PRODUCTIVE EFFICIENCY IN BAHRAIN ECONOMY*

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Abstract

The main objective of this study is to measure and analyze one of the most important components of total productivity, namely productive (economic) efficiency in Bahrain economy over the time period 1980-2002. In order to obtain the cost inefficiency, a stochastic frontier cost function with time-varying cost inefficiency was used. The null hypothesis specifies whether the stochastic frontier specification is an appropriate representation of the underlying technology compared to the average technology being tested. This null hypothesis could not be rejected at any significance level. Thus, it could be concluded that there is no strong foundation for estimating cost inefficiency in Bahrain economy, given the model specifications and testing. It follows that the empirical findings, given the empirical model, showed no evidence of cost inefficiency at the aggregate level. Accordingly, further research at the disaggregated economic levels (i.e., the five digits industrial standard classification, ISC) is strongly recommended in order to obtain clearer explanations and step on the inside economic activities in terms of cost inefficiency.

ملخص

إن الهدف الأساسي من هذه الدراسة هو قياس وتحليل أحد أهم مكونات الإنتاجية الإجمالية، وهي الكفاءة الإنتاجية (الإقتصادية) في اقتصاد دولة البحرين في الفترة من 1980 – 2002. ولقياس عدم كفاءة التكلفة، فقد تم استخدام دالة تكلفة عشوائية ورائدة متضمنة لعدم كفاية التكلفة باختلاف الزمن. إن الفرضية الجدلية توضح فيما غذا كانت المواصفات العشوائية الرائدة هي الممثل المناسب للتكنولوجيا الضمنية بالمقارنة بالتكنولوجيا المتوسطة والتي تم إختبارها. إن هذه الفرضية الجدلية لا تقبل الرفض عند أي مستوى ذو دلالة. لذا يمكن أن نصل إلى أنه ليس هناك أساس قوي لتقدير عدم كفاءة التكلفة في اقتصاد البحرين، وفقاً لمواصفات النموذج والاختبارات. ويتبع ذلك ان النتائج التطبيقية وفقاً للنموذج التطبيقي تظهر عدم وجود شواهد على عدم كفاءة التكلفة على المستوى الكلي. وعليه، فإنه يوصى وبشدة بعمل أبحاث أخرى على المستويات الاقتصادية غير الكلية (مثلاً التصنيف القياسي الصناعي ذو الخمسة أرقام ISC) وذلك للحصول على تفسير واضح ومفهوم داخلي للأنشطة الاقتصادية فيما يتعلق بعدم كفاءة التكلفة.

1. Introduction

Currently, one of the most compelling tasks facing Bahrain's economy is to expand and diversify its economy. With the process of development and the importance of structural transformation, it is very important to understand the fundamental concepts of economic performance measurement and analysis, which could help in the identification of the most proper economic (industry-oriented) policy.

Most agreements of the World Trade Organization (WTO) have emphasized global openness and competition. Only nations with high level economic performance, however, would survive in the face of the harsh international competition. Thus, it is about the right-time for Bahrain policy makers to pay more attention to economic performance (productivity and efficiency) issues.

It follows that it is crucial at this stage to unfold the main components of total productivity that can be used as powerful analytical tools in understanding the economic performance of Bahrain economy. Thus, the main objective of this study is to measure and analyze one of the most important components of total productivity, namely productive (economic) efficiency in Bahrain economy over the time period 1980-2002. Identifying and estimating the level of productive efficiency is essential in the evaluation of alternative policies for Bahrain economy.

This study is organized in the following way: Section 2 presents a review of the underlying theory of measuring productive efficiency. Section 3 presents the importance of efficiency as a major contributing factor to the overall productivity growth. Section 4 discusses the empirical model, the stochastic cost frontier, and methodology to be applied in this study. In Section 5, the data used in this empirical investigation is defined. The empirical findings are presented and analyzed in Section 6. The concluding remarks that could be drawn from the empirical findings are presented in Section 7.

2. Productive Efficiency: Theory Underlying

It is necessary to review the basic theoretical concepts of productive efficiency before any rigorous presentation of its economic modelling takes place. The following presents the theoretical foundation of productive efficiency, using the dual cost frontier which provides a simple framework for analysing productive (cost) efficiency and its two components; technical and allocative efficiencies. Technical efficiency refers to the ability to produce the technically-maximum output for a given set of inputs. On the other hand, allocative (price) inefficiency refers to the extent to which the technically-efficient mix of inputs fails to minimize the cost of production. That is, if a firm is technically efficient (operating on the production or cost frontier) productive efficiency becomes a question of whether the scarce resources are allocated efficiently given their competitive market prices.

