Emir. J. Agric. Sci. 2006. 18 (2): 29-46
http://www.cfa.uaeu.ac.ae/research/ejas.htm

Productivity growth: Bahrain agriculture and fisheries sector

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Abstract: The main objective of this study is to measure and analyze one of the major components of economic performance, multifactor productivity (MFP) growth rate (technological change) adjusted for economies of scale, and to measure and analyze the growth rate partial (input-specific) productivity in Bahrain Agricultural and Fishery Sector (Primary Sector) over the time period 1980-2002. A dual cost measure of multifactor productivity growth was developed to obtain a highly interpretable measure of economic performance. Exploiting recent developments in dual cost theory, a well-defined method for empirical estimation has been established. This approach explicitly takes into account the impacts of non-neutral technological change and economies of scale that may occur in the long-run production process. An empirical model of multifactor productivity was derived as an application of this dual-cost analysis. The translog long-run cost function was employed to estimate the multifactor productivity growth, technological change, the bias of the technological change, and input-specific (partial) productivity in Bahrain primary sector. The findings of this study show that the presently structured primary sector, in general, have experienced a relatively low productivity growth rate, an annual average of 1.7%. The reasons behind this low performance could be the presence of a number of sub-optimal operations with significant low rate of multifactor productivity growth. However, the maximum level of multifactor productivity growth rate was 17.5% in 1994, just before the civil unrest era in Bahrain. It is important not only to measure and to analyze the level of multifactor productivity growth at the industry level, but also at the firm (plant) level in order to draw the appropriate policy regarding the new investments and identifying the relative importance of different types of investments that should be encouraged. Avoiding any misinterpretation of the current economic performance of Bahrain primary sector, the study also recommends, a comparison with that of its challengers among the GCC countries. Therefore, the study calls for further research at disaggregated levels of the industry with emphasis on the decomposition of MFP to identify its main factors that contribute to its rate of growth. Such further research would give policy makers a better vision and know-how to initiate policies that could enhance the productivity growth rate and its major components, thus pressing forward to stronger competitive position in the GCC region.

Keywords: Economic growth, partial (input-specific), economic performance, translog long-run cost function, Bahrain economy.

معدلات نمو الإنتاجية في قطاع الزراعة البحريني

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الملخص: كان الهدف من هذا البحث هو قياس وتحليل معدلات نمو الإنتاجية في قطاع الزراعة وصيد الأسماك البحريني. وقامت الدراسة بتقديم طريقة عملية وذات ملامح واضحة لقياس معدلات نمو الإنتاجية، وذلك بالاعتماد على التطورات الحديثة في نظرية التكاليف المناظرة (Dual Cost Theory) بحث استخدم دالة للتكاليف المناظرة الطويلة الآجل في بناء نموذج قياسي لتقدير معدلات نمو الإنتاجية الكلية والإنتاجية الجزئية. وقد أظهرت نتائج التحليل في هذه الدراسة أن قطاع الزراعة وصيد الأسماك البحريني كان يعاني بصفة عامة من تدني معدلات نمو الإنتاجية خلال فترة الدراسة 1980-2002. حيث كان متوسط النمو في الإنتاجية الكلية خلال فترة الدراسة هو 1.7% . وكما أوضحت الدراسة أن معدلات النمو الإنتاجية قد وصلت إلى أقصى مستوى لها عام 1994 حيث تم تحقيق معدل نمو 17.5%، وذلك مباشرة قبل فترة الاضطرابات المدنية التي مرت بها البحرين في النصف الثاني من التسعينيات. وقد يعني ذلك أن هناك مجالاً كبيراً لزيادة

الإنتاجية من خلال إعادة هيكلة هذا القطاع ومواءمة التقنيات الحديثة بما يضمن تحقيق الكفاءة الاقتصادية اخـ ذين بالاعتبـ ار صغر حجم السوق المحلية للاقتصاد البحريني وإمكانية دفع عملية التكامل الإقليمي.

الكلمات المفتاحية: النمو الاقتصادي، الأداء الاقتصادي، translog long-run cost function، الاقتصاد البحريني.

Introduction

Bahrain's first five-year economic and social development plan (1982-1986) came with main emphasis on having stronger economic and social relationships among various economic and social sectors in exploiting the available resources. In subsequent plans, most of government agencies shared the same objective, providing and upgrading the economic and social infrastructure. Thus, over the last few years the compelling task facing the economic policy makers in Bahrain was to expand and diversify the economic activities. The importance of this task stems primarily from the danger of being dependent, mainly, upon the financial and oil sectors.

One of the promising outcomes of diversification could be the development and expanding of the agricultural and fishery sector (Primary Sector). Over last decade, the average contribution of Bahrain Agricultural and Fishery Sector to the gross domestic product (GDP) was about 1%. As fishery activities stand alone, its contribution to the gross domestic product (GDP) was about 0.3%. However, the primary sector of Bahrain, which is a labor-intensive industry, could be regarded as an important source of income to a large portion of the population and labor force in Bahrain.

Recently, Bahrain has announced a plan for sustainable agriculture development until 2015 that stresses the need to develop its natural resources to improve agricultural products and productivity. The plan is being implemented in association with the Food and Agriculture Organization (FAO)'s experts. Bahrain also considered being keen to follow international and regional agreements establishing a fair and market-oriented trading system through a programmed reforms and encompassing strengthened rules in order to correct and prevent restrictions and distortions in agricultural markets. In addition, considering the new agreements of the World Trade Organization (WTO) that have emphasized global openness and competition, nations with weak economic performance will not be able to survive in face of the international harsh competition. Thus, it is about the right-time for Bahrain policy makers to pay more attention to productivity and efficiency issues. It follows that it is crucial at this stage to measure and analyze the multifactor productivity and its main components which can be used as powerful analytical tools in understanding the economic performance of Bahrain primary sector. Thus, identifying and estimating the level of multifactor productivity and technological change is essential in the evaluation of alternative policies in Bahrain primary sector.

