,\beta)e^{(\mu_t)}} = e^{-\upsilon_t} \qquad (19)$$

where $TE_t \in (0, 1]$, and unity values indicate fully efficient producers.

where, Y_t is the actual or observed output of the industry during *'t'* time period corresponding to the stochastic frontier production function and Y^*_t is the maximum potential output level that can be obtained from the X_{it} set of inputs by following the best practice technological levels. It can be concluded from the above equation (19) that :
(a) if υ_t remains constant over a period of time, then technical efficiency remains constant.
(b) if υ_t increases, decreases, or remains constant, which means that then technical efficiency may deteriorate, improve, or remain constant over a period of time, respectively.

In the present study, the random effect model has been considered in which a stochastic frontier production function allows the error component υ_t representing technical inefficiency to be time-varying. The approaches to measure technical efficiency through econometric based parametric techniques are classified under two broad categories : (a) the one - error structure approach; and (b) the two - error structure approach. The one - error structure approach assumes that there are no random errors and that all of the noise in the error structure is technical inefficiency arising from firm-specific factors. However, the two-error structure on the other hand allows for both technical inefficiency as well as random errors (due to weather, strike, luck, and measurement errors). There are various models available for estimation under these structures, but the discussion here is selective and based only on core models used specifically for measuring technical efficiency and the changes and improvements in the measure of technical efficiency are traced using the models that have evolved over time.

(5) The Two Error Structure Approach : The two-error structure was developed to take explicit account of statistical errors as efficiency scores may be contaminated by noise or measurement error. This relaxes the strong assumption of the single error structure that all observations in the data set are accurate. The stochastic frontier with the two - error structure is given by :

$$\text{In}Y_i = \beta_0 + \Sigma^{m}_{k=1}\beta_i \ln X_{ki} + \mu_i + \upsilon_i \qquad (20)$$

where, μ_i is the difference between the individual firm's practice and the best practice technique ; and υ_i represents statistical errors and other random factors. The two - error structure allows us to find out whether the deviation of firm's actual output from its potential output (that is, technical inefficiency) is mainly because the firm did not use the best practice technique or because of external random factors.

(i) Fixed Effects Model : Technical efficiency can be estimated by using the various types of models. Here, we consider the stochastic frontier model to estimate the technical efficiency of *m* firms over *T* time period, which is given as follows :

$$Y_{it} = \beta_0 + \beta X_{it} + \mu_{it} + \upsilon_{it} \qquad (21)$$

where, $t = 1,2,3..........T$ and $i = 1,2,3....m$

The above model can be estimated by assuming that the technical efficiency effects are time-invariant or time-variant. For time-invariant models, only the intercept is allowed to vary over firms, while the level of efficiency is assumed not to change over time. There are two ways for the fixed-effects model estimation. One way is to suppress the constant term and add a dummy variable for each of the *m* firms or, equivalently, by keeping the constant term and adding (*m* -1) dummies. But as *m* becomes large, this estimation becomes highly parameterized leading to a large loss of degrees of freedom and the estimation is often not feasible as too many dummies bring upon the problem of multicollinearity. Thus, the popular way is to express all data in terms of deviations from the firms' means. This is done by rewriting equation (21) as :

$$Y_{it} = \beta_0 + \beta X_{it} + \mu_{it} \qquad (22)$$

where, $\beta_{0i} = \beta_0 - v_{it}$ and *m* intercepts are recovered as the means of the residuals by firms. Here, the parameters are estimated conditionally on fixed values of the v_{it} and hence, the within estimators of β can be obtained by the OLS estimation of :

$$\mathrm{Y}_{\mathrm{it}} - \overline{Y}_1 = \beta^{'} (X_{it} - \overline{X}_1 + \mu_{it}) \qquad (23)$$

where, $\overline{Y}_1$ and $\overline{X}_1$ are the means of the *Y* and *X* over *T* time period.