Till the early 1950s, the literature generally focused on allocative efficiency. Technical efficiency in contrast did not receive much attention. One of the reasons for this could be the lagged theoretical development of measurement approaches to technical efficiency. In addition, economists may have not considered technical efficiency as a useful tool for economic analysis[1]. However, as work on the measurement and modelling of technical (in)efficiency has developed and grown, different schools of thought have emerged on the topic[2]. The early theoretical presentation of technical efficiency was given by Farrell (1957). Leibenstein (1966) argued that firms or plants can increase their output without any change in the level of inputs, or employing more advanced technology, but simply by reducing their

1 See Leibenstein (1973).

2 For theoretical discussion and criticisms, see De Alessi (1983), Leibenstein (1973), and Stigler (1976).

technical inefficiency. He also introduced the term X-(in)efficiency as synonymous with technical (in)efficiency. Kopp (1981) represents the concept of technical efficiency with some new theoretical considerations.

In this section, the theoretical concept of productive (cost) efficiency is presented using a relatively simple framework, Kopp and Diewert (1982). The presentation aims at showing how productive efficiency could be an important component of the overall economic performance (productivity) analysis. The standard theoretical foundation of productive (cost) efficiency can be explored in Figure 1. The analysis is carried out assuming constant returns to scale technology[3]. The isoquant that describes the production technology as minimum inputs required for a given level of output (Q) is represented by the ISOQ curve. The slope of the line $C_K C_L$ represents the ratio of relative input prices, labour(L) and capital (K).

In Figure 1, point E shows the minimum cost of inputs that are required to produce the given level of output. However, assuming that the firm's observed input combination is represented by point A, then level of cost (economic) inefficiency can be measured as a ratio of CA/OC. Farrell (1957) divides this cost inefficiency into two components. First, technical inefficiency which can be measured as the ratio BA/OC. Secondly, allocative inefficiency which indicates the excess cost of producing a given level of output using a technically-efficient combination of production inputs over the minimum possible cost[4]. Since the cost of producing at point C is the same as that of producing at point E, it follows that allocative efficiency can be measured by the ratio CB/OC. Thus, the two components of cost inefficiency can be obtained if the two input vectors at points B and C are able to be deduced from the observed costs. Kopp and Diewert (1982) suggest an empirical approach that decomposes cost efficiency into its two components.

3. Productivity Growth and Productive Efficiency

In what follows, the discussion begins with a graphical presentation of the economic theory that highlights the concepts underlying the interrelationship between productivity and efficiency.

Most of productivity and production studies assume implicitly, and sometimes explicitly, that the production process is efficient. This implies that it achieves its economic objectives. In a productivity sense, this assumption implies that producers always operate at the production (cost) frontier and any change in productivity is the result of a shift in the frontier. However, the inefficient producers are operating below (above) the production (cost) frontier. In this case, the change in productivity should not be referred to as a shift in the frontier, but should be considered as a movement towards the frontier. Thus, to avoid any misinterpretation of productivity estimates, the impact of inefficiency needs to be identified in the productivity measurement model.

To make the above argument clearer a graphical presentation of the cost frontier follows. This presentation is conducted based on a simple production/cost structure: that assumes constant returns to scale and full capacity utilisation[5], Grosskopf (1993). Figure 2 shows the long-run and short-run average cost curves of a technically efficient producer[6]. There are two

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3 If the assumption of constant returns to scale is dropped, then, the concept of scale inefficiency can be presented. Scale inefficiency occurs when firms produce at either too large or too small scales such that they do not minimise the cost of producing a given level of output. Thus, point such as E in Figure 1, may represent an inefficient combination of inputs, simply because a lower average cost will occur at a different scale of production.

4 In this case, too high capital level and too low labour inputs. Note that B, is a technically efficient combination of inputs, but it does not represent the lowest cost.

5 No fixed or quasi-fixed inputs exist.

6 Cost inefficiency may be decomposed into allocative and technical inefficiencies.

time periods t and t+1 with two observed average cost levels (Q^*, C_t) and (Q^*, C_{t+1}) respectively. Both these cost levels are not located at the cost frontier itself. Figure 2 also shows the difference between the observed and the minimum possible cost (cost-efficient) in two time periods t and t+1.

Productivity growth (technological change[7]) can be measured for an efficient producer by the reduction in cost of producing a given level of output. That is $\partial C(.)/\partial t<0$ when there is a productivity improvement. Thus, the cost-based productivity growth measure (which is equivalent to the shift in the production frontier) can be expressed as:

$$\frac{\partial C(\cdot)/\partial t}{C(\cdot)}=\frac{dC(\cdot)/dt}{C(\cdot)}-\frac{dQ/dt}{Q}-\sum_i\frac{P_iX_i}{C}\frac{dP_i/dt}{P_i}, \qquad (1)$$

where X_i and P_i are the quantity and the price of the i^{th} input, respectively.

