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The Impact of Information and Communication Technology on Economic Growth in MENA Countries

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Abstract

The purpose of this paper is to examine the extent to which the accumulation of Information and Communication Technology (ICT) has contributed to economic growth in MENA countries and how this compares with the role played in different groups of developed and developing countries. Using the neoclassical framework of economic growth, we investigate if the augmented Solow growth model that includes accumulation of ICT as well as physical and human capital could explain cross-country variations in per capita income. We estimate a set of regression equations for four groups of countries, namely MENA countries; OECD countries; a set of developing countries; and a set of developed and developing countries pooled together. Empirical results do not support the predictions of the standard Solow model but imply, however, that ICT plays a significant role in explaining cross-country variations in per capita income. In contrast to the argument that the fast accumulation and diffusion of ICT could have negative consequences on growth convergence, we find that convergence is achieved in all of our samples only when a proxy for information and communication technology enters the regression model as an additional explanatory variable.

Keywords

Economic Growth; Information and Communication Technology; Empirics of Economic Growth; Middle East; North Africa

JEL Classification: O11; O16; O33; O40; O47; O53; O57.

Introduction

The fast accumulation and diffusion of Information and Communication Technology (ICT)[1] and its influence on economic growth, in both developed and developing countries, has been an interesting research issue that received increasing attention amongst economists over the last decade. Research in the 1960s and 1970s showed how telecommunications strengthens production and distribution, public service delivery, and government administration. In the 1980s, information gained recognition as a crucial factor of production, in addition to physical and human capital and labour. Recently, globalization and rapid technological change, made ICT important to competitiveness and growth.

The role of ICT is vital in facilitating, motivating and activating communications and fast delivery of good and services within and across different regions of the world. The World Development Report 1998 entitled Knowledge for Development argues strongly for the increasing role of information technology in facilitating the production and distribution of a growing number of goods and services. According to the World Bank 2006, 'firms that use ICT grow faster, invest more, and are more productive and profitable than those that do not.' For example, sales growth is 3.4 percentage points higher and value added per employee is $3,400 more among developing country firms that use e-mail to communicate with clients and suppliers. Profits are also substantially higher among firms using ICT (Table 1). A recent survey of 56 developed and developing countries found a significant link between Internet access and trade growth—with the greatest benefits accruing to developing countries with the weakest trade links (World Bank 2006).

Recent reports, studies, and statistics point out to the important role ICT plays in economic growth and development. Web sites and e-mail are now widely used in many developing countries, including Middle East and North Africa (MENA) region, suggesting that ICT is no longer a luxury. Latest estimates indicate that worldwide, Internet use more than quadrupled between 2000 and 2004 (International Telecommunication Union 2006). Though Eastern Europe and Central Asia are in the lead among developing regions, with 117 Internet users per 1,000 people in 2004, the fastest growth, 370 percent, occurred in the MENA region (Figure 1). Figure 2 shows that the number of fixed and mobile phone subscribers (per 1000 people) has almost doubled in MENA region between 2000 and 2004. This substantial increase is mainly attributed to the increase in the number of mobile phones, which has an especially significant impact on growth in developing countries in general and MENA countries in particular by substituting for scarce fixed connections. This has led to increasing mobility, facilitating information flow, reducing transaction costs, broadening markets and networks, and facilitating searches for employment. In other words, mobile phones can do for underserved areas what fixed telephone lines did in many other regions and countries years ago. Since in developing countries mobiles are primarily substitutes, not complements, for fixed lines, the growth dividend is very high. The impact of mobile telephony on economic growth is likely to be much larger in developing countries compared to developed countries since mobiles have opened up entirely new communication means (International Telecommunication Union 2006). Figure 3 shows an undisputable positive relationship between GDP per capita and an ICT index, constructed for the purpose of this paper, in a sample of 93 countries, including MENA.

The purpose of this paper is to examine the extent to which ICT accumulation has contributed to economic growth in MENA countries and how this compares with the role played in different groups

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1 Information and communications technology (ICT) is identified with the outputs of computers, communication equipments, semiconductor manufacturing, hardware manufacturing, and software. The key variables are ICT services such as the Internet and telecommunications, ICT equipments such as the number of personal computers and number of telephone lines, and employment in the services and equipment sectors. These items appear in the GDP as investments by businesses, households, and governments along with imports and exports to the rest of the world.

of developed and developing countries. Using the neoclassical framework of economic growth, we investigate if the augmented neoclassical growth model that includes accumulation of ICT as well as physical and human capital could explain cross-country variations in per capita income. We estimate a set of regression equations for four groups of countries. They are MENA countries, OECD countries, a set of developing countries (from Latin America, East and South Asia, Eastern Europe, and MENA), and a set of developed as well as developing countries pooled together.[2] For each set of countries, the textbook Solow model is tested by estimating a regression equation in which physical capital and population growth are the only explanatory variables, whereas GDP per capita is the dependent variable. Second, the Solow model is augmented by including accumulation of human as well as physical capital. To test the augmented Solow model, a proxy for human-capital accumulation is included as an additional explanatory variable in the cross-country regressions. Third, the above relationship is reestimated after including an ICT index as an additional explanatory variable in order to be able to measure the quantitative impact of ICT accumulation on economic growth in each group of countries.

