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Technical Progress and its Impact on the Libyan Economic Growth

Abdalmatlub A. Taher

Faculty of Economics, Omar Al-Mukhtar University, Al-Beida, Libya

Abstract: The main goal of the present study was to contribute to the understanding of the role played by technical progress in the Libyan non-oil productive sector during the period 1970-2008. For this reason two distinct approaches were reviewed, the direct or parametric approach and the indirect or non-parametric approach. Within the direct approach three indices were constructed, i.e. Solow, Kendrick and Wan indices and within the non-parametric approach three specifications were also given to technological change; constant, variable and continuous and variable and discrete. The most important finding of the current study was that the technical progress has a positive impact on the economic growth of the non-oil productive sector during the period under consideration. In conclusion, the Libyan non-oil productive sector gained from technical progress.

Key words: Non oil productive sector · Technical progress · Output · Factor inputs · *Economic growth* · Libya

INTRODUCTION

Technical progress is any change in the production function which make it possible to produce more output by using the same quantity of inputs, or that means that the same amount of output can be produced by employing smaller quantities of one or more inputs [1]. It may be also defined as a shift in the production function, while accumulation of factors is identified with a movement along the function. Technical progress is knowledge and it is the core of economic growth. It is an umbrella term to cover all factors, which contribute to the growth of total productivity [1]. Kennedy and Thirlwall [2] cited Tinbergen [3] who was the first to explicitly estimate technical progress as a separate item in the aggregate production function in the case of the Cobb-Douglas (C-D) production function, using an exponential time trend.

Economic growth theories do not fit all the facts so far. They stated that Gross Domestic Product (GDP), labour and capital must grow to achieve growth in the economy. It is true that capital and GDP do not grow at the same rate. However, they grow more rapidly than labour, the reason for which may lie in technical progress. Solow [4] introduced a mathematical model, which showed the contribution of various factors to national economic growth. He stressed that technical progress supports economic growth more than labour and capital accumulations. Solow's studies helped the US government to redirect their investment to technological research and development in order to improve economic growth [5].

Purposes of the Study: The main purpose of this study is to present an analytical review of the role played by technical progress in the economic growth of the Libyan non-oil productive sectors during the period 1970-2008. The productive sectors have been selected as a case study in this work, because of the large amount of investment allocated to these areas. More practically, this study will answer the following research questions: What is the contribution made by technical progress to the growth of output in the Libyan productive sectors and what conclusions can be drawn?

Motivation and Contribution: The importance of this study arises from the fact that this study is the first attempt to determine the contribution made by technical progress to the growth of output in the Libyan productive sectors. Therefore, the current study is considered to be the first of its kind according to the author's knowledge.

Corresponding Author: Abdalmatlub A. Taher, Faculty of Economics, Omer AlMukhtar University, Elbeida, Libya

Research Methodology: This research adopts a positivist approach and is based on quantitative data. The sources of information are bibliographical reviews, articles, periodicals, the internet and theses regarding the research topic. It also involves published data which are obtained from government organizations. The growth of output, driven by the growth of technical progress, has been chosen as the research aim in this study because of their importance to economic development. Interrelation between changes in production factors and change in technical progress and their impact on growth of output are modelled and tested using econometric techniques. The method used in this study is consistent with previous studies in this field.

Data Collection and Issues: The data used in this study are the time series of Gross Domestic Product (GDP), net capital stock (K) and labour, in terms of the number of people employed, (L). The period 1970-2008 is covered by the study. The sources of the data are: the Libyan Ministry of Planning, the Libyan Ministry of the Economy; Libyan Central Bank; publications of the League of Arab States; publications of the International Monetary Found (IMF); and the Arab Organization for Agricultural Development.

Technology Importance for Economic Development: Classical economists ignored the role of technology and its impact on economic growth. They stated that technical progress might postpone economic recession, but not indefinitely. The club of Rome model also doubted the ability of technical progress to achieve growth. Harrod [6] and Hicks [7] as cited in Thirlwall [1] emploied the concept of the capital-output ratio, given the rate of profit, to classify technical change as capital-saving if it lowers the capital-output ratio and as labour- saving if it raises the capital-output ratio and as neutral if it leaves the capital-output ratio unchanged. According to neo-classical and endogenous theories, technical progress had a vital role in influencing the productivity of input factors. Solow [4] described technical progress as exogenous. However, Romer [8], Parente and Prescott [9], Barrow and Sala-i-Martin [10] and Eaton and Kortum [11] described technical progress as endogenous. It was believed that there were no diminishing returns to capital, especially when capital includes human capital, because of technology. The assumption that poor countries would grow faster than rich ones and that per capita income across the world would converge, would disappear. Loo and Soete, [12] cited Arrow [13] who indigenized technology by assuming learning by doing, stated that technical progress grew at a constant rate and found that long-run economic growth crucially depends on population growth.