(ii) Random Effects Model : The random effect models can also be used to estimate time-variant models. Unlike the fixed effects model, this model allows for firm-specific attributes and thus includes time-invariant regressors, but in doing so, it has to rely on the assumption that the inefficiency effects and input levels are independent. This assumption stems that firms often maximize expected profit and this implies that input quantities are exogenous. The random effects model is often said to be preferred (resulting from gains in efficiency) to the fixed effects model since it utilizes the between estimator in addition to the 'within' estimator of the fixed effects model. It has been argued that the decision on the nature of the effects, whether it is random or fixed, is both arbitrary and unnecessary. It is said that it is up to the user to decide whether he/she wants inference with respect to the population of all effects (random effects) or only with respect to the effects that are in the sample (fixed effects). Statistically speaking, the choice between the fixed effects and random effects model can be made by testing if the regressors, X_{it} are correlated with the technical efficiency effects using the procedure of Hausman and Taylor (1981). If the null hypothesis of correlation could not be rejected, then the instrumental variable estimation can be used to estimate the random effects model with the assumption that all or some of the X_{it} are correlated with v_{it}. If indeed, there is no correlation between X_{it} and v_{it}, then the random effects model can be estimated using either maximum likelihood estimation (MLE) or generalized least squares (GLS) method.

(6) Time Varying Technical Efficiency : As the sample size becomes larger, the assumption that technical inefficiency effects are time-invariant is more difficult to justify since one would expect firms to learn from their previous experience in the production process, so that their technical inefficiency would change over time. Thus, in the last decade or so, along with the most common assumption that v_{it} follows a half normal or general truncated-normal distribution, many empirical studies have relied on MLE using panel data estimation by adopting various time-varying specifications for the technical inefficiency effects. For instance, Kumbhakar (1990) modeled technical efficiency effects as a product of an exponential function of time involving two parameters, γ and δ, as well as a time-invariant non-negative random variable v_{it} :

$$Y_{it} = \beta_0 + \Sigma^{m}_{k=1} \beta_t X_{ikt} - v_{\mathrm{it}} + \mu_{it} \qquad (24)$$

where, $v_{it} = g(t) v_i$: and $g(t) = [1 + \exp(\gamma + \delta t^2)]^{-1}$

Although this allows the level of technical inefficiency to be non-constant, its temporal pattern is the same for all firms since it is determined by the form *g(t)*. This model which uses MLE is yet to be supported by any empirical application. However, there are many empirical applications or at least variations of it based on Battese and Coelli's (1992) model:

$$Y_{it} = \beta_0 + \Sigma^{m}_{k=1}\beta_i X_{ikt} - v_{it} + \mu_{it} \ldots \quad (25)$$

where, $v_{it} = [\exp\{-\eta(t-T)\}]\, v_i$: and η is an unknown scalar to be estimated. Here, the technical inefficiency effect for the *i*th firm in the last period is v_i and for all earlier periods in the panel, technical inefficiency effects are the product of the technical inefficiency effect for the i^{th} firm in the last period and the value of the exponential function $[\exp\{-\eta(t-T)\}]$, whose value depends on η and the number of periods before the last period of the panel, (T-t). Similar to Kumbhakar's (1990) model, the disadvantage in this model is its rigid parameterization. In particular, the technical efficiency must either increase or decrease at a decreasing rate ($\eta > 0$) or an increasing rate ($\eta < 0$) or simply remain constant ($\eta = 0$) . Thus, the model does not account for situations in which some firms may be relatively inefficient initially but become relatively more efficient in subsequent periods.

Analysis and Results

In the present study, we have considered the time series data for the Indian pharmaceutical industry for the period of 1974 -75 to 2011-12. The translog production function has been assumed to represent the frontier technology of the Indian pharmaceutical industry, because the translog production function imposes very few restrictions and it is more flexible as compared to the other forms of production function. The stochastic translog (transcendental logarithmic) production function is defined as :

$$LnY = \beta_0 + \beta_1 t + \beta_{tt} t^2 + \sum_{k=1}^{m} \beta_k LnX_k + \frac{1}{2}\sum_{k=1}^{m}\sum_{j=1}^{m} \beta_{kj}\, LnX_k LnX_j + \sum_{k=1}^{m} \beta_{kt}\,(Ln.X_K)\, t + \mu_t - \upsilon_t \qquad (26)$$

where, *Ln* denotes the natural logarithm, *t* represents the t^{th} year of observation, *Y* represents the gross value added at constant prices at 2004-05 as the base year. X_1 represents the logarithm of number of workers, X_2 represents the logarithm of the gross fixed capital stock at 2004 - 05 prices, X_3 is the time variable. In the above stochastic translog frontier production function, the frontier has been allowed to shift over a period of time with the introduction of time variable in the functional form, which is interpreted as non-neutral technical progress. However, according to Hicksian sense, the technical change will be neutral where the coefficient of the interactions between the input variables and year of observation are zero, that is, $\beta_{kt} = 0$. It means there could not be any technical change in the Indian pharmaceutical industry if the coefficient of all the variables involving years of observations are zero, that is, $\beta_{kt} = \beta_t = 0$. Further, the Cobb-Douglas production function with Hicks-neutral technical change is a case of translog frontier production function if the coefficients of the second order terms are zero, that is, $\beta_{kj} = 0$. μ_t is "noise" error term - symmetric i.i.d (eg. normal distribution $\mu_t = (0, \sigma^2\mu)$ and v_t = "inefficiency error term" - non-negative (eg. half-normal distribution).