The paper has six sections. A brief review of the literature is presented in section II. Section III describes the theoretical framework and empirical specifications used in the paper. Section IV describes the data used and the different measures of the variables employed in the empirical model. Empirical results are presented in section V. Section VI concludes the paper.

II. Literature

While there is substantial evidence that new information technologies are in many ways transforming the operations of modem economies, the impacts on productivity and economic growth have been much harder to detect as evidence remains largely anecdotal. Most studies analyzing the impact of ICT on the economy revolve around ‘productivity’ effects. In developed countries, many studies have been undertaken to analyze productivity gains in the whole economy, and at sector and firm levels. Several comparative studies have been carried out to analyze the difference in productivity gains in different countries and regions of the world. ‘While the extent of the impact may differ, there is a consensus that ICT have a clear impact on economic growth by increasing productivity’ (International Telecommunication Union 2006, 17).

An increasing number of theoretical and empirical studies have concluded that ICT has a positive impact on productivity (Hitt and Brynjolfsson 1996 and Brynjolfsson and Yang 1996), growth and development (Jorgenson and Stiroh 1995; Mansell and When 1998; and Pohjola 2000 and 2001), work place organization (Bresnahan et al. 1999), and human capital development and skill upgrading (Acemoglu 1998 and Hwang 2000).

On the other hand, others have shown that ICT might potentially have a negative impact on labour markets (Aghion and Howitt 1998; Freeman and Soete 1985; Freeman and Soete 1994; and 1997). The main argument of these studies is that ICT could create the so-called labour-saving or skill-bias effect, via the displacement of some unskilled workers due to either reduction or elimination of some of the jobs that do not necessarily require skilled labour. In addition, some economists argue that the fast accumulation and diffusion of ICT could have negative consequences on growth convergence and income inequality across and within countries. In particular, developed countries, which have the vast majority of ICT stock in the world, will have better competitive advantages which could make it harder for developing countries to compete in global markets for both inputs and outputs. This, in turn, could hinder the catching up of developing countries to their developed peers in terms of growth. By the same token, the rapid accumulation of ICT might also have some negative implications on the poor

2 The classification of the samples on regional basis is less compelling because many countries belonging to some regions, like South Asia, lack data especially on variables measuring the diffusion of information and communication technology.

in developing countries and hence aggravate the already-existing issues of income inequality in those countries.

Several notable studies have recently stressed the role of information and communication technology in economic growth. The World Development Report 1998 entitled Knowledge for Development argues strongly for the increasing role of knowledge in economic development. The report concludes that the information revolution stimulates the creation of new knowledge by giving inventors and innovators fast access to knowledge. Information technology is also seen to facilitate the production and distribution of a growing number of other goods and services. A cross-country analysis of economic growth is presented in support of the argument. Pohjola (2000) explores the impacts of information technology investment on economic growth in a cross-section of 39 countries in the period 1980-95. His results indicate that investment in information technology has a strong influence on economic growth in a sample of 23 developed (OECD) countries. Its impact is found to be as large as that of the rest of the capital stock. Also, Dewan and Kraemer (2001) estimate an inter-country Cobb-Douglas production function with GDP as output and IT capital, non-IT capital and labour as inputs-by pooling annual data from 36 countries over the period 1985-1993. Their results indicate that the returns on IT capital are positive and statistically significant for developed countries, but non-significant for developing countries. Along the same lines, Haacker and Morsink (2002) find a positive, large, and significant effect of IT expenditure on the acceleration in TFP growth in the late 1990s, and a smaller-and significant-effect of IT production. Their results also indicate that TFP growth accelerated more in higher income countries, suggesting that they were better at realizing the efficiency gains associated with using IT.

A comprehensive international study comparing the time periods 1989-1995 with 1995-2003 uses separate measures of ICT investment, non-ICT investment, and several measures of labour, to determine the correlation between changes in ICT investment levels and GDP growth across different regions. According to this study, the group that benefited the most from ICT was the G7, where almost one third (27 percent) of the GDP growth that occurred from 1995-2003 was due to ICT investment. However, in major developing and transition countries, ICT capital played a smaller (although increasing) role. Sub-Sahara Africa shows similar economic impact from ICT capital growth over time—about 10 percent—while most other groups showed a greater impact in the later period. Latin America jumped considerably from the first time-period to the second (International Telecommunication Union 2006)

To our surprise, research examining the role of information and communication technology in economic growth in the MENA region is not well articulated yet. To date, only two studies have tried to fill this void. Abutaleb and Hashem (2005) examine the impact of ICT on the GDP rate of growth in MENA by developing a computable general equilibrium (CGE) model that relates the different sectors of the economy to technology, labour, capital, and GDP. They conclude that the diffusion of communications and computer technology will increase the rate of growth of GDP in Egypt and Tunisia. Satti and Nour (2003) find that ICT diffusion correlates positively to economic growth and human capital. However, the significance of the ICT impact on growth is somewhat doubtful and ambiguous.

III. The Model

In his classic model, Solow proposed that we begin the study of economic growth by assuming a standard neoclassical production function with decreasing returns to capital. Taking the rates of saving and population growth as exogenous, Solow showed that these two variables determine the steady-state level of income per capita. Because saving and population growth rates vary across countries, different countries reach different steady states. That is, the steady-state level of income is positively related to the rate of saving and negatively related to the rate of population growth.