Classical economists believed that economic growth would be only in the short-run and the growth of an economy is determined by the accumulation of capital. They ignored the role of technical progress and its impact on economic growth. Classical economists also stated that technical progress may postpone economic recession, but not indefinitely. The Club of Rome model also doubted the ability of technological progress to improve economic growth. It believed that there are essential factors affecting economic growth, namely population, food production, industrialization, environmental pollution and resource depletion. They supposed that those five factors grow at an exponential rate and faster than technical progress. Therefore, their theory asserts that economic growth would stop in less than 100 years, because of the growth or otherwise of the five essential factors [14].

Despite the pessimistic view regarding the economic growth in the long-run, classical economists provided essential ideas and basic insights, which inspired modern theories of economic growth. Harrod and Domar were concerned with explaining the relationship between the growth of the economy and growth of labour. They also believed that economic growth in the long-run is impossible [15].

Consequently, the neo-classical and endogenous growth theories came to explain the possibility of economic growth in the long-run. Neo-classical theory has adopted all the assumptions as given in the Harrod-Domar model, except the assumption of fixed proportion of inputs. Neo-classical theory assumed the possibility of substitution of inputs in the production process in the long-run. It had a vital role in shedding light on essential variables (technical progress and capital accumulation) which influence the productivity of factor inputs.

However, the shortcoming of neo-classical theory, as the endogenous growth theory stated, is the assumption that poor countries will grow faster than rich ones, leading to the convergence of per capita income across countries. Endogenous growth theory also criticised the assumption within neo-classical theory that technical progress is exogenous [1].

Many economists are not satisfied with the exogenous nature of technological advancement, which is the major source of growth in the steady state in the Solow model. Based on what was learned from Solow's literature, [16, 13, 1,7, 18, 8] made technology endogenous by introducing knowledge or human capital into the production function along with physical capital. Lucas models human capital accumulation to be a direct outcome of time spent on studying and learning rather than at work. If people spend more time in studying, they learn more and become more skilled. This raises per capita human capital available in the economy, which complements physical capital and raises the skill and the productivity of workers. Such a rise in productivity is the major source of economic growth.

Barrow and Martin [19] believed that technical progress is endogenous. They also assumed the absence of diminishing returns to capital, especially when the capital includes human capital and their assumption is based on the fact that there are positive externalities, which affect the productivity of labour, such as education, training and research and development (R&D), as well as technological transfer. This will cancel the assumption that poor countries will grow faster than rich ones, as well the assumption of convergence of per capita income across the world [20].

According to neo-classical and endogenous growth theories, it can be seen that there is a possibility of economic growth in the long-run and this mainly depends on labour, capital and the factors which affect the productivity of these elements, such as technical progress.

Types of Technology: There are two kinds of technology, i.e. neutral and non-neutral. Neutral technology is expressed through change in the degree of return to scale and change in technology efficiency [21]. It is change in production resulting from the change in production factors. With neutral technical progress the production function shifts such that the new point of tangency at the same factor-price ratio lies on the same expansion path. This means that the ratio of marginal products has the same capital-labour ratio and equal proportionate amounts of the two factors are saved. The condition for neutral technical progress is simply that the new production function is parallel to the old.

However, non-neutral technology is that which affects one of the production factors, whether labour or capital. This kind of technology reflects that technical change is capital or labour intensive: an increase in capital intensity because of new investment would result in an increase in total productivity. With non-neutral technical progress, the ratio of the marginal product of capital to the marginal product of labour rises in the case of labour-saving technical change, such as a shift in the minimum-cost point of tangency from the old expansion path. However, in the case of capital-saving technical progress, the marginal product of labour to the marginal product of capital rises and the shift in the production function is such that the minimum-cost point of tangency now lies to the right of the old expansion path [1].

Measuring Technological Progress Methods: There are two approaches to measuring the effect of technical change on economic growth. These approaches are the indirect or non-parameter method and direct or parameter method. The direct method, unlike the indirect, assumes that technical change is one of the production factors and it may take a variable value. In other words, the rate of technical change in this case is assumed to be a variable. [22, 4, 23] used the non-direct method; they assumed that rate of technical change is constant. Solow [4] in his well-known pioneering paper derived and estimated the neutral rate of technical change through a two-factor aggregate production function. Solow assumed that technical change is Hicks neutral, which does not change the marginal rate of substitution of capital for labour into a constant capital-labour ratio. The author also assumed full competitive markets of production factors; meaning factors are paid their marginal product [24]. There are two ways to measure the contribution made by technical progress. These ways are: firstly, the indirect or non-parametric approach implying the methods of Solow [4], Kendrick [23] and Wan [25]. The second way is the direct approach or the parametric approach, implying a constant and variant Hicks neutral technical progress method. The direct approach and the Solow method were adopted in this study because they are mostly common used according to previous studies [26].

Solow's Method: Solow [4] considered a standard neoclassical production function with constant returns to scale, in order to isolate change in output per head due to technical change. Solow said that if Q represents output and K and L are production factors which are capital stock and labour respectively and they are measured as physical units, the aggregate production function would be written as follows:

$$Q = f(K, L, t) \quad (1)$$

The variable t for time appears in f to allow for technical change.

