Measuring Productivity Growth in the Bahraini 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 adjusted for economies of scale, and to measure and analyze the growth rate of partial (input-specific) productivity in the Bahraini Agriculture and Fisheries 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 impact 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 reason 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.

1. Introduction

Bahrain's first five-year economic and social development plan (1982-1986) came in 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 the 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 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 would be the development and expanding of the agricultural and fishery sector (primary sector). Over last decade, the average contribution of Bahrain agriculture and fisheries sector to the gross domestic product (GDP) was about 1%. As the fishery sector stand alone, its contribution to the GDP was about 0.3%. However, the primary sector of Bahrain, which is labor-intensive, 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 U.N. Food and Agriculture Organization (FAO). Bahrain also considered getting onto international and regional agreements establishing a fair and market-oriented trading system through programmed reforms and encompassing strengthened rules in order to correct or prevent restrictions and distortions in agricultural markets. In addition, and in accordance with 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 the face of international harsh competition. Thus, it is 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 multifactor productivity and its main components which can be used as powerful analytical tools in evaluating the economic performance of Bahrain primary sector.

The main objective of this study is to measure and analyze the most important components of economic performance, mainly multifactor productivity growth rate and technological change, in the primary sector of Bahrain over the time period 1980-2002. In addition, the study aims to measure and analyze the partial (input-specific) productivity growth rate and the bias of technological change in this sector, another powerful analytical tool in evaluating its performance.

This study is organized in the following way: Section 2 presents an overview of the Bahraini primary sector. Section 3 presents a review of the underlying theory of multifactor productivity measurement. Furthermore, in this section the relationship between multifactor productivity and technological change is also discussed. The model used in estimating the level of multifactor and partial productivity growth rates in the Bahraini primary sector is introduced in Section 4. The data used in the empirical investigation are defined in Section 5. The empirical findings are presented and analyzed in Section 6. Finally, a summary of the study and the concluding remarks are presented.

2. Bahrain Primary Sector: An Overview

Despite the low rate of rainfall and poor soil, agriculture historically was an important sector of the Bahraini economy. Before the 1940s, dates was the major product of Bahrain's agriculture. Dates production was domestically consumed and exported. From the 1950s and up to the 1970s, the demand for date was declining dramatically as a result of social and economic changes affecting food consumption habits. This led to gradual decline in the dates supply. 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 land was decreasing from 11,109 Donums (1000 square meters) in the year 1994/1995 to less than 8,500 Donums in the 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-owned farms. In addition, the number of skilled farm workers progressively declined since the late 1970s due to the availability of relatively high-paying non-agricultural jobs.

In spite of the long history of agriculture in Bahrain, some problems such as a limited supply of skilled labor, limited new investments, and low capital-intensity were common in this sector. The shortage of financial resources has been the main barrier in achieving sustainable agricultural development in Bahrain. This called for urgent cooperation between private and public sectors to develop agricultural projects.

However, regardless of these obstacles, government policy has been aiming 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. The agricultural production has shown an increase over the last few years (early 2000s). However, the limited area of Bahrain's agricultural land restricted the island's possible productive capacity. Thus, agricultural imports including fruits, vegetables, meat, live animals, and dairy products remain one of the main items of Bahrain international trade.

As for fisheries sector, 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 high and steady wages in other jobs. In 1998, only 1,655 Bahraini fishermen were working full time in this sector despite rising demand. Consequently fish imports increased to satisfy local demand.

As the rate of land reclamation and level of pollution in the Arabian Gulf were increasing, fishing 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 leak out, especially those of 1991, destructively affected the regional fishing industry. The long-term ecological impact of the pollution remained uncertain.

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

Recently, officials called for closer cooperation with fishermen to preserve and enhance Bahrain's fish stocks to protect the present and future resources. Officials also strived for enforcement of the existing laws in order to control fishing abuses due to illegal fishing practices.

3. Productivity Measurement: A Dual Cost Approach

In this paper, a non-frontier long-run cost function will be employed to measure economic performance of the Bahraini primary sector. There are two assumptions underlying this empirical investigation are due as follows: (1) all producers are economically efficient; and (2) all input levels are adjusted instantaneously to their optimal levels according to their market prices. 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 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 aggregate level of output, X is aggregate level of inputs vector, and t denotes the state of the available technology, time trend. Technological change is defined as an upward shift in the production function. It follows that if production is efficient and capacity is fully utilized, a primal measure of technological change, productivity growth, may be obtained by differentiating the log of the aggregate production function with respect to time (t), as follows:

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

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

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

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

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

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

In equation (2), the primal rate of technological change or productivity growth 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. It follows that a formalization of the dual cost measure of technological change or productivity growth for a single product technology can be based on defining the minimum dual cost function[2].