Mankiw et al. (1992) assert that the Solow model correctly predicts the directions of the effects of saving and population growth but not the magnitudes. They argue that the effects of saving and population growth on income are too large. So, they go beyond the textbook Solow model by including accumulation of human as well as physical capital. The exclusion of human capital and information technology from the textbook Solow model can potentially explain why the estimated influences of saving and population growth appear too large, for two reasons. First, for any given rate of human capital accumulation, higher saving or lower population growth leads to a higher level of income and thus a higher level of human capital; hence, accumulation of physical capital and population growth have greater impacts on income when accumulation of human capital is taken into account. Second, human-capital accumulation may be correlated with saving rates and population growth rates; this would imply that omitting human-capital accumulation biases the estimated coefficients on saving and population growth. To test the augmented Solow model, we include a proxy for human-capital accumulation as an additional explanatory variable in our cross-country regressions.

To study the impact of information technology on economic growth, we consider an augmented neoclassical model of economic growth following Mankiw et al. (1992). In addition to investment in physical capital (i.e. in machinery, equipment and structures), the basic Solow model is extended to include investment in human capital and in information technology.

Let the production function be

(1) $$Y(t) = K(t)^{\alpha} H(t)^{\beta} C(t)^{\gamma} (A(t)L(t))^{1-\alpha-\beta-\gamma},$$

The notation is standard: *Y* is output, *K* physical capital, *H* human capital, *C* information and communication technology, *L* labour, and *A* the level of technology. *L* and *A* are assumed to grow exogenously at rates *n* and *g*:

$$L(t) = L(0)e^{nt}$$
$$A(t) = A(0)e^{gt}.$$

The number of effective units of labour, $A(t)L(t)$, grows at rate $n + g$. The model assumes that a constant fraction of output, *s*, is invested. Let s_k be the fraction of income invested in physical capital, s_h the fraction invested in human capital, and s_c the fraction invested in information and communication capital. The evolution of the economy is determined by

(2a) $$\dot{k}(t) = s_k y(t) - (n + g + \delta_k) k(t),$$

(2b) $$\dot{h}(t) = s_h y(t) - (n + g + \delta_h) h(t),$$

(2c) $$\dot{c}(t) = s_c y(t) - (n + g + \delta_c) c(t),$$

where *k* is the stock of physical capital per effective unit of labour, $k = K/AL$; *h* is the stock of human capital per effective unit of labour, $h = H/AL$; *c* is the stock of information and communication capital per effective unit of labour, $c = C/AL$; and *y* is the level of output per effective unit of labour, $y = Y/AL$; and δ_k, δ_h, δ_c, are the depreciation rates of physical capital, human capital, and information technology respectively.

We are assuming that human capital and information technology depreciate at the same rate as physical capital. We also assume that $\alpha + \beta + \gamma \prec 1$, which implies that there is decreasing returns to all types of capital.[3] Rewriting the production function (l) in intensive form as

3 In the case of $\alpha + \beta + \gamma = 1$, then there are constant returns to scale in the reproducible factors. In this case, there is no steady state for this model.

(3) $$y(t) = k(t)^{\alpha} h(t)^{\beta} c(t)^{\gamma},$$

the steady-state values of the capital stocks can be solved from the following set of equations.

$$k^*(t)^{\alpha} h^*(t)^{\beta} c^*(t)^{\gamma} = \frac{(n+g+\delta)}{s_k} k^*(t),$$
$$k^*(t)^{\alpha} h^*(t)^{\beta} c^*(t)^{\gamma} = \frac{(n+g+\delta)}{s_h} h^*(t)^{\beta},$$
$$k^*(t)^{\alpha} h^*(t)^{\beta} c^*(t)^{\gamma} = \frac{(n+g+\delta)}{s_c} c^*(t)^{\gamma}.$$

Substituting the solutions in (3), taking logarithms, and adding the error term, the empirical version of the equation showing the steady-state value of output per effective labour can be written as

(4) $$\ln y_i = \ln A(0) + gt + \frac{\alpha}{1-\phi}\ln s_{ki} + \frac{\beta}{1-\phi}\ln s_{hi} + \frac{\gamma}{1-\phi}\ln s_{ci} - \frac{\phi}{1-\phi}\ln(n+g+\delta) + \varepsilon_i,$$

where $y = \frac{Y(t)}{A(t)L(t)}$, $\phi = \alpha + \beta + \gamma$ and $\phi \prec 1$ by assumption. The error term, ε_i, reflects differences not only in technology but also in resource endowment, climate, and institutions among countries. The depreciation rate, δ, is assumed to be the same for all countries and for all types of capital.[4] Equation (4) shows that the steady-state level of output per labour is positively related to the rates of saving in each type of capital but negatively related to the rates of population growth and depreciation of capital.

The model above predicts that countries reach different steady states determined by the factors specified in equation (4). According to Mankiw et al. (1992), the Solow model does not predict convergence; it predicts only that income per capita in a given country converges to that country's steady-state value. In other words, the Solow model predicts convergence only after controlling for the determinants of the steady state, a phenomenon that might be called ‘conditional convergence’. In addition, the Solow model makes quantitative predictions about the speed of convergence to steady state.