Solow used technical change as a short hand expression for any kind of shift in the production function, such as improvement in the education of the labour force. He assumed that technical change is Hicks neutral. Thus, the production function would take the following special case:

$$Q = A(t) f(K, L) \quad (2)$$

where A is a term representing the unknown residual "technical progress" at time t and the multiplicative factor $A(t)$ measures the cumulated effect of shifts over time.

Differentiating both sides of equation (2) with respect to time and dividing them by Q would obtain the following form:

$$\frac{\overset{*}{Q}}{Q} = \frac{\overset{*}{A}}{A} + A\frac{\partial Q}{\partial K}\frac{\overset{*}{K}}{Q} + A\frac{\partial Q}{\partial L}\frac{\overset{*}{L}}{Q} \quad (3)$$

where the asterisks indicate time derivatives.

According to the assumptions of neo-classical theory (Hicks neutral technical change, competitive equilibrium, constant returns to scale and factor rewards being determined by marginal product) the factor inputs are paid their marginal product, this means that:

$$r_K = \frac{\partial Q}{\partial K}\frac{K}{Q} \text{ and } w_L = \frac{\partial Q}{\partial L}\frac{L}{Q}$$

where r_K and w_L are prices of capital and labour respectively. Substituting them in equation (3) the result would be as follows:

$$\frac{\overset{*}{Q}}{Q} = \frac{\overset{*}{A}}{A} + r_K\frac{\overset{*}{K}}{K} + w_L\frac{\overset{*}{L}}{L} \quad (4)$$

where $\overset{*}{Q} = \frac{\Delta Q}{Q} = r_Q$, $\overset{*}{A} = \frac{\Delta A}{A} = r_T$, $\overset{*}{K} = \frac{\Delta K}{K} = r_K$ and $\overset{*}{L} = \frac{\Delta L}{L} = r_L$

Thus, equation (4) will take the following form:

$$r_Q = r_T - \alpha r_K - \beta r_L \quad (5)$$

where r_Q is the rate of change in output per time period because of technical progress, r_T is the annual rate of growth of total productivity of factors, or technical progress, r_K is the annual rate of growth of capital, r_L is the annual rate of growth of labour and α and β are the partial elasticity of output with respect to capital and labour respectively and they represent the shares of production factors in output.

Technical change rate can be calculated from equation (5) as follows:

$$r_T = r_Q - \alpha r_K + \beta r \quad (6)$$

Wan's Method: Wan [25] presented a new non-parametric approach to calculate the rate of total factor productivity (TFP) growth. Wan claimed that the traditional approaches of growth accounting, such as Solow [4], depend on certain assumptions, such as profit maximization and perfect competition, which may be inappropriate for some centrally planned economies. He ignored some of these limiting assumptions in his approach. His method to estimate the rate of technical change was derived from the definition of added values; added value is equal to the sum of the amount of production factors, which are weighted by their prices. The author assumed production function in the case of two factors, which are labour (L) and capital stock (K). The production function was proposed as follows:

$$Q_t = f_t(L_t, K_t) \quad (7)$$

There was no explicit reference to time in the above equation, Wan assumed constant technological return to scale. Wan said that technical change occurs when functional form changes. This means that $f_1 \neq f_{t+1}$. According to Wan's approach, technical change affects the form of a function, or its parametric, or both. However, in the traditional approach, technical change is only reflected in varying parametric values of a production function. Wan's method depends on the fact that technical change enables firms to produce the same amount of output with fewer (cost) factor inputs. Optimal production will be achieved. Mathematically when the curve slant of production is equal to the curve slant of cost function, this means:

$$Y_0 = TC_0 = w_0 L_0 + r_0 K_0 \quad (8)$$

where 0 represents base year and Y_0, TC_0, L_0, K_0, w_0 and r_0 are output, total cost, labour, capital stock, wages and profits respectively and all are measured in real values. Wan claimed that when technical change occurred, either the amount of production factors would increase or their prices would decline, then the production function changes. The new production function would be written as follows:

$$Y_1 = TC_1 = w_1 L_1 + r_1 K_1 \quad (9)$$

Wan said that technical change (*TE*) is the difference between the cost of producing Y_2 using the same technology used to produce Y_0 and the cost of producing Y_1 using different technology, but with the base prices of production factors. Where Y_2 is another production function, its form changes because of technical change. Thus:

$$TE = (w_0L_2 + r_0K_2) - (w_0L_1 + r_0K_1) \quad (10)$$

Consequently, according to Wan the rate of technical change is the saving in cost resulting from using fewer factor inputs. Assuming that:

$L_2 = \gamma L_0$ and $K_2 = \gamma K_0$

where γ is constant value and assuming a constant return to scale, Wan said that:

$Y_2 = \gamma Y_0$

Rearranging equation (10) gives:

$$TE = (w_0\gamma L_0 + r_0\gamma K_0) - (w_0L_1 + r_0K_1) \quad (11)$$

Wan said that the rate of technical change or growth of total factor productivity is equal to *TE* divided by Y_1, thus:

$$TE / Y_1 = [(w_0\gamma L_O + r_0\gamma K_0) - (w_0L_1 + r_0K_1)]/(w_1L_1 + r_1K_1)$$

From definition:

$\gamma = Y_2/Y_0$ and $Y_2 = Y_1$

Thus:

$$T/Y_1 = \frac{(Y_1/Y_0)(w_0L_0 + r_0K_0) - (w_0L_1 + r_0K_1)}{(w_1L_1 + r_1K_1)} \quad (12)$$

Wan used equation (12) to measure the rate of technical change, he comparing his result with those obtained applying Solow's method. Wan concluded that the results were very similar.

Kendrick's Method: Kendrick's method of measuring technical change is based on the comparison between the input and output of the production function [23]. Production factors are often measured by their contribution to national income and where a fully competitive market is assumed, so the production factors will be measured at their cost. The income function would be written as follows:

$$Q = wL + rK \quad (13)$$

where Q is output, w is wages, r is profit and L and K are labour and capital respectively. Assuming that wages and profit are constant, the change will happen in production factors. Therefore, we can obtain the rate of growth from the following function:

$$\frac{Q_1}{Q_0} = w_0\frac{L_1}{L_0} + r_0\frac{K_1}{K_0} \quad (14)$$

where $L_1 = \Delta L$ and $K_1 = \Delta K$

Usually growth in production is greater than the contribution of production factors in the production process. The difference is due to technical change and this requires the addition of another factor to the function, which is T. Thus the final form of the equation would be as follows:

$$\frac{Q_1}{Q_0} = T_0\left[w_0\frac{L_1}{L_0} + r_0\frac{K_1}{K_0}\right] \quad (15)$$

This equation could be rewritten as follows:

$$T_0 = \frac{\frac{Q_1}{Q_0}}{w_0\frac{L_1}{L_0} + r_0\frac{K_1}{K_0}} \quad (16)$$

where T is the rate of technical change.

The rate of technical change in the case of the Constant Elasticity of Substitution (CES) production function is calculated as follows:

$$T_0 = \frac{\frac{Q_1}{Q_0}}{\left[\delta\left[\frac{K_1}{K_0}\right]^{-\rho} + (1-\delta)\left[\frac{L_1}{L_0}\right]^{-\rho}\right]^{-1/\rho}} \quad (17)$$

And in the case of the Cobb-Douglas production function (C-D) is calculated as follows:

$$T_0 = \frac{Q_1}{Q_0}/(\beta_1\frac{K_1}{K_0} + \beta_2\frac{L_1}{L_0}) \quad (18)$$

Direct Method Measurement of the Growth Rate of Technical Change: The growth rate of neutral technical change is estimated directly in this approach. The time trend is included as an explanatory variable in the two types of production functions (C-D and CES). There are two alternative specifications of technical change, outlined as follows:

$e^{\lambda t}$ refers to constant growth of technical change .i.e. Constant Hicks neutral technical progress. "Technical change takes place at constant rate λ, it is assumed to be disembodied and Hicks neutral, so that when there is a shift in the production function K/L ratio remains unchanged at constant prices" [22].

$e^{\lambda t+\lambda t2}$ refers to variable and continuous growth of technical change. i.e. variable Hicks neutral technical progress.

If the two kind of technical change are included to the C-D and CES production function, the following forms would be obtained:

- Cobb-Douglas production function with constant growth of technical change. (Constant Hicks neutral technical progress):

$$Q = Ae^{\lambda t} K^{\alpha} L^{1-\alpha} \tag{19}$$

- Cobb-Douglas production function with variable and continuous growth of technical change (Variable Hicks neutral technical progress):

$$Q = Ae^{\lambda t+\lambda t2} K^{\alpha} L^{1-\alpha} \tag{20}$$

- Constant Elasticity of Substitution with constant growth of technical change (Constant Hicks neutral technical progress):

$$Q = Ae^{\lambda t}[\delta K^{-\rho} + (1-\delta)L^{-\rho}]^{\frac{-\omega}{\rho}} \tag{21}$$

- Constant Elasticity of Substitution with the variable and continuous growth rate of technical change (Variable Hicks neutral technical progress):

$$Q = Ae^{\lambda t+\lambda t^2}[\delta K^{-\rho} + (1-\delta)L^{-\rho}]^{\frac{-\omega}{\rho}} \tag{22}$$

The Production Functions and Technical Progress: The C-D production function quantifies two types of technical change, which are neutral and non-neutral. Neutral technical change is expressed by a change in constant term A in the C-D production function, or by a change in returns to scale $\alpha + \beta$, which is, change in degree of homogeneity of the function. However, this type of technical change does not change the ratio of marginal product and the ratio of labour to capital [27]. The second type of technical change, which is the non-neutral one, refers to change in the relationship between the production factors themselves. It means the elasticity of substitution of production factors would change. Therefore, if the α/β increased, the technical change would be capital saving. That is, the technical change would raise the marginal product of labour in greater proportion than the marginal product of capital [1].

