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Majid Aghaei, Mahdiah Rezagholizadeh

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# The Impact of Information and Communication Technology (ICT) on Economic Growth in the OIC Countries

**Majid AGHAEI and Mahdiah REZAGHOLIZADEH**

**University of Mazandaran, Iran**

**Abstract:** New growth theories hypothesize economic growth processes as heavily dependent on investment in Information and Communication Technology (ICT). However, the full empirical verification of this hypothesis still is an open task, particularly when growth is considered within selected countries such as the OIC<sup>1</sup> countries. Furthermore, the conclusions derived from research concerning the causal relationship between ICT and economic growth is often sensitive to the research methodology employed. This paper employs dynamics and static panel data approach within a framework of growth model and apply them to the economy of OIC countries over the time period of 1990-2014. The estimates reveal a significant impact of investments in ICT on economic growth in the countries considered. The policy implication of this paper is that the OIC countries should design specific policies for promoting investment in ICT.

**Key Words:** ICT, OIC Countries, Panel Data, Economic Growth.

**JEL Classification:** O33, C23

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## 1. Introduction

In recent periods, the causal relationship between Information and Communication Technology (ICT), and economic growth has attracted increasing attention among many economists throughout the world. The incentive has been provided by the theoretical force of endogenous growth models that emphasize the economic growth enhancing effect of investments in ICT and also by some empirical studies showing a positive relationship between ICT investments and

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*Correspondence Address:* Majid Aghaei, Assistant professor of economics, department of economics, university of Mazandaran, babolsar, Iran. P.O.Box: 416, Babolsar, Iran. Phone: 0099128487361. Email: M.Aghaei@umz.ac.ir.  
Assistant professor of economics, department of economics, university of Mazandaran, babolsar, Iran. P.O.Box: 416, Babolsar, Iran. Phone: 0099124794589, Email: M.gholizadeh@umz.ac.ir.

economic growth. Theoretically, the flow of ICT on the supply side of the economy coupled with complementary infrastructural factors can lead to the so-called “capital deepening”, rectifying economic processes and increasing factor productivities and growth. As a derivative it is claimed that countries that have resources to make the required investments in physical and human capital have a higher chance of benefiting from the growth enhancing effect of ICT investments.

Subsequent research turned focus on the causal relationship between ICT and economic growth in “developing countries”, asking whether investments in ICT make any difference to growth in these countries. (Sotiris K Papaioannou, 2004; Hosseini Nasab and Aghaei, 2009). However, these works remain inconclusive and the question of the empirical validity of the growth-enhancing effect of ICT investments in the context of the developing countries is still open to investigation.

The OIC countries<sup>2</sup> have a relatively better physical infrastructure and human resource base that promises positive outcomes for speeding up investments in ICT. Since the conclusions reached from trying to establish a causal relationship between ICT and growth are sensitive to the estimating method employed, this paper employ static and dynamic panel data approche and apply it to the special economy of OIC countries over the time span of 1990-2014.

The focus of this paper is to shed more light on the growth enhancing effect of ICT in the OIC countries by employing the more up to-date dynamic and static panel estimation method. The paper is organized as follows: Section 2 presents the theoretical and 3 the empirical background of the subject. Section 4 formulates the model and applies it to the OIC countries. Finally, in next section, the paper's hypothesis on the effect of ICT investments on economic growth of OIC countries is explored and section 7 summarizes and brings the paper to its conclusions.

## **2. The theoretical aspects of ICT- based growth models.**

Nowadays, economy in most countries is knowledge-based and the information and communication technology has main role in their production process. Also, Consumers use

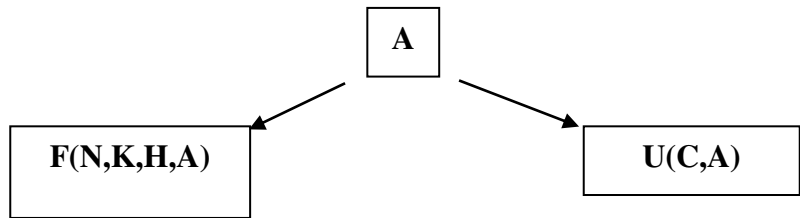
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<sup>1</sup> Organization of Islamic Conference.

<sup>2</sup> OIC members are: Afghanistan, Albania, Algeria, Azerbaijan, Bahrain, Bangladesh, Benin, Brunei, Darussalam, Burkina Faso, Cameroon, Chad, Comoros, Cote d'Ivoire, Djibouti, Egypt, Gabon, The Gambia, Guinea, Guinea-Bissau, Guyana, Indonesia, Iran, Iraq, Jordan, Kazakhstan, Kuwait, Kyrgyzstan, Lebanon, Libya, Malaysia, Maldives, Mali Mauritania, Morocco, Mozambique, Niger, Nigeria, Oman, Pakistan, Palestine Qatar, Saudi Arabia, Senegal, Sierra Leone, Somalia, Sudan, Surinam, Syria, Tajikistan, Togo, Tunisia Turkey, Turkmenistan, Uganda, United Arab Emirates, Uzbekistan, Yemen.

knowledge-based goods and services. So in general, ICT influences both the demand and the supply sides of the economy. On the demand side, it affects costumers' economic behavior and on the supply side it influences producers' behavior (Quah, 2003). Figure 1 shows the general performance of ICT in a modern economy.