In terms of economic performance, multifactor productivity and technological change are frequently being use in most discussions on economic problems that are related to economic performance in a country, particularly in developing countries. This because higher productivity (low average costs per unit) which it could arise from technological change, economies of scale, and the improvements in efficiency and the level of capacity utilization. It follows that it is crucial to determine the main underlying concepts of productivity and use this powerful analytic tool in understanding the economic performance of Bahrain primary sector. Thus, with the process of development and the importance of the structural transformation, it will be very important to understand the fundamental concepts of productivity analysis and measurement, which could help in the identification of appropriate economic policy.

The main objectives of this study are to measure and analyze the most important components of economic performance, mainly multifactor productivity growth rate and technological change, in Bahrain primary sector over the time period 1980-2002. In addition, other objectives of the study are to measure and analyze the partial (input-specific) productivity growth rate and the bias of technological change in this sector.

This study is organized in the following way: (1) an overview of Bahrain primary sector, (2) a review of the underlying theory of multifactor productivity measurement, and the relationship between multifactor productivity and technological change is also discussed, (3) the model and methodology used in estimating the level of multifactor and partial productivity growth rates in the Bahrain primary sector are introduced, (4) the data used in the empirical investigation are defined, (5) the empirical findings are presented and analyzed and (6) an overall summary of the study and the concluding remarks are presented.

Bahrain Primary Sector: An Overview

Despite the low rate of rainfall and poor soil, agriculture historically was an important sector of Bahrain economy. Before the 1940s, dates was the major product of Bahrain's agriculture. Dates production was shared by both domestic consumption and export. From the 1950s and up to the 1970s, the demand for dates was declining dramatically as a result of social and economic changes affecting food consumption habits. Accordingly, these changes led to a gradual decline in dates supply following the guiding or allocating function of price. In the 1980s, dates farms and production had been replaced by new kinds of agricultural products; including vegetables, nurseries for trees and flowers, poultry production, and dairy farms.

Bahrain's farming area was decreasing from 11,109 Donums (1000 square meters) in year 1994/1995 to less than 8,500 Donums in year 2001/2002. The cultivated land consists of many farms ranging in size from a few square meters to few Donums. In year 2002, there were 5,175 farmers, 4,613 of whom work in private own farms. In addition, the number of skilled farm workers progressively declining since the late 1970s due to the availability of a relative high-paying non agricultural jobs.

In spite of the long history of agriculture in Bahrain, still there are some difficulties facing this sector. These difficulties could be itemized as a limited supply of skilled labor, limited new investments, and low capital-intensity investment is common in this industry. The shortage of financial resources has been the main barrier in achieving sustainable agricultural development in Bahrain. This calls for an urgent cooperation between private and public sectors to develop agricultural projects.

However, regardless of these obstacles, government policy has been aimed at expanding domestic production of crops since the early 1980s, through programs such as free distribution of seeds, technical assistance in adopting new and more efficient irrigation technologies, and low interest credit. Yet, agricultural production has shown an increase over the last few years (early 2000s). This increase was mainly a result of the significant technical assistances and guidance that are provided by the government agricultural agencies.

These agencies also provide the necessary agriculture machinery at low price and provide guiding to farmers toward new techniques in farming that leads to higher levels of production. Although these programs have contributed to significant increases in agriculture production, the restricted extent of Bahrain's agriculture area limits the island's possible productive capacity. Thus, agricultural imports including fruits, vegetables, meat, live animals, and dairy products remain one of the main categories of Bahrain international trade.

In terms of fishery activities, the waters surrounding Bahrain traditionally have been rich in varieties of fish. Before the 1930s, most Bahrainis were engaged in some form of fishing. After 1935 fishing as a profession gradually declined as a result of the prospect of steady wages that attracted many fishermen to other jobs. In 1998, only 1,655 Bahrain fishermen were working full time in this industry despite rising demand. The consequence of this situation was an increase in fish imports to satisfy the local demand.

As the rate of land reclamation and level of pollution in the Arabian Gulf were increasing, the fishing industry was affected significantly and fish almost disappeared from waters near Bahrain. Pollution was severe in the early 1980s and 1990s as a result of damaged oil facilities during the gulf wars. The oil seep out, especially those of 1991, destructively affected the regional fishing industry. As it is now, the long term ecological impact of the pollution remained uncertain.

Bahrain government fishery agencies launched several programs to restore the fishing industry by increasing and expanding the landing stages, constructing cold storage facilities, and offering training programs on how to utilize and maintain the modern fishing equipments. These courses contributed to an increase in the total fish catch, which was 11,204 tons in 2002 (Directorate of Marine Resources, 2003a, b).

Recently, officials called for closer cooperation with fishermen to preserve and enhance Bahrain's fish stocks to protect the present and future generations. Officials also called for more enforcement of the existing laws regulating the sector in order to control fishing abuses. The decline in Bahrain's fish stocks could also be attributed to illegal fishing practices which stress the need for a better understanding of fishing practices and of compliance with regulations. Absence of a law-enforcement department makes it very difficult to apprehend the violators in terms of over fishing problem. That is, fail to not enhance and maintain the existing stocks of the fishing sources may face serious consequences in future.

Productivity Measurement: A Dual Cost Approach

In this paper, a non-frontier long-run cost function is to be employed to measure economic performance of Bahrain primary sector. It follows that the two assumptions underlying this empirical investigation are: (1) all producers are cost efficient; and (2) all input levels are adjusted instantaneously to their optimal levels according to their market prices. It follows that the first assumption implies a non-frontier specification of the underlying technology while the second assumption implies a long-run analysis.