Now, suppose that the producer is not cost efficient. It implies that s/he produces a given level of output with higher cost than the potential minimum average cost. That is, the cost of production will be located above the cost frontier in the two time periods t and t+1. The non-frontier productivity measurement model, which ignores efficiency as a component of productivity, would consider the observed cost as equivalent to the minimum cost, at the frontier. Thus, a non-frontier measure of productivity would consider the reduction in cost from C_t to C_{t+1} as a measure of technological change. However, the actual measure of technological change is the reduction in C^*_t to C^*_{t+1}. It follows that the difference between the two measures will be due to the existence of the cost inefficiency, $(C_{t+1}-C_t)\neq(C^*_{t+1}-C^*_t)$. Therefore, to obtain the “true” estimate of technological change, it is necessary to correct the observed cost levels to bring them down to the cost frontier in both periods. Once the observed cost levels have been corrected for the existence of cost inefficiency, true estimates of productivity growth and its major decompositions can be obtained.

The corrected measures of the observed cost levels may be obtained by defining the minimum cost level as:

$$C^*_t = D_t(C_t, Q^*) \cdot C_t, \text{ and}$$
$$C^*_{t+1} = D_{t+1}(C_{t+1}, Q^*) \cdot C_{t+1} \qquad (2)$$

Where $D_t(C_t, Q^*)$ and $D_{t+1}(C_{t+1}, Q^*)$ are distance functions in time t and t+1 respectively[8].

Thus, observed cost saving over the two periods t and t+1, $(C_{t+1}-C_t)$ can be seen as a result of cost-saving due technological change, $(C^*_{t+1}- C^*_t)$, as well as change in cost inefficiency which may be measured as $(D_{t+1}-D_t)$. It follows that frontier based measure of productivity growth can be calculated as:

$$\frac{C_{t+1}-C_t}{C_t}=\frac{(C^*_{t+1}/D_{t+1}(C_{t+1},Q^*))-(C^*_t/D_t(C_t,Q^*))}{C^*_t/D_t(C_t,Q^*)} \qquad (3)$$

Equation 3 shows that frontier-based productivity growth is decomposed into two main parts; technological change and the change in cost inefficiency (both technical and allocative inefficiencies).

7 Since constant returns to scale, no inefficient, and full capacity utilization are assumed, then technological change and productivity growth are synonymous.

8 See Fare and Grosskopf (1990).

To conclude this simple presentation, a measure of productivity growth based on a non-frontier model could not be interpreted as a gain due to downward (upward) shift in cost (production) frontiers unless it is assumed that there is no change in cost (technical and/or allocative) efficiency over time. This type of decomposition of productivity growth has quite important policy implications, Shebeb (2002 and 2003).

4. Productive Efficiency Model: A Stochastic Cost Frontier Approach

The parametric frontier approach to measuring productive efficiency may be traced back to Aigner et al. (1977). This approach can be divided into two categories based on the assumptions underlying the components of the error term; (1) the deterministic approach; and (2) stochastic approach. The deterministic approach assumes no statistical noise component is contained in the error term. It implies that inefficiency can be represented by the error term itself and no further decomposition is needed. On the other hand, the error term in the stochastic approach is assumed to be composed of two parts; the statistical noise and the inefficiency term.

Following Aigner et al. (1977), the basic composite-error term ($\varepsilon_t = \nu_t + \mu_t$) cost frontier function can be presented[9] as:

$$\ln C_t = \ln C(Q, P) + \nu_t + \mu_t \qquad (4)$$

Where

ν_t : is the symmetric component of the error term reflecting statistical noise and assumed to be distributed as $N(0, \sigma_\nu^2)$.

μ_t : is a one-sided disturbance term, $\mu_t>0$, capturing the cost inefficiency and assumed, generally, to be distributed half-normal, $N(0, \sigma_\mu^2)$.

According to the above model specification, producers are said to be cost efficient if $\mu_t=0$, and cost inefficient if $\mu_t>0$. The decomposition of ε_t (ν_t and μ_t) can be obtained by using the technique of Jondrow et al. (1982) with the estimate of the likelihood function of the model (equation 4). It follows that the conditional mean of μ_t given ε_t can be obtained as follows:

$$E(\mu_t|\varepsilon_t) = \frac{\sigma_\mu^2 \sigma_\nu^2}{\sigma^2}\left[\frac{\phi(\varepsilon\lambda/\sigma)}{1-\Phi(\varepsilon\lambda/\sigma)} - \frac{\varepsilon\lambda}{\sigma}\right] \qquad (5)$$

Where

$\phi(.)$ is the standard normal density function,

$\Phi(.)$ is the standard normal distribution function, and $\lambda=\sigma_\mu/\sigma_\nu$.

The non-statistical noise (inefficiency) term in this model consists of the two types of inefficiency, technical and allocative inefficiencies. However, if an assumption of non-existence of allocative inefficiency is made, then the cost inefficiency term would represent technical inefficiency only. Several modifications and extensions have been made to this model to have further decompositions of the error term. This has been carried out by introducing a cost-frontier system which allows the error term to be decomposed into three components; statistical noise, technical inefficiency, and allocative inefficiency.

9 A specific form of the cost function frontier will be employed for econometric estimations of cost efficiency in Bahrain economy as discussed in the empirical investigation below.