The maximum - likelihood estimates of the parameters of model (26) have been obtained by using (STATA Version 11.2). Moreover, it also provides the prediction of technical efficiency of the Indian pharmaceutical industry during 1974 -75 to 2011-12.

The first step in the SFA is to find an appropriate functional form that represents the data. Given the specifications of the translog model, various sub-models of the translog are considered and tested under a number of null hypotheses. The Table 1 presents the results relating to the verification of the consistency of specific hypothesis related to the production function frontier adopted in the empirical model by applying statistical tests. The first null hypothesis relates to the adequacy test of the less restrictive functional form expressed by the translog function relative to the Cobb - Douglas model, which has been hypothesized that all the second order

Table 1. Log Likelihood Tests (Restrictions) for Stochastic Production Frontier Parameters

Test	Null Hypothesis	Value of Chi Square	Prob > Chi Square	Decision (At 5% level)
1	H_0 :	19.03	.000*	**H_0 Rejected**
1)	*[ly]lllk*($\beta_1 = \beta_2$)= 0			
2)	*[ly]ll*sq(β_{11}) = 0			
3)	*[ly]lk*sq(β_{22}) = 0			
4)	$\beta_{kk} = 0$			
2	H_0: *[ly]t* (β_3) = 0	4.78	.028**	**H_0 Rejected**
3	H_0:(1) *[ly]t*(β_3) = 0			
	(2) [ly]*tsq* (β_{33}) = 0	10.81	.028**	**H_0 Rejected**
	(3) [ly]*tll* (β_{13}) = 0			
	(4) [ly]*tlk* (β_{23}) = 0			

Note: * and ** indicates the level of significance at 1% and 5%, respectively.

coefficients of the model and the cross products are equal to zero. The value of the log likelihood probability value is 19.03, which is more than the tabulated value of the (chi-square) with 5% level of significance. Therefore, the first chi-square test that represents the null of Cobb-Douglas production function is rejected and thus the production function is translog production function. The second chi-square represents the null of no technical progress over time, which has also been rejected, and the third chi-square which represents the Hicks-neutral type technical progress has also been rejected. Therefore, given the specification of stochastic translog production function with technical inefficiency effect, it has be observed that the stochastic Cobb-Douglas production function with no technological change and with Hicks-neutral technological progress is not an appropriate representation of the production frontier of the Indian pharmaceutical industry.

Assuming the transcendent logarithmic translog production function, the estimated parameters of the production frontier and estimates of the technical efficiency are presented in Tables 2 and 3, respectively. The Table 2 shows the empirical results pertaining to the estimates of the elasticities of mean output with respect to labor, capital, and rate of technical progress to the tune of 17.09, 19.38, and -0.49, respectively. Therefore, the estimated results of a translog stochastic production frontier show that the coefficients of labor and capital have expected positive signs. The positive and highly significant coefficients confirm the expected positive and significant output effects of labor and capital. The empirical findings suggests that a 1% increase in the labour input or employment leads to 17.09 % increase in output of the Indian pharmaceutical industry and 1% increase in the capital inputs leads to 19.38% increase in the output of the Indian pharmaceutical industry.

Moreover, the elasticity estimates of labour and capital are statistically significant at the 1% level of significance. In contrast, the squared variable of labour $[(ln\, L)^2]$ has negative value and it is statistically significant at the 5% level, which depicts a diminishing return to labour input prevails. The same is also true for the squared capital. Its estimated coefficient, while negative, turns out to be statistically significant at the 1% level, where it also indicates the diminishing returns to capital input. Furthermore, the estimated coefficient of the interacting variable between labor and capital ($lnL * lnK$) is negative and significant at the 10% level, suggesting a little substitution effect between labor and capital. Moreover, for time variables, coefficients of time *(T)* is negative and statistically significant at the 5% level ; whereas, its squares are negative and statistically insignificant. A non- neutral technological progress toward capital is indicated by a positive and statistically significant (at 10% level) coefficient of the interacting variable between time and capital ($T * ln\, K$). Moreover, the empirical analysis suggests that the return to scale seems to be a constant return to scale.