In order to develop the model that can measure economic performance-“productivity”, this section presents the relationship between the primal and dual cost measures of technological change and its linkage to productivity growth. It also shows that under certain assumptions technological change can be given a formal definition that coincides with that of productivity growth. Productivity growth reflects the increase in output from a given level of input as technology progresses over time. It follows that productivity or technological change can be defined either by increased output, holding the level of inputs unchanged, or reduced cost of production, holding the level of output unchanged. These definitions can, however, be presented theoretically either by an upward shift of the isoquant or by a downward shift in the average cost function. Thus, the production and/ or cost function can be used to represent the underlying technology and to develop the theoretical linkage between technological change and productivity growth. In what follows, a primal model that can be used to measure the contribution of technological change to overall productivity change is presented.

Let an aggregate production function be of the form Q=F(X,t) where Q is an aggregate level of output, X is an aggregate level of inputs vector, and t denotes the state of the available technology, generally proxy by a time trend. Given this aggregate production function, it is reasonable to define technological change as an upward shift in the production function. It follows that if production is efficient, and capacity is fully utilized. One may obtain a primal measure of technological change or "productivity" by differentiating the log of the aggregate production function with respect to time, t, as follows:

$$(1) \qquad \frac{d\ln Q}{dt} = \sum_i \frac{\partial \ln Q}{\partial \ln X_i}\frac{d\ln X_i}{dt} + \frac{\partial \ln Q}{\partial t}, \text{ or}$$

$$\frac{\partial \ln Q}{\partial t} = \frac{d\ln Q}{dt} - \sum_i \frac{\partial \ln Q}{\partial \ln X_i}\frac{d\ln X_i}{dt}$$

Thus given the underlying assumptions, technological change ($\partial \ln Q/\partial t$) in equation (1) coincides with the conceptual definition of productivity growth. Given profit maximization and the existence of a competitive equilibrium, output price equals marginal cost and input prices are equal to the value of their marginal products, equation (1) can be rewritten as

$$(2) \qquad \frac{\partial \ln Q}{\partial t} = \zeta_{Qt} = \frac{d\ln Q}{dt} - \sum \frac{P_i X_i}{P_Q Q}\frac{d\ln X_i}{dt}, \text{ or}$$

$$\frac{\partial \ln Q}{\partial t} = \zeta_{Qt} = \frac{d\ln Q}{dt} - \sum_i \frac{P_i X_i}{\sum_i P_i X_i}\frac{d\ln X_i}{dt}$$

Where the ζ_{Qt} represents the primal measure of technological change (the change in output over time for a given inputs mix).

In reference to equation (2), the primal rate of technological change or "productivity" can be defined as the difference between the change in output and the scale-adjusted change in inputs. However, the modern productivity growth measurement models have been motivated by the development of the duality theory of cost. That is, a dual cost measure of technological change can be obtained. It follows that a formalization of the dual cost measure of technological change or "productivity" for a single product technology can be based on defining the minimum dual cost function[1].

A cost function may be defined as C = C(Q, P, t), where C is the total cost, Q is the output level, P is a vector of the input prices, and t is a time trend employed as a proxy for technology. It follows that the change in cost over time, holding output and input prices unchanged, reflects the technological change or the change in multifactor productivity. Thus, differentiating the log of C(Q, P, t) with respect to time gives the rate of change in production cost. This can be written as:

[1] This implies that no fixed or quasi-fixed inputs existed, the long-run equilibrium.

$$(3)\quad \frac{d\ln C}{dt}=\sum_{i=1}^{n}\frac{\partial \ln C}{\partial \ln P_i}\frac{d\ln P_i}{dt}+\frac{\partial \ln C}{\partial \ln Q}\frac{d\ln Q}{dt}+\frac{\partial \ln C}{\partial t}$$

By exploiting Shephard's lemma, the demand for the i[th] input X_i can be obtained as $\partial C/\partial P_i$ and the i[th] input cost share can be written as $S_i=\partial \ln C/\partial \ln P_i$. Thus, equation (3) can be written now as:

$$(4)\quad -\frac{\partial \ln C}{\partial t}=\zeta_{Ct}=\sum_{i=1}^{n}S_i\frac{d\ln P_i}{dt}+\frac{\partial \ln C}{\partial \ln Q}\frac{d\ln Q}{dt}-\frac{d\ln C}{dt}$$

Where ζ_{Ct} is defined as the dual rate of technological change. Equation (4) shows that the dual rate of technological change may be decomposed into three parts of change: (1) the rate of change of in input prices $(\sum_{i=1}^{n}S_i\frac{d\ln P_i}{dt})$, (2) the effect of scale economies $(\frac{\partial \ln C}{\partial \ln Q}\frac{d\ln Q}{dt})$, and (3) the rate of change in total cost (dlnC/dt).