Following Mankiw et al. (1992), let y^* be the steady-state level of income per effective worker given by equation (4) , and let $y(t)$ be the actual value at time t. Approximating around the steady state, the speed of convergence is given by

(5) $$\frac{d\ln y(t)}{dt} = \lambda[\ln y^* - \ln y(t)],$$

where $\lambda = \phi(n+g+\delta)$ denotes the speed of convergence. Equation (5) implies that

(6) $$\ln y_i(t) = (1-e^{-\lambda t})\ln y_i^* + e^{-\lambda t}\ln y_i(0),$$

where $y(0)$ is income per effective labour at some initial date. Equation (6) can be rewritten by subtracting $\ln y(0)$ from both sides yielding,

(7) $$\ln y_i(t) - \ln y(0) = (1-e^{-\lambda t})\ln y_i^* - (1-e^{-\lambda t})\ln y_i(0).$$

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4 According to Pohjola (2000), there do not exist any data that would allow country specific depreciation rates to be estimated, neither there is any strong reason to expect depreciation rates to vary greatly across countries.

As pointed out by Durlauf and Quah (1998) and Pohjola (2000), this convergence equation is obtained by restricting the parameters of the augmented Solow model in such a way that the depreciation rates on the different types of capital are equal. Otherwise, the local dynamics of income would be dependent on the values of the state variables, i.e. of the capital stocks. The steady-state values specified in equation (4) may be substituted in (7) yielding the following equation

$$(8)\ \ln y_i(t) - \ln y_i(0) = \theta + \rho\frac{\alpha}{1-\phi}\ln s_{ki} + \rho\frac{\beta}{1-\phi}\ln s_{hi} + \rho\frac{\gamma}{1-\phi}\ln s_{ci} - \rho\frac{\phi}{1-\phi}\ln(n+g+\delta) - \rho\ln y(0) + \varepsilon_i,$$

where $\rho = (1-e^{-\lambda t})$ and $\theta = \rho \ln A(0)$.

Equation (8) shows that the growth of income is a function of the determinants of the ultimate steady state and the initial level of income.

IV. Data

Most studies on the economic impact of ICT focus mainly on a limited number of developed countries.[5] Very few studies have tried to analyze or measure the impact of ICT on the economies of developing countries. The main reason is that the underlying data necessary to carry out these studies are either not available or not comparable. To overcome this issue, we try in this paper to use more readily available and comparable ICT data for different country groups. The data used are taken from the World Development Indicators Database (2003 and 2005), published by the World Bank, and the Human Development Report (2005), published by the United Nations Development Program. Following the standard practice of many empirical cross-country analysis of economic growth, investment in physical capital (s_k) is measured as the average share of real investment in real GDP over the period considered. Investment in human capital (s_h) is approximated by the education index which constitutes one-third of the human development index.[6,7] As shown in Appendix 1, an index for Investment in Information and Communication Technology (s_c) is computed using data on Personal Computers (per 1000 people), Internet Subscribers (per 1000 people), Fixed Phone Lines (per 1000 people), and Cell Phone Subscribers (per 1000 people). Similar to Mankiw et al. (1992), the sum of

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5 Some of these studies (The International Telecommunication Union 2003) use a comprehensive index that measures current development in the ICT sector. It measures the economy’s ability to take advantage of ICT in the future. It comprises three dimensions: infrastructure (50%); network usage (25%); market structure (25%). The infrastructure cluster measures the development of information and communication technology infrastructure, with a special focus on mobile networks and Internet development. It includes fixed lines; cellular subscribers; estimated Internet users; personal computers; international Internet bandwidth (Mbit/s); broadband subscribers; leased lines; 2.5G and 3G license and deployment. The Network Usage component attempts to gauge how users are taking advantage of the existing network by examining costs of network usage and items that proxy network use. It includes roaming agreements; internet service providers (ISPs); secure socket layers (SSL); mobile cost basket; internet cost basket; telecom revenues. The market structure cluster assigns an overall value for an economy by examining the level of competition in its different ICT markets. The markets are scored as: full competition; partial competition (Duopoloy or Monopoly). It includes privatized incumbent; years incumbent has been private; separate regulator; years regulator has been separate; market structure for local services; market structure for long distance; market structure for international calls; market structure for mobile market structure for leased lines; market structure for Internet service providers.

6 In agreement with Mankiw et al. (1992), we restrict our focus to human capital investment in the form of education-thus ignoring investment in health, among other things.

7 Here we use a proxy for the rate of human-capital accumulation (s_h) instead of the actual spending on human capital accumulation. According to Mankiw et al. (1992), p.419 ‘….explicit spending on education takes place at all levels of government as well as by the family, which makes spending on education hard to measure. In addition, not all spending on education is intended to yield productive human capital: philosophy, religion, and literature, for example, although serving in part to train the mind, might also be a form of consumption. ‘

labour augmenting technological change and the depreciation rate, $g+\delta$, is set equal to 0.05 in estimating equations (4) and (8). Reasonable changes in this assumption are likely to have little effect on the estimates. Finally, *n* is the average annual growth rate of the working age population.

Table 2 shows the definition and the basic data source of the variables used. The data are annual and cover the period 1985-2003. Being interested in the impact of information technology on economic growth, the selection of countries and the time period to be considered is determined by the availability of data on communication and information technology-related variables. We consider four samples of countries. The most comprehensive consists of all countries for which data are available. This sample consists of 93 countries. The second sample consists of 17 MENA countries for which data on information and communication technology variables were available. The third sample includes 29 OECD countries and the fourth sample includes 64 developing countries from East Asia, South Asia, Eastern Europe, Latin America, and also the MENA region.