It has been aptly remarked that a industry is said to be technically efficient, if the estimated technical efficiency

Table 2. Maximum Likelihood Estimation for Parameters of the Translog Production Function

Variables	Parameters	Coefficients	Standard Error	*Z*-Values	*P*-Values
Constant	β_0	-89.18605	25.70461	-3.47	0.001*
Labour	β_1	17.09153	5.516745	3.10	0.002*
Capital	β_2	19.38344	5.504622	3.52	0.000*
Time	β_3	-0.493413	0.225713	-2.19	0.029**
$(\text{Labour})^2$	β_{11}	-1.957729	0.770692	-2.54	0.011**
$(\text{Capital})^2$	β_{22}	-2.096249	0.546066	-3.84	0.000*
$(\text{Time})^2$	β_{33}	-.0007227	0.001475	-0.49	0.624
Labour × Capital	β_{12}	-1.512255	0.910262	-1.66	0.097***
Labour × Time	β_{13}	0.0327601	0.057120	0.57	0.566
Capital × Time	β_{23}	0.0590215	0.031356	1.88	0.060***
Log Likelihood Function		48.981305			0.000*
	σ^2	.0047544	0.001492		
	Λ	.0404023			
	M	.0027835	0.2911156		
	N	.0688956	0.008891		

Note: *, ** , and *** indicates the level of significance at 1%, 5%, and 10%, respectively.

coefficient is 100%(1.000) and technically inefficient otherwise. The Table 3 gives the time-variant prediction of technical efficiency at constant returns to scale, technical efficiency at varying returns to scale, and scale efficiency in the Indian pharmaceutical industry during 1974-75 to 2011-12. The empirical results show that the average technical efficiency at constant returns to scale for the Indian pharmaceutical industry during the entire period is 0.995 and it implies that the Indian pharmaceutical industry has realized about 99.5% of its technical abilities. Moreover, there are very less variations in the technical efficiency in the Indian pharmaceutical industry, which shows stable trends throughout the study period. The issue of efficiency is very weak and the efficiency does not cause any variation in the growth performance of the Indian pharmaceutical industry. Therefore, the variation in the growth of the Indian pharmaceutical industry depends upon some other factors, that is, total factor productivity growth and capacity utilization in the Indian pharmaceutical industry.

It is significant to note that the measurement of technical efficiency *(TE)*, capacity utilization *(CU)*, and total factor productivity *(TFP)* growth has captivated the Indian researchers and policy planners to test the sustainability of growth of the Indian pharmaceutical industry. The measure of TFP growth captures the technological improvements as well as the impact of better utilization of capacities, learning by-doing, and improved skills of labour. More specifically, TFP growth is a composite measure of technological change and changes in the technical efficiency with which known technology is applied to production processes (Ahluwalia, 1991). The productivity changes are the result of change in technical efficiency and technological change. Technological changes refer to the creation and advancement of knowledge, which leads to shifts in the frontier production function ; whereas, the technical efficiency change represents the movement towards the frontier as all producers are not using the best practices and the use of fewer inputs to produce the same output results in greater technical efficiency, Thus, *TFP* growth is regarded as the consequence of two different factors. The introduction of technical innovations in processes and products, shifting the production frontier upward can be measured by the technical change ; whereas, the technical efficiency change reflects the capacity of the firms to improve production with given inputs and available technology. But in the present study, the technical efficiency is 99.5% and there is very little scope for any shift in production frontier with the improvement in efficiency,

Table 3. Time - Varying Prediction of Technical Efficiency of Indian Pharmaceutical Industry