If constant returns to scale is imposed, $(\partial \ln C/\partial \ln Q)^{-1}=1$, the dual cost rate of productivity growth or technological change in equation (4) can be written as:

$$(5)\quad -\frac{\partial \ln C}{\partial t}=\zeta_{Ct}=\sum_{i=1}^{n}S_i\frac{d\ln P_i}{dt}+\frac{d\ln Q}{dt}-\frac{d\ln C}{dt}$$

Following Ohta (1975), the relationship between the primal and dual cost measures of technological change can now be shown by total differentiation of the log of the total cost function, $C=\sum_i P_i X_i$, with respect to time which gives:

$$(6)\quad \frac{d\ln C}{dt}=\sum_{i=1}^{n}S_i\frac{d\ln P_i}{dt}+\sum_{i=1}^{n}S_i\frac{d\ln X_i}{dt}$$

Then substituting equation (6) into equation (5) and using the primal measure of technological change (equation (2)) yields:

$$(7)\quad -\frac{\partial \ln C}{\partial t}=\zeta_{Ct}=\frac{d\ln Q}{dt}-\sum_i S_i\frac{d\ln X_i}{dt}=\frac{\partial \ln Q}{\partial t}=\zeta_{Qt}$$

If non-constant returns to scale exist ($\zeta_{CQ}\equiv(\partial \ln C/\partial \ln Q)^{-1}\neq 1$), then the dual cost measure of technological change may be obtained by substituting equation (6) into (4) which yields:

$$(8)\quad \frac{\partial \ln Q}{\partial t}=\zeta_{Qt}=-\frac{\partial \ln C}{\partial t}/\frac{\partial \ln C}{\partial \ln Q}=\zeta_{Ct}/\zeta_{CQ}$$

In addition, the relationship between dual measure of multifactor productivity growth rate and the proportion shift in cost function (ζ_{Ct}) can be shown as follows:

$$(9)\quad \dot{MFP}=\zeta_{Ct}+(1-\zeta_{CQ})\dot{Q}$$

That is, if constant returns to scale exists then, the dual cost and primal measures MFP will coincide.

Productivity Measurement Model: Econometric Framework

This section presents a detailed discussion of the long-run translog cost function[2]. The discussion of the theoretical properties and regularity conditions of the cost function for the translog technology is considered at the point of approximation[3]. A single-output non-homothetic translog cost function with non-neutral Hicksian

[2] The translog functional form was originally introduced by Christensen et al. (1973) and applied by many researchers in various areas of interest in applied economics. See Jorgenson (1995) for wide range of studies that exploit this approach.

[3] Point of approximation refers to that point where all variables are set to be equal to unity and no technological change exists, t=0.

technical change and symmetry condition[4], $\beta_{ij}=\beta_{ji}$, can be written as follows:

$$\ln C=\beta_o+\sum_i\beta_i\ln P_i+\frac{1}{2}\sum_i\sum_j\beta_{ij}\ln P_i\ln P_j+ \beta_Q\ln Q+\frac{1}{2}\beta_{QQ}(\ln Q)^2+\sum_i\beta_{iQ}\ln P_i\ln Q+ \beta_t t+\frac{1}{2}\beta_{tt}t^2+\sum_i\beta_{it}\ln P_i\,t+\beta_{Qt}\ln Q t \quad (10)$$

Where:
P_i : price of the i[th] input (X_i), and i=Capital (K), Labour (L), and other-inputs (M)
Q : level of output
C : total cost, $C=\sum_i P_iX_i$, and
t : disembodied technological change

For the translog cost function to be consistent with linear homogeneity in input prices for a given level of output, as required of a well-behaved cost function, the following restrictions are required:

$$\sum_{i=1}\beta_i=1, and \sum_{i=1}\beta_{ij}=\sum_{j=1}\beta_{ji}=\sum_{i=1}\beta_{iQ}=\sum_{i=1}\beta_{it}=0 \quad (11)$$

The input cost share equations for the translog cost function can be derived using Shephard's lemma. That is, the share equation for the i[th] input can be obtained as follows:

$$\frac{\partial \ln C}{\partial \ln P_i}=S_i=\beta_i+\sum_{j=1}\beta_{ij}\ln P_j+\beta_{iQ}\ln Q+\beta_{it}t \quad (12)$$

Additional restrictions, however, are imposed on this cost function to restrict the underlying technology. For instance, to restrict the translog cost function to be homothetic it is necessary and sufficient to restrict β_{iQ} to be equal to zero for i=K, L, M. It follows that homogeneity of a constant degree in output can be obtained by restricting β_{QQ} to be equal to zero. The degree of homogeneity, in this case, will be equal to $(\beta_Q)^{-1}$. Thus, a constant returns to scale technology (homogeneity of degree one in output) occurs when $\beta_Q=1$ in addition to the homotheticity and homogeneity restrictions.

However, monotonicity and concavity "curvature" conditions are unlike other regularity conditions of the cost function in the case of the flexible (translog) functional form. They do not satisfy monotonicity or concavity in input prices globally. Thus, they need to be checked locally if they are not imposed. A common approach in most empirical studies is to check the estimated model (cost function) for these properties rather than imposing them on the model[5]. However, failure of the estimated cost function to be concave in input prices or convex in output need not be explained, as a violation of cost function regularity. Rather, it might be explained as a result of bias in the data construction and measurements[6].

Monotonically increasing in input prices for the translog cost function implies the following condition:

$$\frac{\partial \ln C}{\partial \ln P_i}=\frac{\partial C}{\partial P_i}\frac{P_i}{C}>0,\forall_i, i=1,2,3,...n$$

(13) or

$$\frac{\partial \ln C}{\partial \ln P_i}=S_i=\beta_i+\sum_{j=1}\beta_{ij}\ln P_j+\beta_{iQ}\ln Q+\beta_{it}t>0,\forall_i, i=1,2,3,...n$$

[4] The symmetry condition is sufficient to ensure that the Hessian of this cost function is symmetric, and hence twice differentiable(Christensen et al., 1973)

[5] Hence, if all β_{ij} and β_{iQ} are zero, the translog functional form would become a Cobb-Douglas functional form which is globally concave in input prices. An algorithm for imposing these "inequality" restrictions has been developed, see Terrell (1996).

[6] It could also be a result of model misspecification.