Following Greene (1980b), Ferrier and Lovell (1990), Bauer (1990a and 1990b) and Kumbhaker (1991), the basic cost frontier system (cost frontier function and input-share equations) may be presented as follows:

$$lnC_t = lnC(Q,P) + \nu_t + lnT_t + lnA_t \qquad (6)$$

$S_{it} = S_t(Q,P) + \varepsilon_{it}$, where i refers to the i^{th} input.

It is noted that the cost inefficiency term, μ_t, is decomposed into two parts lnT_t and lnA_t. Both these two decompositions, lnT_t and lnA_t, are assumed to be non-negative, one-sided disturbance terms, reflecting technical and allocative inefficiencies respectively. The error term in the share equations is assumed to be a two-sided disturbance term which captures statistical noise and allocative inefficiency[10].

However, the major problem of this system is the "possible" interrelationship between the disturbance terms, ε_{it}, in the share equations and the allocative inefficiency term in the cost function. This problem arises because of the difference in the underlying distribution of these two terms. This was first noticed by Greene (1980b). He overcame the problem by assuming that the two terms are statistically independent. However, more rigorous treatment of this issue has been carried out in other studies[11]. In these studies the problem has been solved by estimating an approximation function to the relationship between lnA_t and ε_{it}. Another method also employed to overcome this problem was based on the existence of a closed-form to the cost/production frontiers. This method was introduced originally by Schmidt and Lovell (1979) and developed by Kumbhakar (1987 and 1989).

However, the interpretation of inefficiency in the context of cost frontier is different from that using the production frontier. This difference mainly results from the existence of allocative inefficiency[12]. Thus, if allocative efficiency is assumed, then the inefficiency term would reflect technical inefficiency alone. In recent years several studies made a further decomposition of the error term to include an allocative inefficiency term[13]. This decomposition of the error term into statistical noise, technical inefficiency and allocative inefficiency is surrounded by unclear specification regarding the interrelation between the allocative inefficiency term in the cost share equations and the allocative inefficiency term in the cost frontier, Bauer (1985, 1987, 1990), Greene (1980).

Bauer (1990a and 1990b) has proposed a more applicable approach to overcoming this problem and avoiding any misspecification of the underlying relationship between lnT_t and lnA_t which may occur when this analytical approach (Equation 6) is employed. His approach is based on restructuring the disturbances in the cost function to consist of two parts; the statistical noise and cost inefficiency terms, ν_t and μ_t. He also assumes that the inefficiency term μ_t is a one-sided disturbance[14]. This modification to the system creates no problem regarding the relationship between the term lnA_t included in the cost function and that included in the error terms, ε_{it}, in cost share equations. He argued that even though this approach is not highly efficient in a statistical sense, it still can be considered as a better alternative than the other approaches such as those that fully ignore the relationship between lnA_t and ε_{it}. He presented the modified frontier system as:

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10 The existence of allocative inefficiency produces non-optimal mixture of inputs. That is some of the inputs may be over- or under-employed, Bauer (1990a).

11 For example, see Schmidt (1984).

12 It implies that a technically efficient production process does not imply cost efficient.

13 See Bauer (1988 and 1990), Kopp and Diewert (1982).

14 Referring to lnAt+lnTt as one part of the error, μt.

$\ln C_t = \ln C(Q,P,t) + \nu_t + \mu_t$ (7)

$S_{it} = S_t(Q,P,t) + \varepsilon_{it}$

Where μ_t is a one-sided disturbance and its two decompositions, $\ln T_t$ and $\ln A_t$ can be obtained using Jondrow et al. (1982), and Kopp and Diewert (1982) respectively.

Thus, in order to obtain the cost inefficiency, a stochastic cost frontier with time-varying cost inefficiency is required to estimate the underlying technology. Following Battese and Coelli (1988, 1992) among others, a stochastic frontier cost function with time-varying cost inefficiency can be presented as follows:

$$C_{it} = C(P_{it}, Q_{it}; \beta) \cdot e^{(v_{it}+u_{it})}, \text{ and} \quad (8)$$

$$u_{it} = \eta_{it} u_i = u_i e^{[-\eta(t-T)]}, \ t \in \varphi(i); i = 1,2,..., N \quad (9)$$

Where

C_{it} represents the production cost of the i^{th} firm/industry at the t^{th} period,

$C(\cdot)$ is the i^{th}-firm's cost function of the input prices (P_{it}) for a given levels of output Q_{it},

β is a vector of parameters,

$v_{it}+u_{it}$ are the two components of the error term (ε). v_{it} are assumed to be iid $N(0,\sigma^2_v)$ random errors, and u_{it} are assumed to be iid $N(\mu, \sigma^2_u)$,

η is a scalar, and

$\varphi(i)$ is a set of T_i time periods in which the observations for i^{th} firm are available in the total period (T).