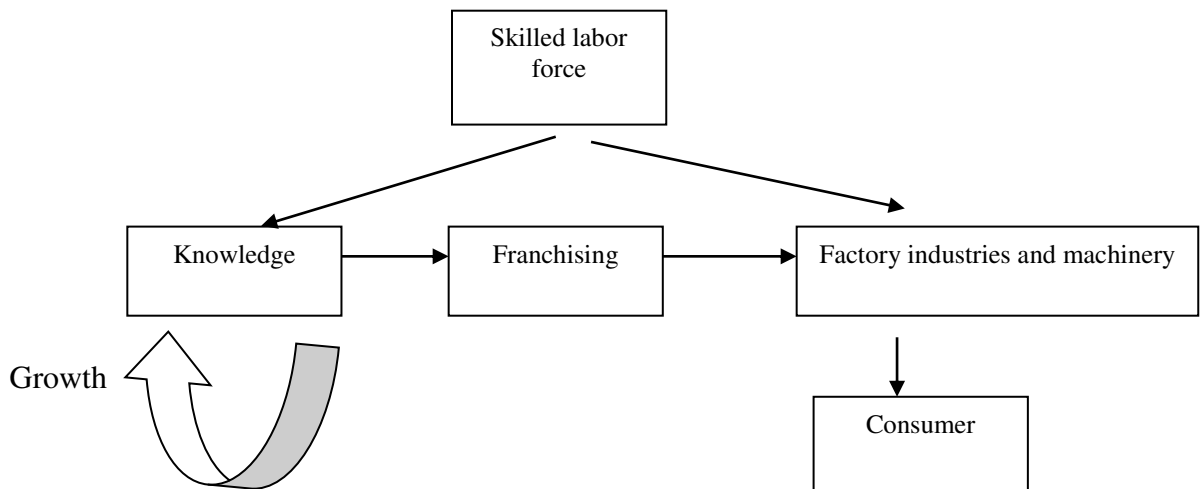
**Figure 1. Digital Goods Performance in a Modern Economy**



Source: Author's own elaboration based on: Quah, 2003

With A (ICT) representing digital goods, the left side of the figure 1 depicts the production or the supply side, and the right side shows the consumption or the demand side. Thus A plays a role in both production and consumption. Considering the production function F of the figure, N, K and H are: labor, physical capital and human capital, respectively that yield production F and considering the utility function U, C is consumption goods that yield utility U. In this new economic structure, as in the traditional structure, digital goods(A) foster economic growth on the supply side, but as in the modern economic view, they also contribute directly to enhance the consumer utility on the demand side (Quah, 2003). Figure 2 shows the process of economic growth as sketched in the traditional sense.

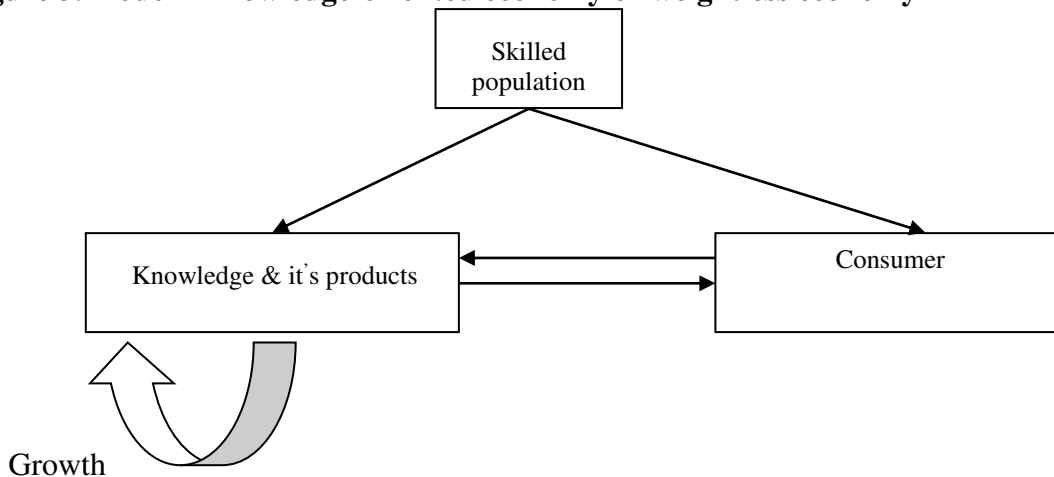
**Figure 2. Traditional model of growth and knowledge**



Source: Author's own elaboration based on: Quah, 2003

Figure 2 shows the performance of skilled labor force in the industrial sectors that finally provide the consumer with goods and services. In figure 3, scientific scholars, engineers and other similar labor force work as skilled labor force. New-born ideas are injected into the bases of economic technology and the economic growth engine is created.