A translog cost function is said to be monotonically increasing in output if the following condition is satisfied:

$$(14)\quad \frac{\partial \ln C}{\partial \ln Q} = \beta_Q + \beta_{QQ}\ln Q + \sum_{i=1} \beta_{iQ}\ln P_i + \beta_{Qt} t > 0$$

Since both ∂lnC/∂lnQ and ∂lnC/∂lnP_i are functions of the observed output and inputs levels for a given t, monotonicity conditions can be reduced to $\beta_Q>0$ and $\beta_i>0$ at the point of approximation, respectively. However, the monotonicity of the cost function in input prices and in output can be verified at each observation as well as at the approximation point.

Thus, the relationship between dual measure of multifactor productivity growth rate (MFP) and the proportional shift in cost function (ζ_{Ct}) can be shown as follows:

$$(15)\quad \dot{MFP} = \zeta_{Ct} + (1 - \zeta_{CQ})\dot{Q}$$

Where

MFP is the dual cost measure of multifactor productivity growth rate,

$$\zeta_{Ct} = -\frac{\partial \ln C}{\partial t} = -[\beta_t + \beta_{tt} t + \beta_{Qt}\ln Q + \sum_i \beta_{it}\ln P_i], \text{ and}$$

$$\zeta_{CQ} = \frac{\partial \ln C}{\partial \ln Q} = \beta_Q + \beta_{QQ}\ln Q + \beta_{Qt} t + \sum_i \beta_{iQ}\ln P_i$$

Equation (15) shows that MFP can be decomposed into technological change and scale effect[7]. It also shows that the elasticity of the cost with respect to output can be decomposed into three components as well; (1) scale effect; (2) technological effect; and (3) input prices effect[8].

Regarding technological change, Hicks' neutrality of technological change exists if and only if $\beta_{it}=0$ for all i=K,L, and M, where β_{it} reflects the bias of the technological change with respect to the ith input. Thus, it can be said that technological change is ith-input-saving or ith-input-using if β_{it} is positive or negative, respectively. An estimate of the bias in technological change can be obtained by differentiating the ith input cost share equation with respect to technology (t) as follows:

$$(16)\quad B_i = \frac{\partial S_i(\cdot)}{\partial t} = \beta_{it}$$

Where the cost share of the ith input (S_i) is obtained by Shephard's lemma.

In order to examine the growth rate of input-specific productivity, define Q/X_i to be the ith input productivity, where Q and X_i are as defined above. It follows that the growth rate of the ith-input productivity can be obtained as:

$$(17)\quad \frac{\partial \ln(Q/X_i)}{\partial t} = -\frac{\partial \ln C}{\partial t} - \frac{\partial \ln S_i/\partial t}{\partial \ln C/\partial \ln P_i} = \zeta_{Ct} - \frac{\beta_{it}}{S_i^*}$$

That is, the growth rate of the ith-input productivity is composed of the growth rate of the overall technological change (ζ_{Ct}) and the ratio of the bias of technological change toward the ith input to the optimum cost share of ith-input (S_i^*). Hence, if Hicks neutral technological change is assumed ($\beta_{it}=0$, $\forall_i$) the growth rate of the overall technological change and that of the specific input will coincide.

Data: Measurement and Sources

The sources and the construction of the inputs and output data that are used for this

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7 That is, if constant returns to scale exist then the dual cost and primal measures coincide. Also note that the change in output over time can be expressed directly by employing the production function ($Q=f(X_i)$); $dQ/dt=\sum_i \partial f(.)/\partial X_i \cdot dX_i/dt + \partial f(.)/\partial t$.

8 However, it the underlying technology is a homothetic, the input prices would have no impact on the elasticity of cost with respect to output.

empirical investigation are discussed in this section. All time series data used for this research are obtained from the Department of Economic Planning, The Ministry of Finance and National Economy, the official economic-data source in the Kingdom of Bahrain. The time period covered in this study is from 1980 to 2002.

Gross Output (Q)

For all productivity measures, output is measured in physical or real values. For products to be regarded as a homogeneous commodity (production in physical units), certain conditions should be satisfied. Physical (quantity) data are often not readily available, but the value (monetary) data usually exist. However, these value data have to be separated into their quantity and price. Then, the value of output could be adjusted for price change by using appropriate price index. The adjusted value is usually known as constant price output which it has been employed in this study.

Labor Input (L)

The number of persons employed is defined as the total number of persons who is working in the industry, which includes working proprietors, active business partners, unpaid family workers, full-time employees, and part-time and seasonal workers. Part-time and seasonal workers are reckoned according to their full-time equivalents. In this study the real value of compensation is used as a measure of the labor input to take into account the difference in skills among workers, assuming that there is a strong relationship between wages and the worker' level of skill and experience. The compensation is defined as comprising of all payments, both in cash and kind, and the supplement to wages and salaries.

Capital Input (K)

In this study, a service price of the available capital stock is computed using the method outlined in Christensen and Jorgenson (1969 and 1970). In view of the fact that data on capital stock is available, an average annual capital depreciation rate of 10%[9] is assumed, then based on this rate, an estimate of capital stock was obtained[10].Thus, this price reflects as a measure of the flow of the capital service. The service price of capital is the opportunity cost of the respective capital stock plus depreciation[11] and net taxes. Opportunity cost is assumed to reflect average returns, which it is assumed to be on average 5%.

Intermediate Inputs (Other-inputs, M)

Intermediate-input are defined as equal to the real value of the purchases of materials and supplies for production. In other words, intermediate inputs represent the cost of all production inputs excluding the cost of labor and capital inputs.