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. This function is assumed to be the lowest cost for a given level of output Q, given input prices and 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 total production cost as follows:

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[2] This implies that no fixed or quasi-fixed inputs exist in the long-run equilibrium.

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

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

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).

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

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

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

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

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

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:

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

In addition, 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:

$$(9) \qquad \mathrm{MFP} = \zeta_{Ct} + (1 - \zeta_{CQ}) \frac{d \ln Q}{dt}$$

That is, if constant returns to scale exist ($\zeta_{CQ} \equiv (\partial \ln C/\partial \ln Q)^{-1} = 1$) then the dual cost and primal measures of MFP will coincide.

4. Productivity Measurement Model: Econometric Framework

This section presents a detailed discussion of the long-run translog cost function[3]. The discussion of the theoretical properties and regularity conditions of the cost function for the translog technology is considered at the point of approximation[4]. A single-output non-

[3] 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).

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

homothetic translog cost function with non-neutral Hicksian technical change and symmetry condition[5], $\beta_{ij}=\beta_{ji}$, can be written as follows:

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

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, $C = \sum_i P_i X_i$

t : disembodied technological change, time trend.

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:

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

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:

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

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

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. 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 in the model[6]. 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 measurement[7].

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

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

(13) or

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

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[6] Hence, if all β_{ij} and β_{iQ} are zero, the translog 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).

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

Since both ∂lnC/∂lnQ and ∂lnC/∂lnP_i are functions of the observed output and inputs levels respectively for a given t, the monotonicity conditions can be reduced to $\beta_Q>0$ and $\beta_i>0$ at the point of approximation. 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) $$\text{MFP} = \zeta_{Ct} + (1 - \zeta_{CQ}) \frac{d \ln Q}{dt}$$

where

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

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

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

Equation (15) shows that MFP can be decomposed into technological change and scale effect[8].

[8] 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 ($Q=f(X_i)$); $dQ/dt=\sum_i \partial f(.)/\partial X_i \cdot dX_i/dt + \partial f(.)/\partial t$. It is worth to note that if the underlying technology is a homothetic, the input prices would have no impact on the elasticity of cost with respect to output.

Regarding technological change, Hicks neutrality of technological change exists if and only if β_{it}=0 for all i=K,L, and M, where β_{it} reflects the bias of the technological change with respect to the i^{th} input. Thus, it can be said that technological change is i^{th}-input-saving or i^{th}-input-using if β_{it} is positive or negative, respectively. An estimate of the bias in technological change can be obtained by differentiating the i^{th} input cost share equation with respect to technology (t) as follows:

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

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

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

That is, the growth rate of the i^{th}-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 i^{th} input to the optimum cost share of i^{th}-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.

5. Data: Measurement and Sources

All time series data used for this research are obtained from the Department of Economic Planning, the Ministry of Finance and National Economy. 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 monetary value 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 the appropriate price index. The adjusted value is usually known as "constant price output" which has been employed in this study.

Labor Input (L)

The number of persons employed is defined as the total number of persons 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 labor input to take into account the difference in skill 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)

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 used, and based on this rate, an estimate of capital stock was obtained[10]. The service price of capital is the

[9] Depreciation 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: $K_{80} = (Depreciation_{80} / 0.1) \Rightarrow$ the service price of capital, $P_{K80} = K_{80}*.05 + Depreciation_{80}+Tax_{80}$.

opportunity cost of the respective capital stock plus the depreciation[11] and net taxes. The opportunity cost reflects the average returns which is assumed to be 5%.

Intermediate Inputs (Other inputs, M)

Intermediate input is defined as 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.

6. 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 preliminary estimations and hypothesis testing, a homogenous version of the model was estimated. The model consists of the long-run translog function and three cost-share equations (capital, labor, and other-inputs). The cost-share 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 parameters are independent of which cost-share equation is dropped. Additive normally distributed stochastic error terms are incorporated into the three equations of the model (cost function and two cost-share equations). 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).

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

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

change. Table 1 also shows that the parameter related to the technological change (t) and its rate of change (t^2) were highly significant at the 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 of the underlying cost function in the Bahraini primary sector.