**Figure 3. modern knowledge-oriented economy or weightless economy**

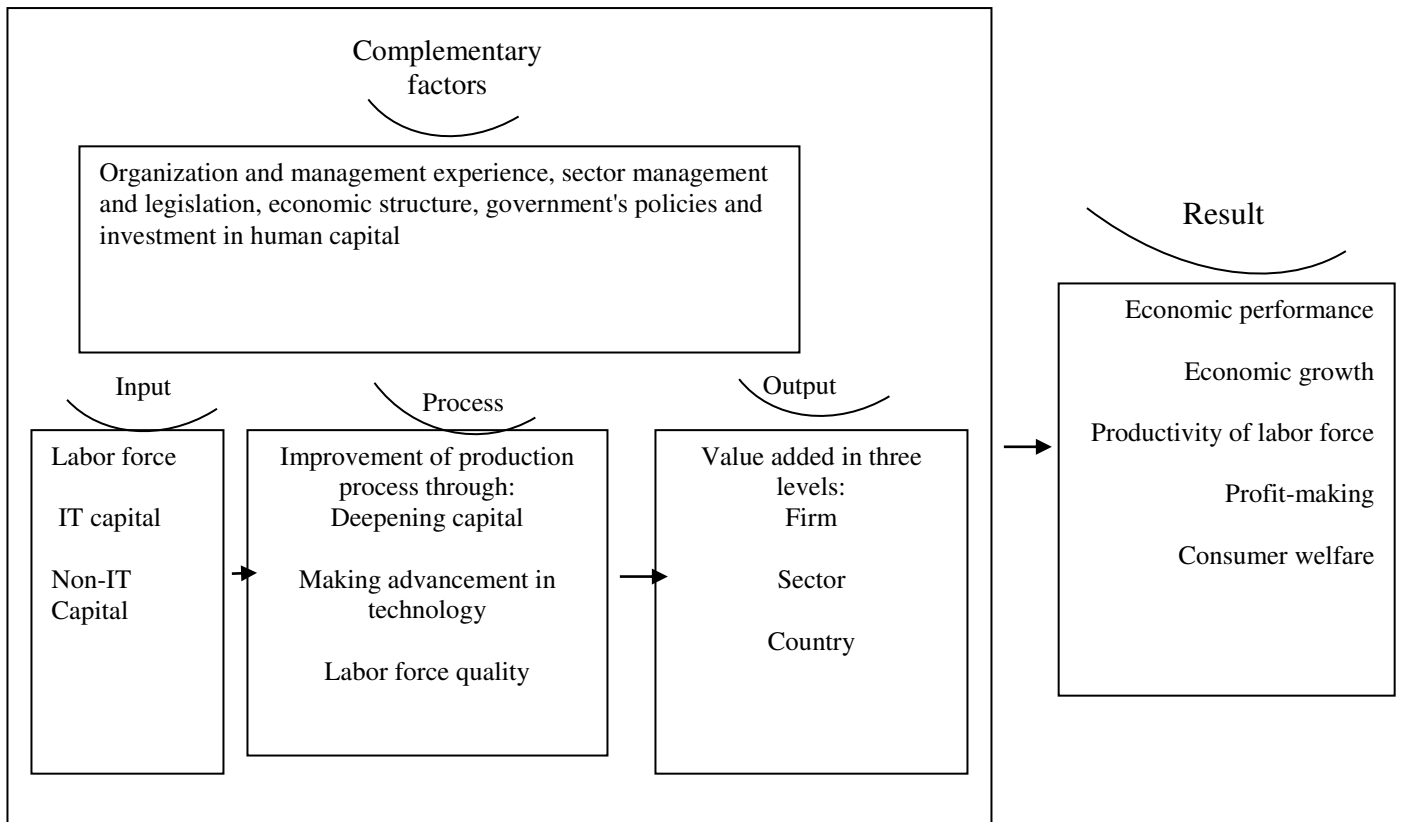


Source: Quah, 2000

What is valuable in a modern economy is a matter of changes in the economic information, but these changes are not durable enough to get linked to other information processes. The final consumer is related directly to some samples of computer software's utilization of digital means or financial, sanitary, and consultative information in the network through wireless communication infrastructure. In this kind of economy not all new ideas are generated from laboratories and economic research. Therefore, a modern economy is weightless and it is different from the traditional knowledge-oriented economy in which the inductive influence of knowledge in improving productivity in some industrial processes is represented (Quah, 2000).

In traditional knowledge-oriented economy, franchising and machinery are mediators between knowledge/science production and user/consumers, whereas in knowledge-oriented modern economy the distance between knowledge/science and consumer has been decreased (Quah, 2003).

**Figure 4. ICT performance on the supply side**



Source: Quah, 2000

Figure 4 shows how ICT influences economic growth. As it can be seen from the diagram, along with some complementary factors such as organization and management experience, sectoral management and legislation, government's policies and investment in human capital, ICT enters as input into the economic supply in the form of capital and causes the improvement of production process through deepening capital and making advancement in technology and labor force quality. Its output is value added at the three levels: firm, sectoral and the national, and finally, growth in labor force productivity, profit-making and consumer welfare will follow (Dedrick et al, 2003).

Early studies done in the field of economic growth emphasized the accumulation of physical capital as the main factor for growth, but in recent studies, the concept of capital has been widened from the limited field of equipment and machinery to include knowledge and technology with the latter acting as the main factors of growth. In fact, in recent years, a substantial body of endogenous growth models, have tried to explain how new knowledge and technology can act as the main factor for growth. The separation of human capital from

technology as codified (or embodied) knowledge is one of the highlights of the models that pose ICT as an endogenous factor for growth. Some have proposed ICT as the familiar R & D in endogenous growth models that posit long-term growth as a function of information technology (IT) growth. The distinction is also used in some neoclassical type models to relate long-term growth of per capita production to technology growth, and per capita income levels to human capital (Moshiri and Jahangard, 2004).

To see how ICT influences production, this paper proposes two alternative economic growth models with two alternative production functions that distinguish between forms of capital (see: Quah (2002) and Pahjola (2002)).

First, we begin with the following model in an accounting framework:

$$Y_t = Y(Y_t^{ICT}, Y_t^0) = A_t F(C_t, K_t, H_t, N_t) \quad (1)$$

Where  $t$  is time in all cases,  $Y$  is the total added value,  $Y^{ICT}$  is added value of goods and services related to ICT, and  $Y^0$  represents the value added related to other products. Production is possible through ICT inputs ( $C$ ) and non-ICT inputs: physical capital ( $K$ ), human capital ( $H$ ), and labor force ( $N$ ).

ICT influences economic growth, production and productivity in three basic ways. First ICT's goods and services ( $Y^{ICT}$ ) are a part of the value added of the economy. Second, utilizing ICT capital, or  $C$ , as input in the production of all goods and services will lead to economic growth. Finally, ICT can cause economic growth through its contributions to technological change. If the growth of ICT's production is based on the benefits of efficiency and productivity in the activities, it will lead to an increase in productivity growth at the macro-economic level (Pahjola, 2002).

The economic literature reveals different approaches to estimating the effect of ICT investments: the production function approach, the growth accounting approach and the applied growth theory approach. We start with the production function approach and propose the following generalized form of the Cobb Douglas production.

$$Y = AC^{\alpha_c} K^{\alpha_k} H^{\alpha_h} N^{\alpha_n} \quad (2)$$

In this model the subscript of time has been eliminated to simplify the presentation, but we should note that all variables are dated. Conversion to logarithm yields the following in linear form:



$$\ln Y = \ln A + \alpha_c \ln C + \alpha_k \ln K + \alpha_h \ln H + \alpha_n \ln N \quad (3)$$

This relationship can be estimated using time-series within a country or cross section data across countries. Differentiating with respect to time, we have:

$$\dot{Y} = \dot{A} + \alpha_c \dot{C} + \alpha_k \dot{K} + \alpha_h \dot{H} + \alpha_n \dot{N} \quad (4)$$

Where the dot over a variable indicates rate of change. Assuming constant returns to scale, and each factor receiving its marginal product, the parameters  $\alpha_c$ ,  $\alpha_k$ ,  $\alpha_h$ , and  $\alpha_n$  measure the share in total income of ICT input, physical capital, human capital and labor respectively. Here, the usual method of growth accounting for determining the degree of contribution of production factors to economic growth can be applied directly. All factors except technological change ( $A$  in the above equation) are observable. In practice, the use of either one of these formulations is constrained by lack of data on ICT and its share in national income. Analysts would need to depend on simplifying assumptions and alternative information resources in estimating the influence of ICT investment, prices and capital stock.