Econometric Estimation and Empirical Results

The model presented above has no prior assumptions about the underlying technology, the degree of substitution among the production inputs, and the neutrality of technological change. However, following Shebeb et al (1996), Shebeb (2002), and based on some

[9] Depreciation is known that it is a measure which mainly refers to the capital consumed not capital services, and based on different accounting methods. For a justification of this assumption, see Hulten and Wykoff (1981a, 1981b).

[10] For example, the Capital Stock and the service price of capital in year 1980 is calculated as follows: K_{80} = (Depreciation$_{80}$ / 0.1) ⇨the service price of capital, $P_{K80} = K_{80}$*.05 + Depreciation$_{80}$+Tax$_{80}$.

[11] Due to many difficulties of measuring the capital flow, in productivity studies and in this study the capital depreciation is normally used in relations to the method mentioned above

preliminary estimations and hypothesis testing, a homogenous version of the model was estimated. The model is composed of the long-run translog function and three cost share equations (capital, labor, and other-inputs). The share cost equation of other-inputs (M) is dropped out to avoid singularity of the estimated covariance matrix which would arise due to the sum of the cost shares being unity. The estimates of the model's parameter are independent of which cost share equation is deleted. Additive normally distributed stochastic error terms are incorporated into the three equations of the model (cost function and two share equation). The error terms are assumed to be uncorrelated. The parameters of the model were then estimated using multivariate regression techniques. Efficient estimates of the parameters were obtained by Zellner's iterative technique (seemingly unrelated regressions) which is asymptotically equivalent to the estimate of maximum likelihood.

The estimated parameters of the model are reported in Table 1. All of the estimated parameters were statistically significant at a significant level less than 0.05, with the exception of two parameters that are related with output level and labor-bias technological change. It shows that the parameter related to the technological change and its rate of change were highly significance at the significant level less than 0.05. The estimates of the parameters reveal several key aspects about the underlying technology and technological change. Monotonicity of the cost function in prices is generally satisfied at the point of approximation. Generally, the estimates show that the estimated cost function *reasonably* satisfies most of the theoretical properties of a cost function. Thus, it could be employed as an approximation to the underlying cost function in Bahrain primary sector.

A hypothesis testing of non-constant returns to scale, the neutrality of technological change, and existence of technological change in Bahrain primary sector are conducted as follows:

Test 1: Constant returns to scale technology, H_o: $\beta_Q=1$

Test 2: Hicks neutral technological change, H_o: $\beta_{it}=0, \forall_i$

Test 3: Non-existence of technological change, H_o: $\beta_t=\beta_{tt}=0$.

These tests were carried out using the Wald test, the statistic of which is asymptotically distributed as a chi-square (χ^2) random variable under the null hypothesis with degrees of freedom equal to the difference between the number of free parameters estimated in the unconstrained and constrained models under investigation. The outcomes of these tests are reported in Table 2.

Table 1. The Model's Estimated Parameters

Estimation Method: Iterative Seemingly Unrelated Regression, Sample: 1980 2002, Convergence achieved after 16 iterations	Coefficient+	Std. Error
intercept	9.2190*	0.0535
log(Q)	-0.0045	0.1828
t	0.0434*	0.0089
tt	-0.0031*	0.0007
$\log(P_K)$	0.1911*	0.0056
$\log(P_L)$	0.4505*	0.0091
$\log(P_K)\log(P_K)$	-0.1659*	0.0307
$\log(P_L)\log(P_L)$	-0.1276*	0.0466
$\log(P_K)\log(P_L)$	0.1752*	0.0240
$\log(P_K)\,t$	-0.0061*	0.0005
$\log(P_L)\,t$	0.0010	0.0008
TC-Equation		
R-squared	0.5864	
S.E. of regression	0.0988	
S_K-Equation		
R-squared	0.9265	
S.E. of regression	0.0130	
S_L-Equation		
R-squared	0.2447	
S.E. of regression	0.0226	

+The estimates of the parameters of the omitted cost share equation could be calculated by exploiting the homogeneity restriction.
* Statistically significant at 0.01

Table 2. The Outcome of the Hypothesis Tests

Constant Returns to Scale, H_o: β_Q=1	Hicks Neutral technological change, H_o: $\beta_{it}=0,\forall_i$	No technological change, H_o: $\beta_t=\beta_{tt}=0$
30.1819 (0.0000)*	169.4666 (0.0000)*	23.7708 (0.0000)*

*Values in brackets refer to the P-value. That is, the minimum significance level at which the null hypothesis can be rejected.

It is clearly shown in Table 2 that the hypothesis testing of constant returns to scale technology has been rejected at less than the 0.001 significance level. This finding indicates that the elasticity of cost with respect to output does not equal unity which implies that the MFP growth rate is comprised of at least two parts; technological change and the scale effect. Therefore, technological change will be an invalid measure of MFP and needs to be adjusted for the existence of non-constant returns to scale. Neutrality of technological change, and non-existence of technological change tests were also rejected at the 0.001 significance level. Generally, these hypothesis testing results are very significant and reasonably acceptable.

It follows that the econometric estimations of MFP growth should be based on the results of the hypothesis tests presented above. That is, the calculation of the MFP growth rate and its decomposition are obtained based on the estimation of cost function (Table 1) with no prior restrictions involving neutrality of technological change. As shown in Table 1, the growth rate of technological change (ζ_{Ct}) at the approximation point was negative[12].

The multifactor productivity growth rate reported in Table 3 refers to the dual cost measure of multifactor productivity growth rate. This measure derives from the fact that technological change is no longer a valid measure of productivity growth when non-constant returns to scale exist. Thus, the MFP is more accurate and informative indicator of the overall performance.