It follows that given the model specification in equations (8 and 9), the non-negative cost efficiency term, u_{it}, may be decreasing, increasing, or unchanged given that $\eta>0$, $\eta<0$, or $\eta=0$, respectively. The exponential modeling of cost efficiency over time (equation 9) implies that cost efficiency can be either increasing at a decreasing rate or decreasing at an increasing rate. However, in the case of $\eta=0$ there would be no change over time in cost efficiency. Thus, an estimate of time-varying cost inefficiency may be obtained from the maximum-likelihood estimates of the required parameters of the above model[15]. This is carried out in the next by employing translog cost function frontier. Following Battese and Broca (1995), Battese and Coelli (1993), and Bauer (1990) among others, a modified version of the single-output translog[16] cost function frontier with three variable inputs (Capital, Labor, and intermediate-input) can be hypothesized as follows (with no industry and time subscripts):

$$\ln C = \beta_C + \beta_Q \ln Q + \sum_i \beta_i \ln P_i + \frac{1}{2}\beta_{QQ}(\ln Q)^2 + \frac{1}{2}\sum_i \sum_j \beta_{ij} \ln P_i \ln P_j + \sum_i \beta_{iQ} \ln P_i \ln Q + \varepsilon \quad (10)$$

Where:

C is total cost

P_i is price index of the i^{th} variable input, and i = Labor (L), Capital (K),

and intermediate inputs (M).

Q is aggregate real output index

15 A detailed derivation the likelihood function for this system is given in Battese and Coelli (1992 and 1993).

16 Translog is short writing of the Transcendental Logarithmic Function, See Christensen, L.R., D.W. Jorgenson and L.J. Lau (1973).

ε is a composite disturbance term

The decomposition of the error "disturbance" term consists of two independent components that are ε = v + u, where v is a symmetric component which accounts for statistical noise such as factors not controlled by the "firm" and u is a one-sided (u>0) component which measures cost inefficiency relative to the stochastic cost frontier. That is, given the distribution assumed for the two components of ε and assuming that they are independent from one another, cost inefficiency, the conditional mean of u given ε=e can be expressed as in equation (11) below:

$$E(e^{u} \mid \varepsilon = e) = \{\exp[-\mu_{*} + \frac{1}{2}\sigma_{*}^{2}]\} \cdot \{\Phi[\frac{\mu_{*}}{\sigma_{*}} - \sigma_{*}][\Phi \frac{\mu_{*}}{\sigma_{*}}]^{-1} \qquad (11)$$

Where $\mu_{*} = \dfrac{\sigma_{v}^{2} z\delta - \sigma^{2} e}{\sigma_{v}^{2} + \sigma^{2}}$, $\sigma_{*}^{2} = \sigma_{v}^{2}\sigma^{2} / (\sigma_{v}^{2} + \sigma^{2})$, *and*

Φ represents the distribution function for the standard normal variable

The cost frontier model defined by equation 10 accounts for scale economies and for the effect of the input prices in addition to the cost inefficiency.

Certain parameter restrictions are needed for this cost frontier to satisfy linear homogeneity in prices of variable inputs for a given level of output and technology, as required by a well-behaved cost function. Thus, symmetry is imposed, $\beta_{ij} = \beta_{ji}$, and the following restrictions are sufficient:

$$\sum_i \beta_i = 1, \text{ and } \sum_j \beta_{ji} = \sum_i \beta_{ij} = 0 \qquad (12)$$

And assuming that the underlying production technology is homogenous of degree 1/η in output requires the following additional restrictions:

$$\beta_{iQ} = 0, \forall_i \text{ and } \beta_{QQ} = 0. \qquad (13)$$

5. Data: Measurement and Sources[17]

Output is measured in physical (real values). For products to be regarded as a homogeneous commodity (production in physical units) certain conditions should be satisfied. In this study, output (Q) is equal to the summation of the real values of the produced output.

In this study, the real value of compensation is used as a measure of labor (L) input to take into account the difference in skill among workers, assuming that there is a strong relationship between wages and the workers' level of skill and experience. Compensation is defined as comprising of all payments, both in cash and in kind, and any supplements to wages and salaries.

The most preferred measure of capital input for productivity analysis is the flow of capital services used. The flow of capital services, which should in principle include the value, at current replacement cost, of the reproducible fixed assets used up during the year as a result of normal wear and tear, and the normal rate of accidental damage. Thus, flow measures could be a good indication of the amount of capital employed to produce current output. In practice, however, data are generally not available in the details required for the estimation of capital flow, Shebeb (2000 and 2002). In this study the capital depreciation (in real terms) and the opportunity cost of the capital stock have been used as a measure of the flow of the

17 Data used for this research was obtained from the Department of Economic Planning, Ministry of Finance and National Economy, an official source of economic data in the Kingdom of Bahrain. The time period covered is from 1980 to 2002.

capital service[18]. This opportunity cost is estimated to be equal to the normal rate of return on investment (it is assumed to 10%)[19]. The capital stock, on the other hand, has been computed as inverse relation assuming that the average depreciation rate of the fixed capital is 6%. Thus the capital stock could be found as the value of the depreciation divided by the depreciation rate.

The intermediate-inputs are defined as equal to the real value of all production inputs (including indirect tax and excluding cost of labor and capital inputs).