In the third approach, we can consider a form of production function that is somewhat different from (2):

$$Y = C^{\alpha_c} K^{\alpha_k} H^{\alpha_h} (AN)^{1-\alpha_n-\alpha_c-\alpha_h} \quad (2)$$

The difference has to do with technological changes. The assumption here is that these changes are the labor augmenting type with constant return to scale features. Capital is divided into three kinds of human, ICT, and physical capital. In this model,  $Y$  is the production level per unit of efficient labor force ( $Y=Y/AN$ ) and  $h$ ,  $k$ ,  $c$ , respectively are human, physical and ICT capital per each unit of effective labor. In this formulation, the growth equations become:

$$dc(t)/dt = s_c y(t) - (\alpha + n + \delta_c)c(t), \quad (6)$$

$$dk(t)/dt = s_k y(t) - (\alpha + n + \delta_k)k(t), \quad (7)$$

$$dh(t)/dt = s_h y(t) - (\alpha + n + \delta_h)h(t), \quad (8)$$

Where  $S$  refers to the saving rate and  $\delta$  to depreciation rate. It is assumed that technology and labor force grow at exogenous rates of  $n$  and  $\alpha$ , respectively. Solving the above equation for the steady-state amount of capital stock and substituting the result in the production function gives:

$$\ln Y/L = \alpha_0 + (\alpha_c/1-\beta) \ln s_c + (\alpha_k/1-\beta) \ln s_k + (\alpha_h/1-\beta) \ln s_h - (\alpha_c + \alpha_k + \alpha_h/1-\beta) \ln(\alpha + n + \delta) \quad (9)$$

where,

$\alpha_0 = \ln A(0) + at, \beta = \alpha_c + \alpha_k + \alpha_h$  By assumption, all capital depreciates at a rate  $\delta$  and  $\beta < 1$ . The steady state per capita production or labor force productivity has a positive relationship with saving rates of all types of capital, but a negative relationship with population growth rate and capital depreciation. Equation (9) can be estimated using investment (saving) rates, which overcomes the constraint on data availability on capital stock.

There are at least three issues regarding the characteristics of the above model. First, using the specific Cobb Douglas technology implies that ICT income is a fixed share of national income and this may not hold well. Second, using a single depreciation rate for all types of capital is problematic, since the life expectancy of ICT capital is less than that of other capitals. Third, equation (9) is based on the assumption that all countries are in a steady state whereas steady-state convergence may not take place smoothly. The first two simplifying assumptions can not be simply dismissed. The third is a matter of convergence as in the following formulation

$$\begin{aligned} \ln \frac{Y(t)}{L(t)} - \ln \frac{Y(0)}{L(0)} &= \theta \ln A(0) + at + \theta \frac{\alpha_c}{1-\beta} \ln s_c + \theta \frac{\alpha_k}{1-\beta} \ln s_k + \theta \frac{\alpha_h}{1-\beta} \ln s_h \\ -\theta \frac{\alpha_c + \alpha_k + \alpha_h}{1-\beta} \ln(a+n+\delta) - \theta \ln \frac{Y(0)}{L(0)} & \quad (10) \\ \lambda = \beta(a+n+\delta) \quad \quad \quad \theta &= (1 - e^{-\lambda t}) \end{aligned}$$

Where the convergence speed is measured through  $\theta$  and  $\lambda$  parameters<sup>3</sup>. This equation states that production can grow faster in countries that invest more on ICT capital.

### 3. Empirical studies on ICT, economic growth and productivity

Early macro level studies, going back to late 1980s and early 1990s, concluded that ICT's share in productivity and economic growth is very small (Roach, 1987, 1989, 1991; Oliner and Sichel, 1994; Jorgenson and Stiroh, 1995). The explanation provided was that investment in ICT comprised a very small proportion of the total capital stock (Sichel, 1997). For example, nominal investment in information technology in the US in 1980 and 1990 comprised only 3.5 and 9 percent of the total investment respectively. With the increase in the price of computers during the 1990s, the rate of investment in IT also increased compare to the preceding periods; it rose from the average annual rate of 18 percent during the 1959-95 period to about 32 percent during the period of 1995-99 (Jorgenson, 2001). An increase in prices of goods and services having an

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IT content lead to a meaningful and significant increase in the demand for IT and also provided an incentive for substituting IT for labor and non-IT capital such as machinery or other equipment. On another front Investments in ICT had a considerable effect on the productivity of labor force and on economic growth at the macro level. In most of macro-economic studies, the increase in productivity and economic growth has been attributed to the significant and meaningful influence of ICT investment (Jorgenson, 2001, Oliner and Sichel, 2004, Jorgenson and Stiroh, 2000). Some scholars (e.g., Gordon, 2000) attribute productivity growth of 1995-2000 to business cycles, whereas Stiroh (2001) and some others show that business cycles have little Influence on productivity growth during those years. These different results basically use different arguments with regard to the impact of ICT's influence on productivity. Jorgenson and Stiroh (1995, 2000), Jorgenson (2000), and also Oliner and Sichel (1994, 2000) are based on growth accounting and separation of IT capital from non-IT capital, focusing mainly on business cycles. They compare the degree of IT's influence over business cycles with IT's influence in the in last decade. The results of these studies are shown in Table (1) below.