In Table 3, the average annual rate of change of technological change and multifactor productivity of Bahrain primary sector are shown. These measures are reported over the selected time periods. First is the time period from 1980 to 1989, which refers to the time period prior Gulf War I. Second period is from 1990 to 1996, which refers to the time period post Gulf War I and it envelops the years of civil unrest conducts. The time period from 1997 to 2002, covers the years post to the civil unrest and the new theme of political and social stabilities.

Overall Bahrain primary sector had experienced a positive average annual growth rate of MFP over the time period covered in this study. Prior to the Gulf War I, the average growth rate of MFP was negative. However, after 1989 and up to year 1996, Bahrain primary sector had experienced a positive average growth rate of MFP. This finding may be explained as a result of scale operation changes in Bahrain primary sector, especially in fishery. This explanation has its support when the change in the cost-output relationship is considered. Post to the 1996, the negative growth rate of MFP may be explained as a result of scale and price components of the MFP measure.

Figure 1 shows the annual growth of multifactor productivity over the study time period (1980-2002) [13]. However, in the early 1990s, Bahrain primary sector had experienced an improvement in the average annual growth rate of technological change.

Table 4 presents an alternative measures to examine the economic performance in Bahrain primary sector. These are the growth rate inputs-specific (partial) productivity. It is evident from Table 4 that the average annual growth rate of capital productivity was increasing over all sub periods. In addition, over the time period covered in this study, capital productivity also showed a positive average annual growth rate of 4.3%.

[12] This finding could be thought of as a result of the lack of an efficient management in comparison to the most recent years in the study.

[13] For MFP year 1980 is lost due to the lag adjustment process, see equation 15.

Table 3. Economic Performance Measures of Bahrain Primary Sector

Time Periods	Technological Change*	Multifactor Productivity*
1980 to 1989	-0.0267	-0.0107
1990 to 1996	0.0004	0.0707
1997 to 2002	0.0206	-0.0020
Overall Mean	-0.0061	0.0176
Median	-0.0060	0.0134
Minimum	-0.0407	-0.1144
Maximum	0.0284	0.1754

* As it was defined in equation 15.

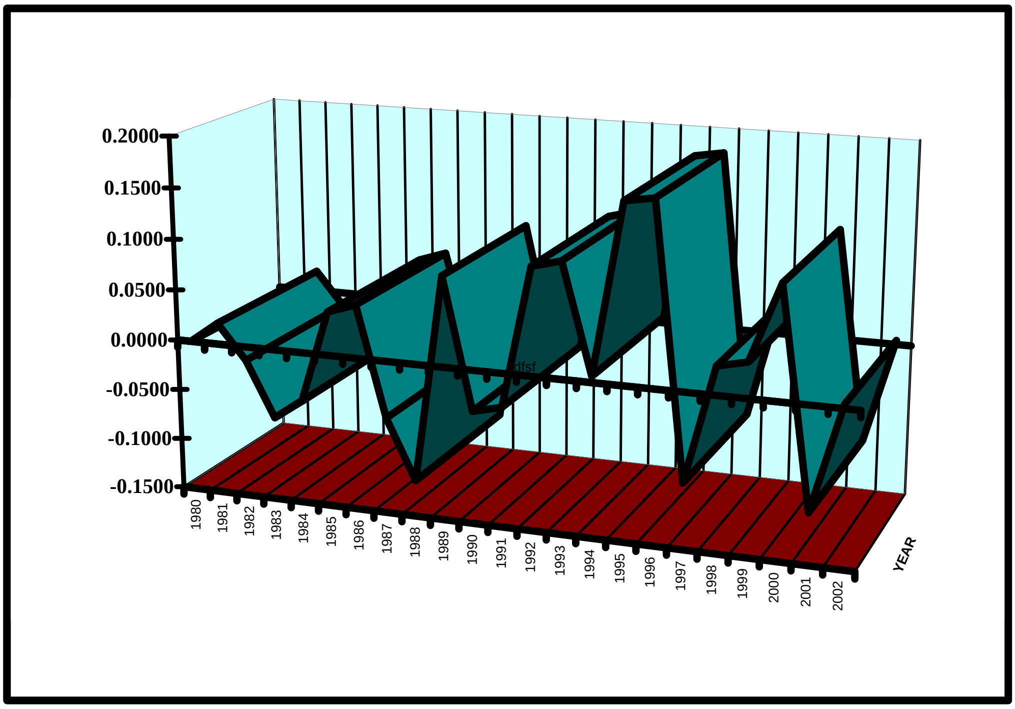

Figure 1. Annual Growth Rate of Multifactor Productivity In Bahrain Primary Sector

Table 4. Growth Rates of Partial Productivity In Bahrain Primary Sector

Time Periods	Capital	Labor	Other-Inputs (intermediate-inputs)
1980 to 1989	0.0078	-0.0290	-0.0401
1990 to 1996	0.0582	-0.0002	-0.0100
1997 to 2002	0.0827	0.0168	0.0076
Overall Mean	0.0430	-0.0083	-0.0185
Median	0.0473	-0.0081	-0.0182
Minimum	-0.0105	-0.0430	-0.0548
Maximum	0.0968	0.0262	0.0172

As shown it Table 4, the average growth rate of the labor productivity was negative prior to 1997. However, technological change could have a positive impact on the growth of labor productivity over the time period of 1997 to 2002, as it was shown in Table 3 above. The intermediate-input productivity growth rate is considered to be one of the most important partial productivity measures in the context of a resource-based industry. It indicates the improvement in the production process of the output and how efficient is the technology of production. Table 4 shows that the average annual growth rate of intermediate-input productivity had improved over the sub periods of 1990-1996 and 1997-2002. However, it has a negative average growth rate of 1.85% over the study time period (1980-2002).