6. Empirical Results and Results Interpretation

The basic model is applied to measure the level of productive efficiency in Bahrain economy over the time period 1980-2002. The cost frontier function model Equation 10 has 18 parameters, however imposing linear homogeneity in variable input prices, homogeneity of degree $1/\eta$ in output and the symmetry restrictions (Equations 10 and 13) reduces the number of parameters to be estimated to 10, three of which can be deduced indirectly by exploiting the directly estimated parameters and the model restrictions. The Maximum-likelihood estimates of the parameters of the model were obtained using the Frontier© computer program[20].

The hypothesis that the error term in equation 10 is composed of two significant components is tested to determine whether the stochastic frontier specification is an appropriate representation of the underlying technology compared to the average technology (using the OLS estimator). This test implies (if this null hypothesis cannot be rejected) that the σ^2 term is not significantly different from zero. It follows that the inefficiency term in cost frontier model (equation 10) is not significant which would reduce the frontier specification to the average specification of the underlying technology. Referring to many trials, this null hypothesis could not be rejected at any significance level. This is presented clearly in Table 1 in which the estimation of the average technology and the frontier technology are presented. That is the likelihood value of the frontier model is less than that obtained using OLS (average cost function).

Thus, it could be concluded that there is no strong foundation that could be used to estimate cost inefficiency in Bahrain economy given the model specifications and testing. The author was not satisfied with these results, therefore several alternative modeling to the underlying technology were used, for example, Cobb-Douglas Cost Frontier and Cobb-Douglas Production Frontier. Unfortunately, none of these trials could give satisfactory results that support the frontier technology[21].

7. Summary and Concluding Remarks

The main objective of this study is to measure and analyze one of the most important components of total productivity, namely productive (economic) efficiency in Bahrain economy over the time period 1980-2002. Identifying and estimating the level of productive efficiency is essential in the evaluation of alternative policies in Bahrain economy.

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18 It is known that this measure mainly refers to the capital consumed not capital services, and is based on different accounting methods. However, due to many difficulties of measuring capital flow, in productivity studies capital depreciation is normally used as approximate Shebeb (2000 and 2002).

19 For a justification of this assumption, see Hulten and Wykoff (1981a, 1981b) and Al Sadiq (1998).

20 Coelli (1992).

21 Since the underlying technology is assumed to be Cobb-Douglas technology, which is fairly limited, it is quite reasonable to regard the findings of this study with some degree of caution.

In order to obtain the cost inefficiency, a stochastic cost frontier with time-varying cost inefficiency is required to estimate the underlying technology. Following Battese and Coelli (1988 and 1992) among others, a stochastic frontier cost function with time-varying cost inefficiency was used. The hypothesis specifies whether the stochastic frontier specification is an appropriate representation of the underlying technology compared to the average technology (using the OLS estimator) was tested. The null hypothesis could not be rejected at any significance level. Thus, it could be concluded that an estimate of cost inefficiency in Bahrain economy is not possible given the model specifications and testing.

It follows that the empirical finding has been rather disappointing (unexpected) due to the fact that it showed no evidence of cost inefficiency. One of the possible explanations for this finding may be due to methods in which the row data has been prepared by the official sources. Accordingly, further research at the disaggregated economic levels (i.e. industry levels) is strongly recommended in order to obtain clearer explanations to unanticipated finding of this investigation.

References

Aigner, D.J., C.A.K. Lovell, and P. Schmidt. 1977. "Formulation and Estimation of Stochastic Frontier Production Function Models", *Journal of Econometrics*, Vol.6, pp.21-37.

Al Sadiq, A. M**.** 1998. "Bahrain's Economy and Total Factor Productivity", *Working Paper of Bahrain Centre for Studies and Research*, No. 11, December 1998.

Battese, G.E. and S. Broca. 1995. "Functional Forms of Stochastic Frontier Production Functions and Models for Technical Inefficiency Effects: a Comparative Study for Wheat Farmers in Pakistan", Contributed paper presented at the New England Conference on Efficiency and Productivity at the University of New England, 23-24 November.

Battese, G.E. and T.J. Coelli. 1988. "Prediction of Firm-Level Technical Efficiency with a Generalized Frontier Production Function and Panel Data", *Journal of Econometrics,* Vol.38, pp.387-399.

____**.** 1992. "Frontier Production Functions, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India", *Journal of Productivity Analysis*, Vol.3, No.1/2, pp.153-169.

____**.** 1993. "A Stochastic Frontier Production Function Incorporating a Model for Technical Inefficiency Effects", *Working Paper in Econometrics and Applied Statistics,* No.69, Department of Economics, University of New England.

Bauer, P.W**.** 1990a. "Decomposing TFP Growth in the Presence of Cost Inefficiency, Non-constant Returns to Scale, and Technological Progress", *Journal of Productivity Analysis*, Vol.1, No.4, pp.287-301.

____. (1990b), "A Survey of Recent Econometric Developments in Frontier Estimation", *Journal of Econometrics*, No.46, pp.21-39.