**Table 1. The degree of IT's influence on economy growth and productivity growth in America (All figures in percent)**

<b>Jorgenson and Stiroh, 2000 ; Jorgenson, 2001</b>	<b>1959-1973</b>	<b>1973-95</b>	<b>1995-99</b>
Annual economic growth	4.32	3.04	4.08
Capital share of total	33	50	71
IT share in production growth	4	13	28
Annual productivity growth	2.94	1.4	2.11
IT share in productivity growth (percent)	6	27	42
<b>Oliner and Sichel, 2000</b>	<b>1959-73</b>	<b>1973-95</b>	<b>1995-99</b>
Annual economic growth	2.99	4.82	-
Capital share of total	42	38	-
IT share in production growth	17	23	-
annual productivity growth	1.52	2.67	-
IT share in productivity growth	31	41	-

Source: Dedrick and et al, 2003

Mankiw, Romer, and Weil (1992) using data from 42 developing and 24 high income developed countries over the period of 1985-1999 and also Pahjola (2001) using Panel Data modeling, estimated ICT/GDP influence on growth in these countries and concluded that the influence is

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<sup>3</sup> See also Mankiw, Romer, and Weil, 1992.

meaningful and positive in high income countries, positive but not meaningful in developing countries. Sotiris K Papaioannou (2004) explored the effects of ICT on productivity and economic growth in both developing and developed countries over the time period of 1993-2001 by considering foreign direct investment (FDI) as a variable for measuring technological growth in a production function framework and concluded that FDI has a positive and meaningful effect on productivity and economic growth in the countries under study and that this effect is greater in developing countries. There was also a positive but not meaningful effect of ICT on productivity and economic growth in all of the countries in the model. Dewan and Kraemer (2001) and Pahjola (2001) drawing data from more than 36 countries over different continents concluded that in more prosperous and industrial countries, there is a highly positive and meaningful relationship between ICT and growth and productivity, but there is not any evidence of such a relationship in in developing countries. Dewan and Kraemer suggest that this gap is caused by low levels of IT investment in developing countries and the lack of complementary assets such as knowledge-based structures for developing the use of IT goods. They engage 36 countries over the time span of 1982-99 in a cross country and growth accounting and Panel Data modeling framework, and then proceeded to estimate the influence of ICT on economic growth in two groups of developed and developing countries. The estimates are based on generalized least squares with Random Effect and production function framework where IT elasticity was  $-0.012$  and  $0.057$  in developing and developed countries respectively.

While there have been numerous studies in US and other developed countries on the effect of ICT on economic growth, little is done in this regard in developed countries. The following might be considered as exceptions to the rule: In a study of Egypt and some of the Persian Gulf countries, Nour S. (2002) found that in most cases ICT expenditures had a positive correlation with economic growth based on per capita gross domestic product, but the effect of ICT investments on economic growth was insignificant. Lee and Khatri (2003) investigated the influence of ICT on economic growth of South Asian countries. The model used was a Cobb Douglas production function with non-ICT capital, ICT capital (including hardware, software and communications) and labor force as variables. The study draws on ICT expenditure data provided by WITSA<sup>4</sup> for the periods of 1990-94 and 1995-99. The results show that ICT's contribution to economic growth originated from capital deepening effect of the ICT sector in 1990s. In particular, the capital deepening effect of the ICT sector in 1995-2000 played a significant role in

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<sup>4</sup> Word Information Technology and Services Alliance

improving labor force productivity. In the first half of the 1990s capital deepening effect of the ICT sector led to an increase in labor force productivity in several countries such as Hong Kong, Singapore, and South Korea. The effect was greater in the second half of the 1990s.

Wolf (2001) carried out an investigation on small and average industries in Kenya and Tanzania and concluded that the effect of ICT on output level was positive but not statistically meaningful. The study concludes that ICT would lead to an increase in small industries' competitive power. On the other hand, it enables large industries to increase their flexibility in renewed engineering which in turn leads to their ability to deal with changes more rapidly. The study uses data from 150 firms in 1999 and 2000 and adopts a production function framework in which production is a function of labor force, ICT, and non-ICT capital and productivity of all production factors including a weighted sum of labor force skill and firm's useful life. The modeling method in this study is Panel Data. The elasticity of growth with respect to ICT was estimated to be -0.015 and 0.69 in Tanzania and Kenya respectively and 0.021 in general. The coefficient was meaningful in Kenya but not in Tanzania.

In Iran, Moshiri and Jahangard (2004) investigated the effect of ICT on Iran's productivity and economic growth. This study is carried out in two phases. In phase one, the relationship between ICT and economic growth was explored with the conclusion that there was no meaningful relationship between economic ICT and economic growth in Iran up to year (2000). In this study, investment in communication is used as a proxy for ICT. The implications drawn are a lack of such factors complementary to ICT as organizational and managerial expertise, appropriate government's policies, human capital, and appropriate trade space for effective utilization of ICT in the Iranian economy. The second phase of the study is devoted to a test of the relationship between ICT and productivity in industries employing more than ten people, in the form of the four-number ISIC codes covering the period of 1995-2001. The estimated parameters show a positive and meaningful but insignificant effect of ICT on manufacturing production, However, the effect was moderately significant in industries with middle technologies (car-making, petroleum industry) and highly insignificant in industries with basic technologies (based on natural resources). The results also show a positive and meaningful effect of IT on labor force productivity. Faghih-Nasiri and Goudarzi (2005), following Romer (1986), estimated a model with physical, ICT, R&D and human capital and explored the effects of ICT on economic growth of 37 countries (including developing and developed countries) over the

period of 1995-2003. The results indicate that the ICT investments were more effective effect in developed countries compare to developing countries.