Table 3 contains the correlation coefficients between the variables used.[8] Preliminary analysis of the data, using these correlation coefficients, reveals that per capita income does not have the presumed positive correlation with investment ratio and negative correlation with population growth. Its highly positive correlation with proxies for human capital and information and communication technology is evident in all of the four samples. The highly positive correlation between measures of human capital and information and communication technology implies that there is strong complementarity between the two variables. This observation is well in line with that of Satti and Nour (2003).

V. Empirical Results

Equation (4) assumes that the observed levels of GDP per working age population correspond to the steady state. Our estimation strategy for equation (4) is to first test the textbook Solow model by estimating a regression in which physical capital and population growth are the only explanatory variables, whereas GDP per capita is the dependent variable. Second, we augment the Solow model by including accumulation of human as well as physical capital. To test the augmented Solow model, we include a proxy for human-capital accumulation as an additional explanatory variable in our cross-country regressions. Third, we reestimate the above relationship after including an ICT index as an additional explanatory variable in order to be able to measure the quantitative impact of ICT accumulation on economic growth in each group of countries.

Table 4-6 show estimation results of both unrestricted and restricted regressions of the above-mentioned versions of equation (4) for MENA countries, OECD countries, a set of developing countries, and a bigger sample that includes 93 developing and developed countries. In the first version of equation (4), the restricted regression imposes on the parameters the constraint that the coefficients on $\ln(s_k)$ and $\ln(n+g+\delta)$ are equal in magnitude and opposite in sign.[9] In the second version, the constraint is such that the sum of the coefficients on $\ln(s_k)$ and $\ln(s_h)$ are equal to the negative value of the coefficient on $\ln(n+g+\delta)$. Finally, we impose the constraint that the sum of the coefficients on $\ln(s_k)$, $\ln(s_h)$, and $\ln(s_c)$, on the one hand, and the coefficient on $\ln(n+g+\delta)$, on the other, have equal magnitude but opposite signs. For each regression version, an F -test is carried out to see whether the restriction is appropriate, as shown in the lower panel of Tables 3-5.

8 However, high correlations between the initial level of income, ln(y85), and the proxies for human capital and information and communication technology might be seen to create problems in estimating their separate contributions to economic growth. A similar argument applies to the correlation between the proxies for human capital and information and communication technology.

9 Following Mankiw et al. (1992) and Pohjola (2000), we assume that $g+\delta=0.05.$ As Mankiw et al. (1992) asserts, reasonable changes in this assumption have little effect on the estimates.

As shown in Table 4, results do not support predictions of the textbook Solow model. The coefficients on $\ln(s_k)$ and $\ln(n+g+\delta)$ do not have the predicted signs and are insignificant for the four samples.[10] Also the restriction that these two coefficients are equal in magnitude and have opposite signs is rejected for two of the four samples as the significance level of the F–test is less than 0.10. In addition, differences in saving and population growth do not account for a large fraction of the cross-country variation in per capita income. In the four regressions, the value of the adjusted $\overline{R}^2$ is very low. So, in contrast to the results by Mankiw et al. (1992) and Phjolia (2000), the two observable variables on which the standard Solow model focuses in fact do not account for most of the variation in per capita income. This result is partially well in line with Lucas (1988) that asserts that variation in population growth, for example, can not account for any substantial variation in real incomes along the lines predicted by Solow model. One way to interpret the insignificance of the coefficient on physical capital is that most of developing countries included in our samples have surely passed early development stages where physical capital plays a significant role in economic growth. At the current development stage, human as well as other forms of capital (including ICT) are expected to play a more significant role than physical capital. Moreover, the significantly negative coefficient on physical capital in the OECD equation suggests that developed countries might be experiencing a period of 'diminishing returns'. That is, further accumulation of physical capital does not help increase growth in these countries anymore. Also the insignificance of the coefficient on population growth in the first three samples in Table 4 might be due to the demographic transition that many of countries included in the samples (especially Latin American and Eastern European countries) have gone through. Even in MENA countries, fertility rates have decreased substantially over the last five decades and since the standard Solow model was first developed.

However, the regression results parented in Table 4 leaves out human capital as an important explanatory variable. Economists have long stressed the importance of human capital to the process of growth. Therefore, one might expect that ignoring human capital would lead to incorrect conclusions.[11] Table 5 shows the estimation results of the Solow model augmented by human capital as proposed by Mankiw et al. (1992). The inclusion of human capital can potentially alter either the theoretical modeling or the empirical analysis of economic growth. In Table 5, the results are for regressions of the logarithm of per capita income on the logarithms of the investment rate, population growth, and the education index constituting one-third of the human development index. The human capital measure enters significantly in the four samples. It also improves the fit of the regression as indicated by the value of $\overline{R}^2$ compared with Table 4. Human capital alone is capable of explaining 45 percent of the cross-country variation in per capita income in MENA countries as opposed to 62 per cent in OECD countries. We, thus, conclude that adding human capital to the Solow model greatly improves its performance as we are able to dispose of a fairly significant part of the model's residual variance.

Nonetheless, the bottom half of Table 5 shows that, for the four samples used, the restriction that the coefficients on $\ln(s_k)$, $\ln(s_h)$, and $\ln(n+g+\delta)$ sum to zero is rejected. We postulate that this has to do with the insignificance of $\ln(s_k)$ and $\ln(n+g+\delta)$ that still have neither the sign nor the magnitude predicted by Solow model.