Table 1: The Model's Estimated Parameters

Estimation Method: Iterative Seemingly Unrelated Regression, Sample: 1980 2002, Convergence achieved after 16 iterations		
Variables	**Coefficient+**	**Std. Error**
Intercept	9.2190*	0.0535
ln Q	-0.0045	0.1828
t	0.0434*	0.0089
t^2	-0.0031*	0.0007
ln P_K	0.1911*	0.0056
ln P_L	0.4505*	0.0091
ln P_K ln P_K	-0.1659*	0.0307
ln P_L ln P_L	-0.1276*	0.0466
ln P_K ln P_L	0.1752*	0.0240
ln P_K t	-0.0061*	0.0005
ln P_L t	0.0010	0.0008
C-Equation		
R-squared	0.5864	
S.E. of regression	0.0988	
S_i-Equation for i = K		
R-squared	0.9265	
S.E. of regression	0.0130	
S_i-Equation for i = L		
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

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

Test 1: Constant returns to scale technology, H_o: β_Q=1

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

Test 3: Non-existence of technological change, H_o: β_t=β_{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 2: The Outcome of the Hypothesis Tests

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

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

It is clearly shown in Table 2 that the hypothesis test 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 the 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 the Bahraini 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 to Gulf War I. The 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 era. The time period from 1997 to 2002 covers the years post the civil unrest era, the political and social stabilities.

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

Table 3: Economic Performance Measures of the Bahraini 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 was defined in equation 15.

Overall the Bahraini 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 up to year 1996, the Bahraini 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 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, the Bahraini primary sector had experienced an improvement in the average annual growth rate of technological change.

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

Figure 1: Annual Growth Rate of Multifactor Productivity in the Bahraini Primary Sector

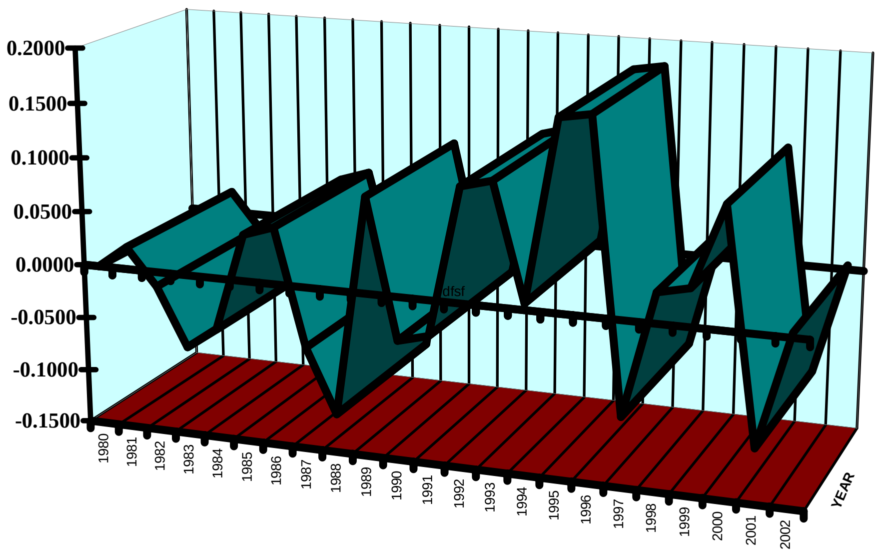

Table 4 presents alternative measures to examine the economic performance in the Bahraini primary sector. These are the growth rates of the labor, capital, and intermediate inputs productivity. It is evident from Table 4 that the annual growth rate of capital productivity was increasing with an average annual growth rate of 4.3% a year over the time period covered in this study.

Table 4: Growth Rates of Partial Productivity in the Bahraini 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, as was shown in Table 3 above technological change had a positive impact on the growth of labor productivity over the time period of from 1997 to 2002. 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 improvement in the production process of the output and the efficiency in the technology of production. Table 4 shows that the average annual growth rate of intermediate inputs 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 the Bahraini primary sector is reported in Table 5 and it 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 was mainly a result of the intensities of other production factors.

Table 5: The Bias of the technological Change in the Bahraini Primary Sector

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

*See equation 11.

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

7. Summary and Concluding Remarks

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

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 (equation 15). The economic performance indicators that were analyzed in this study included technological change and multifactor productivity growth rate (technological change that was adjusted for economies of scale) 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 the Bahraini primary sector. Homogeneity of degree one (constant returns to scale) was rejected 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 testing of no technological change was rejected at less than 0.01 significance level.

Two measures of the overall economic performance of the Bahraini 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 calls for government policy that attracts investment in resources-saving innovations.

To conclude, the empirical analysis performed in this study suggests that the productivity gain in the Bahraini 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 the Bahraini primary sector basically depend on the reduction in the average cost associated with scale economies. The impact of technological change was mostly negative. Thus, the findings suggest that the Bahraini primary sector need to improve 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.

However, 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 the 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.

Appendix : 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

Sources: Department of Economic Planning, the Ministry of Finance and National Economy.
And author calculations based on the empirical model.

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