#### 4. Empirical Model of Economic Growth with ICT

Based on the existing theoretical and empirical bases of modeling the effect of ICT investment on economic growth reviewed above, and some experimentation, the following model with all variables in logarithm seems a suitable candidate for application, we first specify a simple double log-linear Cobb-Douglass production function as:

$$\text{LnGDP}_{it} = \beta_0 + \beta_1 \text{LnKict}_{it} + \beta_2 \text{LnK}_{it} + \beta_3 \text{LnHC}_{it} + \beta_4 \text{LnFDI}_{it} + U_{it} \quad (11)$$

Where:

$\beta_0$  is a constant coefficient,  $\text{LnGDP}_{it}$  is natural logarithm of real GDP per capita in constant 2000 prices in US dollar,  $\text{LnKict}_{it}$  is investment in ICT,  $\text{LnK}_{it}$  is gross domestic investment,  $\text{LnHC}_{it}$  is log of secondary and tertiary school enrollment used as measure of investment in human capital,  $\text{LnFDI}_{it}$  is foreign investment as an indicator of technical and technological improvement.  $U_{it}$  is the model's random error component, the subscripts  $i$  and  $t$  refer to country and time respectively.

The data mainly are based on the World Bank (2007) tables. The time period under investigation was confined to 1990-2014. The variable HC (human capital) was included because according to Lucas, R., (1998) what really affects economic growth is educated and skilled labor force (knowledge-based labor force).

Another explanatory variable of the model that deserves some explanation is technical growth. Some previous studies (Sotiris K, Papaioannou, 2004) have confirmed the spill over effects of technology through direct foreign investment and used direct foreign investment variable as a proxy variable for technology. So we use the growth in foreign direct investment as the proxy variable representing technological growth<sup>5</sup>. The Data on foreign direct investment have also been compiled from the statistical resources published by the World Bank.

The data on ICT includes:

- 1- Computer hardware (computers, accessories and enhancements)
- 2- Software (agent systems, programming means, etc)
- 3- Computer services (IT devices, etc) and communication services

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<sup>5</sup> See also Archanun Kohpaiboon, 2003; Magnus Blomstrom and Ari Kokko, 2003; Nicole Madariaga and

4. Wire and wireless communication equipment (WITSA, 2004).

Pahjola's (2001), was used as a basis for estimating ICT investments in OIC countries. Since there were no uniform and agreed-upon data on investment in ICT (a percentage of gross domestic products) for OIC countries, we took the ICT expending/GDP ratio from the World Bank's statistical Information. Gross Capital Formation (or Gross Domestic Investment) includes expenditures on fixed assets (land and land improvement, plant, machinery and equipment, road and rail transportation, school, administrative, hospitals, and industrial and business buildings) plus net changes in inventories. The change in inventories also comprises investments in the form of goods held in stocks to deal with temporary unexpected fluctuations (World Bank, 2004).

**5. The Model Estimation**

To estimate the parameters corresponding to variables of interest from the data under consideration, we employ a panel data estimation, an empirical exposition of which is provided in equation (12) below.

$$Y_{it} = \delta_i + \Gamma_t + (X_{it})\Phi + \psi_{it} \tag{12}$$

Where  $Y_{it}$  is gross domestic product in constant 2000 prices in US dollar in country  $i$  at year  $t$ , and  $X_{it}$  is a vector of the explanatory variables ( investment in ICT, gross domestic investment, human capital, foreign investment as an indicator of technical and technological improvement) for country  $i = 1, 2, \dots, m$  and at time  $t = 1, 2, \dots, T$ ,  $\Phi$  a scalar vector of parameters of  $\beta_1, \dots, \beta_5$ ;  $\psi_{it}$  is a classical stochastic disturbance term with  $E[\psi_{it}] = 0$  and  $\text{var}[\psi_{it}] = \sigma_\epsilon^2$ ,  $\delta_i$  and  $\Gamma_t$  are country and time specific effects, respectively.

If we assume the country specific effects to be constant across countries and the time specific effects are not present [i.e.  $\delta_i = \lambda$  and  $\Gamma_t = 0$ ], then model (12) is estimated by the Ordinary Least Squares (OLS) method, or restricted OLS method. The second estimation technique assumes that the country specific effects are constant, but not equal (i.e.  $\delta_i = \lambda_i$  and  $\Gamma_t = 0$  which yields a one-way fixed effects model. The third assumption is a situation where the country effects are not constants, but rather are disturbances; the time effects are not present [i.e.  $\delta_i = \lambda + w_i$  and  $\Gamma_t = 0$ ] where  $E[w_i] = 0$  and  $\text{var}[w_i] = \sigma_w^2$  and  $\text{cov}[\psi_i, w_i] = 0$ . In this case, model (12) is estimated by the generalized least squares (GLS) which yields random-effects model.

Given that some of the traditional growth explaining factors are either pre-determined, or endogenous, or both, and current period growth could depend on its values in the past, a dynamic variant of the fixed and random effects provided in Equation (12) above, known as the Arellano-Bond estimation (1991) is specified as follows:

$$\Delta Y_{it} = \alpha' \Delta Y_{it-1} + \beta' \Delta X_{it-1} + \gamma' Z_{it} + \nu_i + \varepsilon_{it} \quad (13)$$

where  $\Delta Y_{it}$  is first difference of gross domestic product in constant 2000 prices in US dollar in country  $i$  during time  $t$ ,  $\Delta Y_{it-1}$  is lagged difference of the dependent variable,  $\Delta X_{it-1}$  is a vector of lagged level and differenced predetermined and endogenous variables,  $z_{it}$  is a vector of exogenous variables, and  $\alpha$ ,  $\beta$ , and  $\gamma$  are parameters to be estimated. and  $\varepsilon_{it}$  are assumed to be independent over all time periods in country  $i$ . The term  $\nu_i$  represents country specific effects which are independently and identically distributed over the countries while  $\varepsilon_{it}$  noise stochastic disturbance term and is also assumed to be independently distributed.

We derive the coefficients using the Arellano-Bond (1991) Generalized Method of Moments (GMM) estimator to evaluate the joint effects of ICT investment and the other explanatory variables on the economic growth of OIC COUNTRIES member countries while controlling for the potential bias due to the endogeneity of some of the repressors.

## 6. Empirical Results and Interpretations

We start the discussion of our findings based on the fixed-effects and random-effects results reported in Tables 2. Broadly, the results of both models reveal the expected relationship between the gross domestic product in constant 2000 prices in US dollar and the explanatory variables. In both models, the variables representing the sources of growth have the expected signs. Because we estimated a logarithmic model, all the coefficients represent elasticities.