The bias of the technological change in Bahrain primary sector is reported in Table 5. The bias of technological change is estimated using equation (16). Table 5 shows that technological change was biased towards capital saving. This finding was expected since it is consistent with the movements of the average annual growth rate of capital which it was, mainly, a result of the intensities of other production factors.

Table 5. The Bias of the technological Change in Bahrain Primary Sector.

Input	Bias of the technological Change*
Capital	Saving
Labor	Using
Intermediate Inputs	Using

*See equation 11.

The findings of Table 5 also indicates that the technological change was biased toward intermediate-input-using which shows that Bahrain primary sector is not that much concerned about the conservation and management of its natural resources. This finding also implies that the Bahrain primary sector did not invest enough in the new technology that could have helped to improve and save its resources. The materials-using bias of technological change in the Bahrain primary sector may be explained as a result of the relative price of capital to other intermediate inputs which encouraged the substitution of other-inputs for capital, and thus decreased the cost of employing labor- and other-inputs- saving innovations. It follows that a policy may be needed to encourage the use of materials-saving innovations.

Summary and Concluding Remarks

The objective of this study was to measure and analyze economic performance and determine the impact of scale economies and technological change on the growth rate of multifactor productivity in Bahrain primary sector, agriculture and fishing sector.

It followed that in order to meet the objective of this study, an empirical investigation and implementation of the underlying theory of productivity measurement was performed. The impact of scale economies and technological change on MFP growth rate was considered. The economic performance indicators that were analyzed in this study included technological change and multifactor productivity (technological change that was adjusted for economies of scale) growth rate over the time period from 1980 to 2002.

The empirical estimations of the economic performance measures were obtained by exploiting the dual cost form of the underlying production technology. The translog functional form was employed in estimating the cost function. Most of the theoretical properties of a well behaved cost function were satisfied.

Several tests were conducted on the structure of the underlying technology in Bahrain primary sector. Homogeneity of degree one (constant returns to scale) was rejected in Bahrain primary sector which leaves no room for accepting any economic studies assuming the existence of constant returns to scale. The test indicates that the level of output has a significant impact on the cost-minimization inputs mix. Hicks neutral technological change was also rejected. It follows that the technological change shifts the isoquant and changes the marginal rates of substitution between inputs which leads to a change in the cost share of inputs over time. The hypothesis test of “no technological change” was rejected at less than the .01 significance level.

Two measures of the overall economic performance of Bahrain primary sector were analyzed. These were technological change and multifactor productivity(a cost-based measure of the primal measure of multifactor productivity). The growth rate of technological change at the approximation point was negative. The estimated average annual growth rate of MFP was positive over the study time period.

Technical change was found to be biased towards capital-saving and labor- and material- using, possibly as a result of the change in relative prices of capital. This finding suggests government policy that attracts investment in resources-saving innovations.

To conclude, the empirical analysis performed in this study suggests that the productivity gain in Bahrain primary sector has been a result of scale economies and the impact of the change in the relative prices of inputs. It implies that the competitive position and power of Bahrain primary sector is basically dependent on the reduction in the average cost associated with scale economies. The impact of technological change was mostly negative. Thus, the findings suggest that Bahrain primary sector need to improve its performance to reduce the cost of production, thereby, leading to a better competitive position by adopting new techniques and investing in the new technology as well as the investment in human capital via intensive workshops and training programs.

Appendix A: Data Set

Table A1. Model's Data Set.

Year	Q	TC	P_K	P_L	P_M	S_K	S_L	S_M
1980	18273.600	11616.150	0.907	1.004	0.961	0.199	0.399	0.402
1981	19483.500	11637.100	1.040	1.059	1.025	0.193	0.416	0.391
1982	19913.800	10756.100	1.103	1.134	1.070	0.158	0.480	0.362
1983	19147.500	10795.800	1.113	1.213	1.108	0.177	0.464	0.358
1984	18736.300	11528.700	1.054	1.219	1.148	0.186	0.459	0.354
1985	20137.600	14234.100	0.974	1.226	0.880	0.199	0.426	0.375
1986	21698.600	14221.300	0.896	1.274	1.017	0.209	0.408	0.382
1987	20936.800	14602.950	0.883	0.983	0.983	0.191	0.441	0.368
1988	18889.000	13002.300	0.887	1.142	0.990	0.187	0.444	0.369
1989	20976.300	13467.900	1.000	1.000	1.000	0.108	0.466	0.426
1990	20338.100	13383.550	1.055	1.000	1.028	0.102	0.471	0.427
1991	19782.300	13772.100	1.071	1.050	1.032	0.120	0.471	0.409
1992	22005.700	15079.200	1.084	1.077	1.013	0.117	0.467	0.416
1993	24312.600	16412.600	1.165	1.140	1.000	0.111	0.490	0.398
1994	24359.900	14395.200	1.195	1.208	1.064	0.101	0.469	0.430
1995	27782.200	13360.950	1.199	1.280	1.087	0.104	0.432	0.465
1996	31244.200	15206.900	1.146	1.305	1.050	0.095	0.464	0.441
1997	29187.000	14163.250	1.152	1.337	1.072	0.099	0.443	0.458
1998	29402.900	14137.050	1.334	1.357	1.023	0.099	0.442	0.459
1999	29716.100	14343.300	1.126	1.353	1.036	0.097	0.455	0.449
2000	31531.800	15408.700	1.117	1.292	1.129	0.095	0.430	0.475
2001	28922.400	13728.150	1.114	1.423	1.026	0.091	0.478	0.431
2002	28416.000	14401.300	1.093	1.354	0.971	0.093	0.465	0.442

Acknowledgement

This study was financially supported by the Scientific Research Council, Deanship of Scientific Research, University of Bahrain, project #1/2003.

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