Table 6 shows the most interesting results in this paper. The results are obtained by estimating the augmented model when a proxy for information and communication technology is included. The inclusion of the ICT index further improves the performance of the model and shows that ICT has a large and significant impact on the level of per capita income. Adding the ICT index reduces the size of the coefficient on human capital and improves the fit of the regression compared with Table 5. As

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10 The only exception is the coefficient on $\ln(n+g+\delta)$ in the sample of 93 countries which has the expected sign and is highly significant.

11 For instance, Kendrick (1976) estimates that over half of the U.S. capital in 1969 was human capital.

indicated by $\overline{R}^2$ reported in Table 6, only human capital and ICT can explain up to 60 percent in the case of MENA countries compared to 80 percent in the OECD sample.

In Tables 7-10, we report regression results of estimating the dynamic version of the augmented Solow model specified in equation (8). We examine the issue of convergence, which has received much attention over the last two decades. We report regressions of the change in the logarithm of per capita income over the period 1985-2003 on the logarithm of per capita income in 1985 with and without controlling for physical capital, population growth, human capital, and information and communication technology.

In Table 7, the logarithm of per capita appears alone on the right-hand side. Its coefficient, though has a negative sign in the four samples, it is only significant in the case of the set of developing countries and MENA countries, implying convergence in these two groups. However, for both OECD and the sample of 93 countries, the coefficient on initial level of per capita income is insignificant and the adjusted $\overline{R}^2$ is essentially zero. This implies that there is no tendency for poor countries to grow faster on average than rich countries. This result of no convergence for the sample of the 93 developing and developed countries is consistent with the vast majority of findings in the literature on convergence. The result that there is no convergence among OECD countries is a little surprising. However, convergence in per capita income among OECD countries is restored when we exclude the new OECD member countries, particularly Eastern European countries and Mexico, from our sample.

Table 8 adds our measures of the rates of investment and population growth to the right-hand side of the regression. In all four samples, the coefficient on the initial level of income is negative but significant only in the sample of developing countries. Moreover, the inclusion of investment and population growth rates improves substantially the fit of the regression. Table 9 adds our measure of human capital to the right-hand side of the regression in Table 8. Human capital improves the fit of the regression but it enters significantly only in the samples of OECD countries and in our bigger sample of the 93 developing and developed countries. Convergence is now apparent in two of the samples, namely the OECD countries and the set of Developing countries. When the ICT index is added to the right-hand side of the regression, as shown in Table 10, convergence becomes evident in all four samples. The coefficient on initial income becomes significantly negative. Adding ICT improves the fit of the regression as implied by the high value of $\overline{R}^2$.

VI. Conclusion

The purpose of this paper is to examine the extent to which the accumulation of Information and Communication Technology has contributed to economic growth in MENA countries and how this compares with role played in different groups of developed and developing countries. We adopt principally the discipline of the neoclassical framework for economic growth to investigate if the augmented neoclassical growth model that includes an index for the accumulation of Information and Communication Technology as well as physical and human capital could explain cross country variations in per capita income. We estimate a set of regression equations for four groups of countries, namely MENA countries, OECD countries, a set of developing countries (from Latin America, East and South Asia, Eastern Europe, and the Middle East), and a set of developed as well as developing countries pooled together. For each set of countries we, first test the textbook Solow model by estimating a regression equation in which physical capital and population growth are the only explanatory variables, whereas GDP per working-age person is the dependent variable. Second, we augment the Solow model by including accumulation of human as well as physical capital. To test the augmented Solow model, we include a proxy for human-capital accumulation as an additional explanatory variable in our cross-country regressions. Third, we reestimate the above relationship after including an ICT index as an additional explanatory variable in order to be able to measure the quantitative impact of ICT accumulation on economic growth in each group of countries.

Our results show that the Solow model is not capable of explaining cross-country variations in per capita income in the four samples we used. In contrast to previous studies that supported the predictions of Solow model, physical capital and population growth do not account for most of the variation in per capita income. This result is partially well in line with Lucas (1988) that asserts that variation in population growth, for example, can not account for any substantial variation in real incomes along the lines predicted by Solow model. However, the inclusion of human capital to the Solow model greatly improves its performance, as we are able to dispose of a significant part of the model's residual variance.

The most interesting results in this paper are obtained by estimating the augmented model after adding a proxy for information and communication technology. The inclusion of the ICT index substantially improves the performance of the model and show that ICT has a large and significant impact on the level of per capita income. This implies that information and communication technology plays a significant role in explaining cross-country variations in per capita income. When testing for convergence, we find that there is no tendency for poor countries to grow faster on average than rich countries in two of our samples. Though this result is consistent with the vast majority of findings in the literature, convergence becomes evident in all four samples *only* when an index for information and communication technology is used as an additional explanatory variable. Our results, therefore, cast no doubt that the role of ICT is vital in facilitating, motivating and activating communications and fast delivery of good and services within and across different regions of the world. In contrast to the argument that the fast accumulation and diffusion of ICT could have negative consequences on growth convergence, we find that ICT has a significant explanatory power in restoring convergence among countries.