However, if the α/β ratio decreases, it means that technical change would be labour saving. That is, the technical change would raise the marginal product of capital in greater proportion than the marginal product of labour [1]

Similar to the Cobb-Douglas production function, the constant elasticity of substitution production function (CES) also quantifies two types of technical change, which are neutral and non-neutral technical change. However, in the CES production function, neutral technical change refers to change in technological efficiency and return to scale. The non-neutral technical change rate affects the relationship between the production factors and then the ratio of marginal product of these factors. Hicks in [28] stated that the non- neutral technical change either affects the capital factor (labour saving), or affects the labour factor (capital saving). It can be seen as the following:

$$H = \frac{\partial \ln MRTS_{KL}}{\partial L}$$

where H and $MRTS_{KL}$ are Hicksian neutrality and marginal rate of technical substitution between capital and labour respectively and H is equal to or more or less than zero. Mathematically:

$$MRTS_{KL} = \frac{MP_K}{MP_L} = \frac{\partial Q}{\partial K} / \frac{\partial Q}{\partial L}$$

Thus,

$$MRTS_{KL} = \frac{\delta}{1-\delta}(\frac{L}{K}) \tag{23}$$

Non-neutral technical change also affects the δ value, which denotes the parameter of capital factor. If the value of δ increases, the value of the marginal rate of technical substitution between capital and labour also increases. Non-neutral technical change also affects the value of the elasticity of substitution of production factors (σ). This shows that Hicksian neutrality is a function of capital intensity and the elasticity of substitution [29].

A Review of Empirical Studies: Solow [4] applied the C-D production function by using non-agriculture data for the USA over the period 1919-1957. He attempted to isolate the shifts of aggregate production function from movement along the same function. The shift was an estimated increase in total factor productivity (TFP). He attributed this shift to technical progress. Massel [30] used Solow's methods for estimating the growth of manufacturing sector in USA. Solow's results showed that 90% of the increase in output per man-hour was created as a result of an increase in technical progress. Bruton [31] examined the sources of the growth of GDP in Five Latin American countries (LAC) over the period 1940-1964. The aim of his study was to compare these countries with more economically advanced ones[1]. Bruton used the C-D production function, he found the lowest rate of productivity growth was in Argentina, where it was 0.5% of the growth of output, while the highest rate of productivity growth was in France during the same period, where it was 79%. In general he found that the productivity growth was lower in Latin American countries than in more advanced countries. Bruton argues that the lack of technology in Latin American countries can explain part of this difference in productivity growth. Hall and Jones [21] and Klenow and Andres [32] showed that most of the variation in output per worker could be attributed to variation in TFP. Easterly and Levine [33], Chanda and Dalgaard [34] showed that variation in TFP explain the difference in income per capita across countries. Ozyurt [35] proposed a study to analyse the main source of economic growth in the Chinese industrial sector over the period 1952-2005. His study investigates empirically to what extent factor accumulation and total factor productivity (TFP) growth have contributed to output growth in the Chinese industrial sector. The result of his study gave strong evidence for the existence of Constant Return to Scale (CRS) for production technology in the Chinese industry over the period of the study. Minh and Long [36] studied the source of Vietnamese economic growth for the period 1985-2008 and they found that economic growth was largely driven by capital and labour inputs and partly driven by technical progress. Minh and Long [36] attributed the low technical efficiency to the inability of workers to adapt to new technology, or mismanagement in business activities. Adak [37] tested the influence of technical progress and innovation on the Turkish economic growth by using the Ordinary Least Squares (OLS) method. He found a significant relation between technological import and the number of total patent applications and also between the total patent applications and Turkish GDP.

Statistical Methods: In this section the impact of technical progress on the Libyan non-oil productive sector development was investigated during the period 1970-2008. Both direct and indirect methods were used; the indirect method contained the estimates of Solow method. The direct method involved direct estimate of the Cobb-Douglass production function as described earlier. The Cobb-Douglass production function has been estimated in order to investigate the relative importance of technical progress on economic growth in the Libyan productive sector. The data are time series of the output value, number of workers and net capital stock in these sectors. The growth rate of technical progress is expressed in two ways, the first one includes t in the production function in order to capture a constant acceleration or deceleration of technical change; and the second one includes t^2 in the function in order to express a continuous acceleration or deceleration of technical change during the period from 1970 onwards. The basic specification of the function is represented in the following equations:

$$Q = Ae^{\lambda t+\Pi t^2+\psi D} K_i^{\beta_1} L_i^{\beta_2} e^u \tag{24}$$

where A, $\lambda + \Pi$, Ψ, β_1 and β_2 are parameters to be estimated representing the efficiency parameter, the constant and variant rates of Hicks neutral technical progress, the parameters of dummy variables and the elasticity of substitution of output with respect to capital and with respect to labour respectively. U is assumed to be a random error term with zero mean and a constant variance. The C-D production function in productive sector was estimated using Ordinary Least Squares (OLS) after taking a natural logarithm and adding an error term (u) in order to transfer the equation to its linear form. This yields:

$$\ln Q = \ln A + \lambda t + \Pi t^2 + \Psi D + \beta_1 \ln K_i + \beta_2 \ln L_i + u \tag{25}$$

where $\beta_1 = \alpha$ and $\beta_2 = 1 - \alpha$

In estimating the C-D production function under the restriction of Constant Returns to Scale (CRS), the equation is estimated in the following form:

[1]The Latin American countries studied were Argentina, Brazil, Chile, Colombia and Mexico. The advanced countries used for comparison included Belgium, Canada, France, Italy, Japan, the Netherlands, Norway, Sweden, the United Kingdom, the United States and West Germany.

$$\ln(\frac{Q_i}{L_i}) = \ln A + \lambda t + \Pi t^2 + \Psi D + \beta_1 \ln(\frac{K_i}{L_i}) + u \quad (26)$$

In order to choose between the specification of constant and variant Hicks neutral technical progress and of constant and variable returns to scale in (25) and (26), their determination coefficients (R^2) value is compared. The $F - test$ and $T - test$ are also used, in order to discriminate the preferred specification. The $T - test$ can be applied to a test of significance of the parameter estimates. The $F - test$ is used to test the overall significance of a regression. This test aims to find out whether the explanatory variables (dependents variables) do actually have any significant influence on the independent variable. Formally the test of the overall significance of the regression implies testing the null hypothesis that:

H_0: $\beta_1 = \beta_2 = \beta_3 = ... \beta_k = 0$

H_1: not all β_i are zero.

If the null hypothesis is accepted, that all the parameters of the regression model are zero, meaning there is no linear relationship between independent variables and dependent variables.

Estimation Results: The estimation of technical change that occurred in the Libyan economy during the period 1970-2008 has been made by using indirect and direct methods as applied earlier by Solow method and the direct method.

Firstly: Indirect Method (Solow Method): The calculation of Solow's index of technical change for the Libyan productive sector is presented in table (1) the function (5) has been used to calculate the index of Solow. From the table:

The index shows an increasing trend for overall the period.

The Solow's index technical change increased substantially after the period 1980 and this might be attributed to the high investment which took place after success of the oil nationalization and the increase of oil price in that time.

The largest decline happened during the period of study was in 1971, 1972, 1974, 1975, 1977, 1979, 1987. These declines maybe due to late start of development, where Libya started its development after 1975.

Secondly: Direct Method: Estimation results of the C-D production function using the absolute value of variables of long-run time series are presented in Table (1) in appendix. The right side of the table shows the estimation result of the equation under restriction of Constant Returns to Scale (CRS), while the left side of the table shows the estimation result of the function under the restriction Variant Returns to Scale (VRS). From the table most equations, especially those which included dummy variables, are statistically significant and equation 4 is the best that can be chosen. Equation 4 on the left side of Table (A) in appendix has been chosen to explain the relative importance of factor inputs and of technical progress on economic growth in this sector.

Table 1: Solow's index of technical change for the Libyan productive sectors during the period 1970-2008

Year	ΔQ/Q	ΔK/K	ΔL/L	ΔA/A	Solow Index
1970					100.00
1971	-19.5189	-0.05669	1.36612	-19.6642	80.33
1972	39.45346	37.07695	1.48248	18.12687	98.45687
1973	43.78445	50.41379	2.855246	14.6774	113.1343
1974	8.901193	47.36359	3.744351	-18.5828	94.55145
1975	17.24677	26.6397	3.484754	1.609126	96.16058
1976	17.54503	20.85893	7.396272	4.693927	100.8545
1977	-0.14188	10.36347	4.367301	-6.61681	94.23769
1978	12.33305	7.839381	4.774678	7.243894	101.4816
1979	-1.99848	0.198135	3.891449	-2.61731	98.86428
1980	15.33299	8.618867	4.189256	9.875631	108.7399
1981	13.63026	20.68489	7.095553	0.917449	109.6574
1982	-6.28324	1.214596	6.537102	-7.82538	101.832
1983	3.699033	1.392743	5.099502	2.242234	104.0742
1984	-3.79003	-1.56115	1.577909	-3.1053	100.9689
1985	2.296187	-4.13985	-2.13592	4.933571	105.9025
1986	-5.68369	-0.99372	1.388889	-5.29783	100.6047
1987	-3.99563	-3.22808	1.369863	-2.33371	98.27095
1988	6.686377	-1.91176	5.289575	7.088433	105.3594
1989	2.55809	-0.77446	4.070407	2.470381	107.8298
1990	1.600499	-7.37018	1.585624	5.59537	113.4251
1991	-3.0892	-12.2474	0.832466	3.783584	117.2087
1992	1.203293	-13.9957	3.577571	8.715745	125.9245
1993	-0.91781	-11.3418	4.217868	4.998701	130.9232
1994	-20.5895	-18.1506	4.047164	-10.7698	120.1534
1995	-6.33616	-17.0092	3.277182	2.933048	123.0864
1996	-11.6615	-11.7116	3.202847	-5.40224	117.6842
1997	-2.21083	-12.1881	5.45977	4.026634	121.7108
1998	21.10092	17.92994	4.059946	10.35306	132.0639
1999	-6.30411	-12.4429	3.613511	0.318611	132.3825
2000	7.507941	5.007691	3.285317	4.226466	136.6089
2001	3.142627	14.35547	-43.9687	0.675938	137.2849
2002	5.625	33.68915	-1.35371	-13.4018	123.8831
2003	1.084813	14.58533	-0.97388	-7.10222	116.7808
2004	5.219512	11.57205	5.230219	-2.05649	114.7243
2005	4.891052	11.3836	5.437553	-2.30448	112.4199
2006	4.309392	11.40144	5.600322	-2.91747	109.5024
2007	0.572034	1.177813	-25.0668	3.15936	112.6618
2008	-7.14135	-0.60029	-9.2668	-5.5945	107.0672