Year	Efficiency *(VRS)*	Efficiency *(CRS)*	Scale Efficiency
1973-74	0.9977	0.9955	0.9977
1974-75	0.9977	0.9954	0.9977
1975-76	0.9978	0.9958	0.9980
1976-77	0.9978	0.9959	0.9981
1977-78	0.9978	0.9959	0.9980
1978-79	0.9978	0.9959	0.9980
1979-80	0.9977	0.9957	0.9980
1980-81	0.9977	0.9956	0.9979
1981-82	0.9977	0.9956	0.9978
1982-83	0.9977	0.9957	0.9979
1983-84	0.9978	0.9959	0.9980
1984-85	0.9977	0.9956	0.9979
1985-86	0.9977	0.9957	0.9979
1986-87	0.9977	0.9956	0.9979
1987-88	0.9977	0.9957	0.9979
1988-89	0.9977	0.9957	0.9979
1989-90	0.9978	0.9957	0.9979
1990-91	0.9977	0.9956	0.9978
1991-92	0.9977	0.9957	0.9979
1992-93	0.9977	0.9957	0.9979
1993-94	0.9978	0.9958	0.9979
1994-95	0.9977	0.9956	0.9978
1995-96	0.9977	0.9955	0.9978
1996-97	0.9977	0.9955	0.9978
1997-98	0.9978	0.9958	0.9980
1998-99	0.9978	0.9958	0.9980
1999-00	0.9978	0.9958	0.9980
2000-01	0.9977	0.9955	0.9978
2001-02	0.9977	0.9957	0.9979
2002-03	0.9978	0.9957	0.9979
2003-04	0.9977	0.9957	0.9979
2004-05	0.9977	0.9957	0.9980
2005-06	0.9977	0.9957	0.9979
2006-07	0.9977	0.9957	0.9979
2007-08	0.9977	0.9957	0.9979
2008-09	0.9978	0.9958	0.9980
2009-10	0.9978	0.9956	0.9978
2010-11	0.9977	0.9956	0.9979
2011-12	0.9978	0.9958	0.9980
Average	**0.9977**	**0.9957**	**0.9979**

therefore, technological advancement or technological innovation leads to shift the production frontier of the Indian pharmaceutical industry upward. However, the efficiency and productivity comparisons are always redundant or spurious if the capital is not adjusted as per the CU levels. The measure of CU is required to estimate the production frontiers using the capital in operation but not capital in place. Therefore, the variations in the output growth of Indian pharmaceuticals are associated with the capacity utilization and total factor productivity.

Conclusion and Policy Implications

In the present study, an attempt has been made to analyze the inter-temporal variations in technical efficiency of the Indian pharmaceutical industry during 1974 -75 to 2011-12. For analysis purpose, the stochastic frontier approach has been used to estimate the production function and the time varying technical efficiency in the Indian pharmaceutical industry. The maximum likelihood technique has been used to estimate the different variants of the stochastic frontier production function. The empirical analysis based on the econometric technique shows that the Cobb-Douglas production function with Hicks-neutral technical progress is not appropriate in case of the Indian pharmaceutical industry. Therefore, it has been observed that the translog production function with capital using non-neutral technological progress represents the technological relationship in the Indian pharmaceutical industry.

Moreover, the time-variant prediction of technical efficiency at constant returns to scale, at varying returns to scale, and scale efficiency in the Indian pharmaceutical industry during 1974-75 to 2011-12 reveals that the average technical efficiency at constant returns to scale for the Indian pharmaceutical industry during the entire study period has turned out be 0.995, and it implies that the Indian pharmaceutical industry has realized about 99.5% of its technical abilities.

Moreover, there are very less variations in the technical efficiency in the Indian pharmaceutical industry and shows stable trends throughout the study period. Therefore, the result shows that the efficiency does not cause any variation in the growth performance of Indian pharmaceutical industry, which implies that the growth of this industry depends upon other factors like total factor productivity growth and capacity utilization during the globalized regime. In the present study, the technical efficiency is 99.5% and there is very little scope for any shift in production frontier with the improvement in efficiency, therefore, technological advancement or technological innovation leads to a shift in the production frontier of the Indian pharmaceutical industry upward. There is no need to increase the size of the scale of production, as the returns-to-scale for the Indian pharmaceutical industry are not found to be significantly different from constant returns-to-scale. In order to shift the production frontier upward, a significant amount of investment in human resource development and radical upgradation of research and development capabilities are essentially required in the post-reforms and post-TRIPS period for technological advancement. Moreover, the Government must initiate the measures to promote public investment in research and development activities for the sustainability of the Indian pharmaceutical industry to make India the largest global provider of quality medicines at reasonable prices under the 'Make in India' campaign.

Limitations of the Study and Scope for Future Research

The main limitation of the study is that the technical efficiency can be measured approximately and not exactly which should be kept in mind before policy formulation. The stochastic frontier analysis also has some limitations as it requires an explicit imposition of a particular parametric functional form representing the underlying technology and also an explicit distributional assumption for the inefficiency terms. The determinants of the technical efficiency are not discussed in the study, which is also very important to know the factors influencing the variations in technical efficiency of a industry. Moreover, the present study is confined only to the aggregate level analysis, therefore, it can be extended at the disaggregate level. Further, an analysis both at State level and at firm level for the Indian pharmaceutical industry can be done and incorporated in future studies.

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