The aforementioned results have several policy implications. First, physical capital accumulation, though necessary, is not sufficient for achieving higher economic growth. Like most conventional factors of production, physical capital is subject to diminishing returns, which yield only sluggish growth. Second, investment in human capital, namely education and health, is very crucial to growth. Growth models with the assumption of increasing or even constant-returns-to-scale have shown that human capital accumulation can contribute significantly to growth either directly or indirectly. On the one hand, investment in education and health leads to higher productivity and, hence, growth rates. On the other hand, human capital complements physical capital, which augments its contribution to growth. Our results, more importantly, imply that investment in ICT could raise growth rates significantly. Thus, policymakers in MENA countries should plan allocating more investments to ICT sectors. Given the inevitable highly positive correlation and mutual spillover between human capital and the information technology, investments in the ICT sector would certainly require additional public spending in order to enhance the quantity and improve the quality of education in MENA countries.

Finally, a few remarks are worth mentioning to help understand the limitations of the empirical results in this paper and to help develop a further research agenda. First, this paper has tried to measure the 'total impact' of ICT on economic growth. However, one would need to separate out the direct from the indirect impact of ICT on growth. The real potential of ICT is not the direct impact of the ICT sector itself. The key economic impact of the spread and use of ICT is indirect, by transforming the way individuals, businesses and other parts of the society work, communicate and interact (World Bank 2006). Second, the findings reported in this paper cast doubt on the recent trend among economists to dismiss the neoclassical growth model in favour of endogenous-growth models. One can still explain much of the cross-country variation in income while employing the neoclassical model. This conclusion does not imply, however, that the neoclassical model is a complete theory of growth as one would still like also to understand the determinants of saving, population growth, human capital, and ICT all of which the neoclassical model we used treats as exogenous. Our conclusion does imply, however, that the neoclassical model gives the right answers to the questions it is designed to address. Third, in constructing an appropriate ICT index, one should use data on the number of users rather than subscribers to the respective ICT service. This gives a clearer picture on the intensity of ICT diffusion, especially in developing countries where the number of users exceeds by far the number of subscribers. However, data on the number of subscribers to different ICT services are still employed in this paper due to the unavailability of some of the ICT data on ‘users’ for many countries. In addition, available data on users of ICT services are still rough estimates, especially in developing countries.[12]

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12 Many ICT users in developing countries are not really subscribers, as they tend to seek the service through telecenters, cyber cafes, or other public places providing ICT services. Many of these places belong to the informal sector where it is difficult to keep track of the actual number of people using the ICT services.

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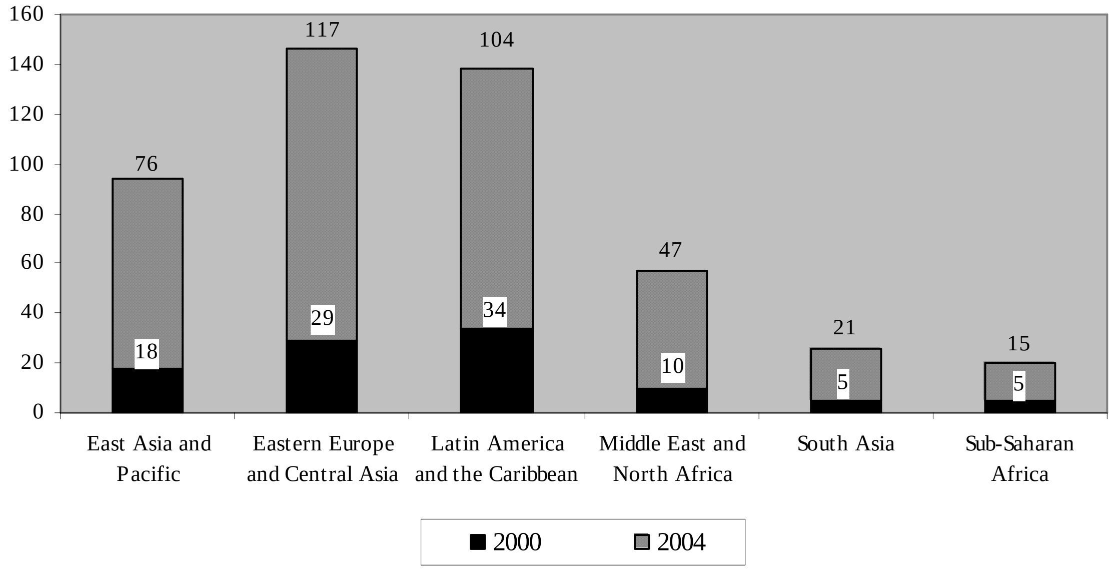
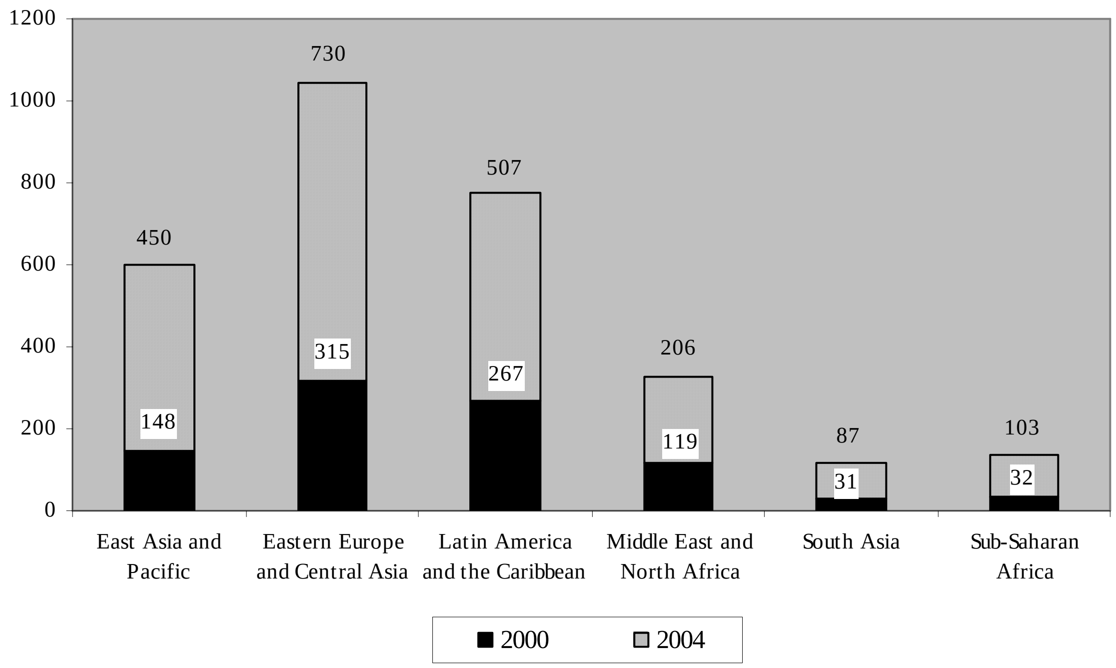
Figures and Tables