Source: was calculated as in equation (5) and from Table (2) in appendix

Table (A): Estimation of the C-D production function, using the absolute value of variables under both specifications of Constant and Variant Hicks neutral technical progress and under the restriction of Constant and Variable Returns to Scale, specific to the Libyan productive sector

	Variable Returns to Scale (VRS)								Constant Returns to Scale (CRS)					
Equations	1	2	3	4	5	6	7	8	1	2	3	4	5	6
Variables														
Constant	-0.53	0.30	-0.08	0.66	0.59	0.59	0.15	0.15	-0.80	-0.79	-0.85	-0.86	-0.87	-0.85
	(-1.52)*	(1.02)	(-0.31)	(2.49)***	(2.22)**	(2.18)**	(0.40)	(0.42)	(-13.2)***	(-14.5)***	(-10.5)***	(-10.9)***	(-10.8)***	(-13.6)***
ln *K*	0.51	0.50	0.51	0.57	0.56	0.56	0.57	0.57						
	(17.7)***	(23.5)***	(23.6)***	(23.21)***	(23.2)***	(22.6)***	(23.1)***	(23.7)***						
ln *L*	0.45	0.29	0.36	0.13	0.14	0.14	0.22	0.22						
	(8.16)***	(5.8)***	(7.81)***	(2.24)***	(2.47)***	(2.42)***	(2.94)***	(3.00)***						
ln(*K*/*L*)									0.52	0.53	0.55	0.55	0.55	0.57
									(22.5)***	(24.0)***	(16.2)***	(16.4)***	(16.1)***	(21.3)***
(ln *K* – lnL^2)														
t		0.01		0.01	0.01	0.01	0.002	0.002	0.004		0.003	0.004	0.004	-0.002
		(5.6)***		(5.72)***	(5.93)***	(5.78)***	(1.06)	(1.10)	(3.61)***		(2.65)***	(3.12)***	(3.01)***	(-1.35)*
t^2			0.0001						0.0001					
			(5.33)***						(4.36)***					
D_1				0.15	0.14	0.14	0.15	0.15			0.04	0.04	0.04	0.12
				(3.93)***	(3.82)***	(3.76)***	(3.99)***	(4.05)***			(0.91)	(0.89)	(0.91)	(3.11)***
D_2					0.04	0.04	0.04	0.04				0.07	0.07	0.05
					(1.31)*	(1.29)	(1.25)	(1.28)				(1.67)*	(1.59)*	(1.34)*
D_3						0.006	-0.003						-0.04	-0.03
						(0.10)	(-0.05)						(-0.48)	(-0.46)
D_4							0.08	0.08						0.19
							(1.63)*	(1.65)*						(4.7)***
R^2	0.92	0.96	0.95	0.97	0.97	0.97	0.97	0.97	0.93	0.94	0.93	0.94	0.94	0.96
F	218.5	282.2	266.3	303.3	248.1	200.6	181.1	218.1	255.2	288.9	169.6	134.5	105.2	149.8
D.W	0.83	1.36	1.34	1.80	1.88	1.87	2.12	2.12	1.13	1.25	1.08	1.23	1.26	2.22

Figures in the brackets are the *t – value*, *** significant at the 1% level; **significant at the 5% level; * significant at the 10% level.

t refers to constant rate of technical progress.

t^2 refers to variable rate of technical progress.

ln *Q* and ln(*Q*/*L*) are dependent variables for the unrestricted and the restricted specifications respectively.