Christensen, L.R., D.W. Jorgenson and L.J. Lau**.** 1973. "Transcendental Logarithmic Production Frontiers", *Review of Economics and Statistics*, Vol.55, No.1, February, pp.28-45.

Cobb, C.W. and P.H. Douglas. 1928. "A Theory of Production", *American Economic Review*, Vol.18, No.1 (supplement), pp.139-165.

Coelli, T. 1994. *A Guide to Frontier Version 4.1c: A Computer Program for Stochastic Frontier Production and Cost Function Estimation,* Department of Economics, the University of New England.

DeAlessi. 1983. "Property Rights, Transactions Costs, and X-efficiency: An Essay in Economic Theory", *American Economic Review*, Vol.75, March, pp.64-81.

Farrell, M. J**.** 1957. "The Measurement of Productive Efficiency", *Journal of the Royal Statistical Society*, Vol.120, No.3, pp.253-82.

Fare, R. and S. Grosskopf 1990a. "A Distance Function Approach to Measuring Prices Efficiency", *Journal of Public Economics*, No.43, pp.123-126.

Ferrier, G. and C.A.K. Lovell. 1990. "Measuring Cost Efficiency in Banking: Econometric and Linear Programming Evidence", *Journal of Econometrics,* No.46, pp.229-245.

Greene, W**.** 1980a. "Maximum Likelihood Estimation of Econometric Frontier Functions", *Journal of Econometrics*, Vol.13, No.1, pp.27-56.

____**.** 1980b. "On the Estimation of a Flexible Frontier Production Model", *Journal of Econometrics*, Vol.13, No.1, pp.101-115.

Grosskopf, S**.** 1993. “Efficiency and Productivity”, in H.O. Fried, C.A.K Lovell, and S.S. Schmidt (eds.), *The Measurement of Productive Efficiency: Techniques and Applications,* Oxford: Oxford University Press.

Hulten, C.R. and F.C. Wykoff. 1981a. “The Estimation of Economic Depreciation Using Vintage Asset Prices: An Application of Box-Cox Power Transformation”, *Journal of Econometrics,* Vol.15, No.3, August, pp.367-396.

____. 1981b. “The Estimation of Economic Depreciation”, in C. R. Hulten (ed.), *Depreciation, Inflation and the Taxation of Income from Capital,* Washington, D.C., The Urban Institute.

Jondrow, J., C.A.K. Lovell, I.S. Materov, and P. Schmidt**.** 1982. “On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Function Model”, *Journal of Econometrics,* Vol.19, No.2/3, pp.233-238.

Kopp, R.J. 1981. “The Measurement of Productive Efficiency: A Reconsideration”, *Quarterly Journal of Economics*, 96, Aug., 477-504.

Kopp, R.J. and W. Diewert. 1982. “The Decomposition of Frontier Cost Function Deviations into Measures of Technical and Allocative Efficiency”, *Journal of Econometrics,* Vol.19, No.2/3, pp.319-332.

____. 1987. “The Specification of Technical and Allocative Inefficiency in Stochastic Production and Profit Frontiers”, *Journal of Econometrics*, Vol.34, No.3, pp.335-348.

____**.** (1989), “Modelling Technical and Allocative Inefficiency in Translog Production Function”, *Economics Letters*, Vol.31, No.2, pp.119-124.

____. 1991. “Estimation of Technical Inefficiency in Panel Data Models with Firm and Time-Specific Effects”, *Economics Letters*, Vol.36, No.2, pp.43-48.

Leibenstein H. 1966. “Allocative Efficiency vs 'X-Efficiency’”, *American Economic Review*, Vol.56, June, pp.392-415.

____**.** 1973. “Competition and X-Efficiency: Reply”, *Journal of Political Economy*, Vol. 81, May, pp.765-777.

Lovell, C.A.K and P. Schmidt. 1988 “A Comparison of Alternative Approaches to the Measurement of Productive Efficiency”, in A. Dogramaci and R. Fare (eds.), *Applications of Modern Production Theory: Efficiency and Productivity,* Kluwer Academic Publishers, Boston.

Malmquist, S. 1953. “Index Numbers and Indifference Surfaces”, *Trabajos de Estatistica,* No.4, pp.209-242.

Nishimizu, M. and J.M. Page. 1982. “Total Factor Productivity Growth, Technological progress and Technical Efficiency Change: Dimensions of Productivity Change in Yugoslavia 1965-78”, *Economic Journal*, No.92, pp.920-936.

Schmidt, P. 1984. “An Error Structure for Systems of Translog Cost and Share Equations”, *Workshop Paper,* No.8390, Department of Economics, Michigan State University.

Shebeb, B. 2000. “Productivity Decomposing Model: Theoretical Presentation”, *Arab Economic Journal*, Vol. 9, No.21, pp.3-19.

____. 2002. “Productivity Growth and Capacity Utilization in the Australian Gold Mining Industry: A Short-Run Cost Analysis”, *Economic Issues*, Vol.7, Part 2.