**Table 2. Estimation results of the relationship between ICT investment and economic growth using Fixed Effects and Random Effects procedure**

Variable	Description	Fixed-Effects Coefficients	Random- Effects Coefficients
K <sub>ict</sub>	investment in ICT inflows (% of GDP)	0.0377*** (2.95)	0.0387*** (2.82)
K	Gross fixed capital formation (% of GDP)	0.0232** (2.98)	0.0422** (2.39)
HC	School enrollment, secondary + tertiary (% gross)	0.0231* (1.79)	0.0245* (1.74)
FDI	Foreign direct investment, net inflows (% of GDP)	0.057** (2.121)	0.0263** (1.96)
Constant	Intercept	1.34** (2.46)	0.99** (2.136)
<i>R-Squared</i>		0.58	
<p>Note: t statistic in parentheses.            *** indicate statistical significance at the 10% level, respectively            ** indicate statistical significance at the 5% level, respectively            * indicate statistical significance at the 1% level, respectively            All Variables are log Transformed.</p>			

Source: authors' own elaboration.

Comparison of the consistent fixed-effects model with the random-effects model using the Hausman specification test, reject the random effect estimator in favor of the fixed effect estimator at  $p < 0.05$ . The results from our model of choice indicate that ICT has a positive and statistically significant effect on GDP per capita (at  $p < .01$ ) of OIC countries.

Accordingly, we find that a 10 percent increase in the ICT investment of a typical OIC countries economy would result in a 0.3 percent increase in the average per capita GDP. Similarly, a 10 percent increase in investment in human capital (SCH) through increases in secondary and tertiary levels school enrollment will increase GDP per capita by 0.1 percent. Consistent with the findings of Barro (1990), Dritsakis (2004), and Durbarry (2004), we also find that investment in physical capital (K) as measured by the gross fixed capital formation as a percent of GDP and Foreign direct investment (FDI) have a positive and statistically significant impact on the real GDP of the OIC countries' economies.

While results based on the fixed and random effects models in which we simultaneously account for the heterogeneity and time to time fluctuations in the economic performance of OIC

countries' economies are appealing, we note that several of the explanatory variables we include in the regression either pre-determined or endogenous, thus confounding the results. For example, while FDI and investment in human capital (HC) have often been credited for their role in the economic growth of a country, there is also ample evidence (Hansen and Rand, 2006; de Mello, 1999) that the level of GDP and its growth rate have feedback effects on the amount of FDI a country receives, and the rate of investment in human capital formation. Given that we are mainly interested in analyzing the effect of ICT investment on OIC countries economic growth while accounting for the explanatory factors that are either pre-determined (e.g., HC) or endogenous (e.g., FDI), or both, we employ the difference estimator GMM developed by Arellano and Bon (1991) that addresses those problems more effectively and obtain robust estimates. In this method, lagged values of the explanatory variables are used as instruments and over-identification test is applied to ensure there is no bias due to correlation with the error term.

Another estimation problem in such growth equations of the kind that also shows itself in our paper is the existence of unobservable country specific effects and also lagged dependent variables among the explanatory variables. This problem was overcome by the use of Generalized Method of Moment (GMM) estimator too. This requires a decision on which variable to use as instrumental variables.

In this paper the lagged values of dependent and explanatory variables are used as instruments. Furthermore, these type of models require substantially large number of observations in order to produce results that are dependably stable (Bond, 2001).

Considering that our data extends over a time span 24 years, which is sufficiently large, the problem of stability is not expected to affect our results. Table 3 present the results of the model we estimated for the seven OIC countries, using the dynamic Panel Method and GMM estimator.

**Table 3. ICT investment and economic growth (The dependent variable is the first-difference of the logarithm of real per capita GDP and all variables are in Logarithm)**

Explanatory variables	discription	coefficients	statistic <i>t</i>
c	constant	1.89	1.65
GDP(-1)	Lagged GDP per capita	0.62	2.65
K <sub>ict</sub>	investment in ICT inflows (% of GDP)	0.52	5.69
K	Gross fixed capital formation (% of GDP)	0.39	3.63
HC	School enrollment, secondary + tertiary (% gross)	0.066	1.29
FDI	Foreign direct investment, net inflows (% of GDP)	0.081	1.69
R <sup>2</sup>		0.59	
Wald Test Statistic		114.82	
Sargan Test		80.78	

Source: authors' own elaboration.

As the table shows all variables have signs that are consistent with theory predictions, based on the Wald Test which has a distribution with degrees of freedom equivalent to the number of explanatory variables minus the constant term, the null hypothesis of zero for all coefficients is rejected at the 1 percent of significance level. This means that there is 99 percent confidence that the estimated coefficients are true coefficients. The Sargan test statistics which has a  $\chi^2$  distribution equivalent to the number of over identified constraints reject the null hypothesis of correlation between residuals and instrumental variables. So the credibility of the results for interpretation is verified and the results can be interpreted with a high degree of confidence. The null hypothesis of Sargan's test for validity of the instruments assumes that the instruments are not correlated with the residuals. Put in another way, it assumes that the over-identifying moment conditions are close enough to zero. Notice that, for inference on model specification the two step Sargan test is used to avoid the problems arising from heteroscedasticity. However, for inference on coefficients as Arellano and Bon (1991) suggest, the one-step estimation result is provided. Based on the results, the growth of GDP in the OIC countries depends on a one period lag in the growth of GDP in these countries. Investment in ICT, gross domestic investment, human capital and direct foreign investment show a positive effect on economic growth of the OIC countries.