D_1 refers to the period 1992-2002 (a period of economic embargo on Libya). D_2 refers to the period 1973-1974 (the time of the Arab-Israel war). D_3 refers to the period 1982 (the time of a world recession) D_4 refers to the period 2002-2008 (major structural and management changes in the country, surge in oil prices and an increase in the quota of oil exports resulting in huge increases in output)

The equation with the specification of constant Hicks neutral technical progress has been adopted, because it is the best function to explain the effect of variable inputs on the change in output in the Libyan productive sector. The form of the equation is written as follows:

$$\ln Q = 0.66 + 0.57 \ln K + 0.13 \ln L + 0.01t + 0.15D_1 \quad (27)$$

$T - values$ (2.49) (23.2) (2.24) (5.72) (3.93)

$R^2 = 0.97$ $F = 303.3$ $D - W = 1.80$

where ln *Q* is the value of the natural logarithm of GDP of productive sector, *K* and ln *L* are the value of the natural logarithms of capital stock and number of workers in the sector respectively. *t* indicates time trend expressing a constant Hicks neutral technological change. *D* is a dummy variable.

According to table (A) in appendix and equation (27), the model which was chosen to express the production function of the Libyan productive sector is statistically significant for all parameters estimated at the level of 5% and 1%. The *R – Square* of estimation is highly close to one, indicating a very good fit for the model, it also shows that the independent variables explain the gain of 97% of the changes in the value of production in the Libyan productive sector. The *F* statistics confirmed that the estimation result of the model is globally significant at the level of 5% and 1%. The value of the Durbin Watson (*D – W*) coefficient at the level of 1% and 5% indicates the absence of an autocorrelation problem.

Economically, analysis of function (27) gives a clear picture of a long-run relationship between production and its factors. A positive relationship between capital and labour inputs on one side and GDP of productive sector on the other side in the productive sector can be seen, as well as the fact that the coefficient of technology has a positive impact on economic growth in the Libyan productive sector. Therefore, an increase in GDP in this sector requires an increase in a combination of these factors or increases in one of them. A growth in factor inputs (capital and labour) by 1% leads to a growth in the contribution to the GDP of the productive sector of 0.70%. This means that the productive sector in Libya is characterized by decreasing returns to scale. The results of this function also show that capital stock is the most

Table A(2): The real value of variables used to estimate the production functions in the productive sectors during the period 1970-2008. The value in million L.D The number of labour in thousand.

Year	*Q*	*K*	*L*
1970	145.5	529.2	146.4
1971	117.1	528.9	148.4
1972	163.3	725	150.6
1973	234.8	1090.5	154.9
1974	255.7	1607	160.7
1975	299.8	2035.1	166.3
1976	352.4	2459.6	178.6
1977	351.9	2714.5	186.4
1978	395.3	2927.3	195.3
1979	387.4	2933.1	202.9
1980	446.8	3185.9	211.4
1981	507.7	3844.9	226.4
1982	475.8	3891.6	241.2
1983	493.4	3945.8	253.5
1984	474.7	3884.2	257.5
1985	485.6	3723.4	252
1986	458.0	3686.4	255.5
1987	439.7	3567.4	259
1988	469.1	3499.2	272.7
1989	481.1	3472.1	283.8
1990	488.8	3216.2	288.3
1991	473.7	2822.3	290.7
1992	479.4	2427.3	301.1
1993	475.0	2152	313.8
1994	377.2	1761.4	326.5
1995	353.3	1461.8	337.2
1996	312.1	1290.6	348
1997	305.2	1133.3	367
1998	369.6	1336.5	381.9
1999	346.3	1170.2	395.7
2000	372.3	1228.8	408.7
2001	384.0	1405.2	229
2002	405.6	1878.6	225.9
2003	410.0	2152.6	223.7
2004	431.4	2401.7	235.4
2005	452.5	2675.1	248.2
2006	472.0	2980.1	262.1
2007	474.7	3015.2	196.4
2008	440.8	2997.1	178.2

Q = Gross domestic product of Libyan productive sector
L = Number of workers in the Libyan productive sector(manufacturing and agriculture)
K_t = capital stock

important factor affecting growth in the contribution to GDP of the Libyan productive sector. When capital stock increases by 1% given the stability of other factors, the contribution to GDP will increase by 0.57%, while increasing labour input by 1% leads to GDP in the Libyan productive sector increasing by 0.13%. From the equation it is also clear that the rate of technical progress has a positive relationship with GDP in this sector; its contribution to the GDP growth rate is about 0.1%. The coefficient of the dummy variable indicates that the period of economic blockade had a positive impact on GDP in the Libyan productive sector.

CONCLUSION

This study was concerned with the impact of technical progress on economic growth in the Libyan non-oil productive sector, during the period 1970-2008. The type of technology and its measurement methods were displayed with reference to several studies in this area. Two approaches were used for measuring technical change. The indirect or non-parametric approach, implying the methods of Solow and the direct approach or the parametric approach, implying a constant and variant Hicks neutral technical progress method. The principal findings of the study that the calculation of Solow's index of technical change for the Libyan productive sector showed an increasing trend for overall the period. And the direct approach showed that the coefficient of technology had a positive impact on economic growth in the Libyan productive sector and the rate of technical progress has a positive relationship with GDP in this sector; its contribution to the GDP growth rate is about 0.1%.

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