Shephard, R.W. 1970. *Theory of Cost and Production Functions,* Princeton: Princeton University Press.

Stigler, G.J**.** 1976. “The Xistence of X-inefficiency”, *American Economic Review*, Vol.66, pp.213-226.

Figure 1: Allocative and Technical Inefficiencies

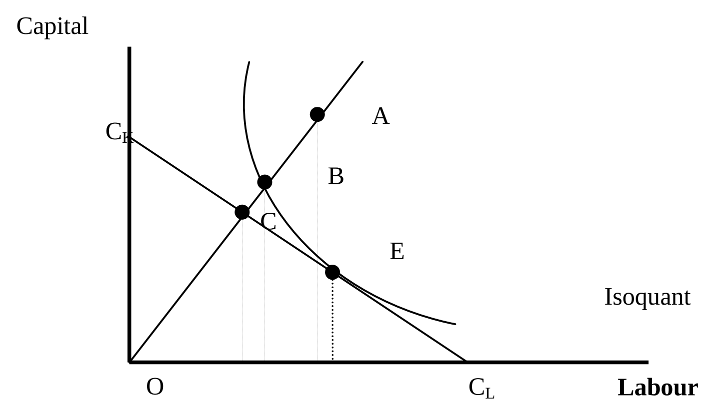

Figure 2: Cost-Based Measure of Productivity Growth Allowing for Cost Inefficiency

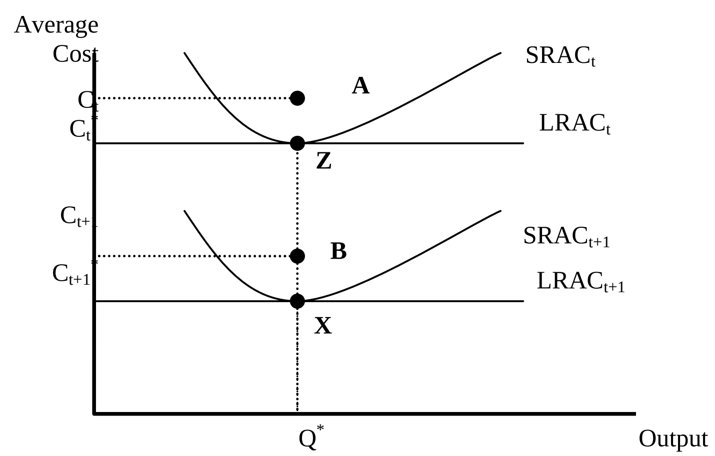

Table 1: Model Estimation -Output from FRONTIER V4.1c

```
Output from the program FRONTIER (Version 4.1c)

instruction file = cost.ins
data file =        COSTnew.dta

 Error Components Frontier
 The model is a cost function
 The dependent variable is logged

the ols estimates are :

                 coefficient     standard-error    t-ratio
  beta 00.15477141         E+010.17488036  E+000.88501311  E+01
  beta 10.15877429-        E+000.19002807  E+00 -0.83553070E+00
  beta 20.48281504         E+000.98172666  E-010.49180191  E+01
  beta 30.98628648-        E+000.34014720  E+01 -0.28995873E+00
  beta 40.10523374-        E+010.15532355  E+01 -0.67751310E+00
  beta 50.10269064-        E+010.40219316  E+01 -0.25532668E+00
  beta 60.75472220         E+000.27219520  E-010.27727241  E+02
  sigma-squared0.10562074  E-03

log likelihood function =   0.76827870E+02

the estimates after the grid search were :

  beta 00.15461598         E+01
  beta 10.15877429-        E+00
  beta 20.48281504         E+00
  beta 30.98628648-        E+00
  beta 40.10523374-        E+01
  beta 50.10269064-        E+01
  beta 60.75472220         E+00
  sigma-squared0.75890979  E-04
  gamma0.50000000          E-01
  mu0.00000000             E+00
  eta0.00000000            E+00

the final mle estimates are :

                 coefficient     standard-error    t-ratio
  beta 00.15461598         E+010.10000000  E+010.15461598  E+01
  beta 10.15877429-        E+000.10000000  E+01 -0.15877429E+00
  beta 20.48281504         E+000.10000000  E+010.48281504  E+00
  beta 30.98628648-        E+000.10000000  E+01 -0.98628648E+00
  beta 40.10523374-        E+010.10000000  E+01 -0.10523374E+01
  beta 50.10269064-        E+010.10000000  E+01 -0.10269064E+01
  beta 60.75472220         E+000.10000000  E+010.75472220  E+00
  sigma-squared0.75890979  E-040.10000000  E+010.75890979  E-04
  gamma0.50000000          E-010.10000000  E+010.50000000  E-01
  mu0.00000000             E+000.10000000  E+010.00000000  E+00
  eta0.00000000            E+000.10000000  E+010.00000000  E+00

log likelihood function =   0.76649653E+02

the likelihood value is less than that obtained using ols!
```