The coefficient of ICT investment is positive and statistically meaningful at the probability level of more than 99 percent. Since all variables are in logarithm, the value of 0.52 for the ICT coefficient means that the elasticity of economic growth within the OIC countries is actually 0.52 implying that a one percent increases in ICT investment would lead to a 0.52 percent economic growth in these countries. The increasing trend of using ICT in these countries as reflected by the statistics presented by the World Bank and other international organizations may be an indication that the growth inducing effect of ICT use has already been realized by the OIC Members. In short, these results verify the meaningful and stable growth inducing effect of ICT investments in the countries with OIC membership. They also verify the hypothesis of this paper that ICT investments have a meaningful growth inducing effect. Therefore, ICT investments in the OIC countries' economies are justified because of their effect on rising living standards in these countries overtime. Kraemer and Dedrick (2001), Lee, Hong, and Yougesh Khatri, (2003) and Pahjola (2001) also have reached similar conclusions.

The gross domestic investment(K) coefficient in the estimated model is 0.39 and statistically meaningful at the confidence level of more than 99 percent which implies that non-ICT investments also had a positive and meaningful effect on economic growth of the OIC countries, but this effect is weaker than the effect of ICT (0.39 vs 0.52. Levine and Renelt (1992), Barro (2001), and Sachs and Warner (2001) also reach a similar conclusion.

The foreign Direct Investment (FDI) coefficient, which is an indicator of the technical and technological indices of the model is positive, equal to 0.066 and acceptable at about 95 percent confidence level. Capital deepening and technical growth are the main factors of economic growth in any society, but relatively low value of the estimated coefficient for the FDI variable for the period of 1990-2014 does not reflect this prediction. This discrepancy can be attributed to the observation that the Middle East has been a risky and insecure environment and that there has been a capital flight incidence affecting OIC countries after Iraq and Afghanistan wars. This conclusion is consistent with Sotiris K. Papaioannou (2004).

The sign of proxy variable of human capital is positive but statistically meaningful only at the confidence level of less than 95 percent. It appears that in spite of some improvements in human capital in the OIC countries, human capital has not yet reached a level to have a positive and strong effect on economic growth and. Dewan and Kraemer, (1998, 200) and Pahjola (2001) suggest that lack of complementary assets and substructures, such as knowledge-based structure

to support use of ICT goods, may be the reason for why the effect of ICT in developing countries in the 1980s was low.

Finally, our main finding on the effect of ICT on economic growth are close to those of Nour's (2002).

## **7. Summery and Conclusions**

Regarding the effect of ICT on economic growth, it was shown that ICT affects the economy both on the supply and on the demand sides. The supply side effect of ICT may be explained through the production function and the demand side through utility function. This paper concentrated on exploring the supply side of ICT in the OIC countries. The results of the growth model estimations with ICT as an explanatory variable using Panel Data method in the context of the OIC countries show that ICT has a meaningful effect on the economic growth of these countries. The coefficient measuring the effect of the ICT gross domestic investment on economic growth in the model was positive, indicating that ICT investments affect economic growth of the OIC countries in a positive way. Direct foreign investment coefficient, which is the technical and technological index of the model, is positive and meaningful at the probability level of about 95 percent. This shows that direct foreign investment growth has a positive effect on the economic growth of OIC countries. The low reliability of this coefficient in the model can be attributed to such events as East Asia crisis that took place in 1990 and also September 11 events that led to instability in the Middle East. The September 11 events led to political and economic insecurity and instability in Asian countries in general and most of OIC countries in particular. This in turn led to capital drain in these countries. The OIC countries were left with the alternative of using their internal resources for investment to keep production and job creation. The positive and meaningful coefficient of gross domestic investment in the estimated model points to the direction of this argument. Also the effect of human capital coefficient in the economic growth model was positive but not meaningful statistically, which can be justified by the lack of (or not creating) complementary assets such as knowledge-based structure to support using ICT goods in OIC countries.

Since ICT can play a vital role as a mean for economic growth, it becomes necessary for the OIC countries to encourage the utilization of ICT in order to boost economic growth. From the results presented in this paper some tentative conclusions can be drawn.

The OIC countries cannot get the full benefits of ICT unless they have the social and cultural Infra-structures and skills required for utilizing ICT's capabilities. It is essential for governments to provide the society with information and on-time services and to educate people on how to use ICT. They should encourage institutions which are active in the field of IT, and underscore the role of R&D capital stock in these countries.

Since direct foreign investment is a technological variable of the model and has a positive effect on economic growth, it is crucial for OIC countries and Iran to be more active in attracting direct foreign investment.

To fill the gap that exists between OIC countries and the leading countries in the field of ICT development, it is essential to allocate and ensure necessary financial resources for investing in network infrastructures and technology with the aim of providing new potentials in OIC countries.

Since international trade plays an important role in ICT dispersion and allows domestic producers and costumers to have access to more diverse goods and services with lower prices, policy makers should encourage free trade through decreasing tariffs and eliminating non-tariffs barriers to ICT imports and thereby facilitate ICT development.

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***Wpływ Technologii Informatyczno-Komunikacyjnych (TIK) na wzrost gospodarczy w krajach OIC***

***Streszczenie***

Nowe teorie wzrostu zakładają, że procesy wzrostu są w dużym stopniu zależne od inwestycji w Technologie Informatyczno-Komunikacyjne (TIK). Jednak pełna weryfikacja empiryczna tego założenia nadal pozostaje otwartym zadaniem, zwłaszcza jeśli wzrost jest rozważany w grupie wybranych krajów, jak kraje OIC (ang.: Organization of Islamic Conference, pl.: Organizacja Konferencji Islamskiej). Co więcej, wnioski wynikające z badań dotyczących zwykłych zależności pomiędzy TIK a wzrostem gospodarczym są często wrażliwe na zastosowaną metodologię badawczą. Niniejszy artykuł stosuje podejście oparte na dynamicznych i statycznych danych panelowych w ramach modelu wzrostu i odnosi je do gospodarek krajów OIC w latach 1990-2014. Szacunki wykazują, że istnieje znaczący wpływ inwestycji w TIK na wzrost gospodarczy w analizowanych krajach. Implikacje polityczne wynikające z wniosków zakładają, że kraje OIC powinny projektować specjalne programy polityczne ukierunkowane na promocję inwestycji w TIK.

***Słowa kluczowe:*** TIK, kraje OIC, dane panelowe, wzrost gospodarczy