Figure 1. Internet Users (per 1000 people)



Source: World Bank (2006)

Figure 2. Fixed and Mobile Phone Subscribers (per 1000 people)



Source: World Bank (2006).

Figure 3

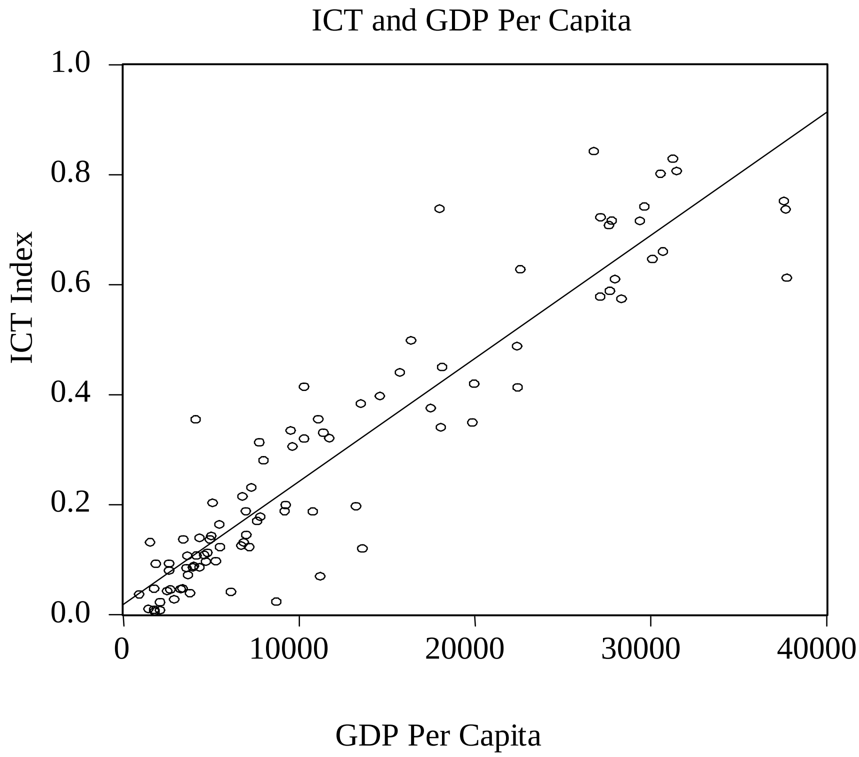

ICT and GDP Per Capita
ICT Index
1.0
0.8
0.6
0.4
0.2
0.0
0
10000
20000
30000
40000
GDP Per Capita

Table 1: Effect of ICT Use on Enterprise Performance in Developing Countries

Indicator	Enterprises that do **not** use ICT	Enterprises that use ICT	Difference
Sales growth (%)	0.4	3.8	3.4
Employment growth (%)	4.5	5.6	1.2
Profitability (%)	4.2	9.3	5.1
Investment rate (%)	N/A	N/A	2.5
Labor productivity (value added per worker, $US)	5,288	8,712	3,423
Total factor productivity (%)	78.2	79.2	1.0

Source: World Bank (2006).

Table 2: Definition of Variables

Variable	Definition
y(2003) and y(85)	Real GDP per working age (i.e. age 15 to 64) population in 2003 and 1985, respectively, measured in $US purchasing power parities ($PPP). Source: World Bank (2003 and 2005).
n	Average of annual growth rate of working age population, 1985-2003. Source: World Bank (2003 and 2005).
s_k	Average of annual ratios of gross domestic investment to GDP, 1985-2003. Source: World Bank (2003 and 2005).
s_h	Education Index. Source: United Nations Development Program (2005).
s_c	Information and Communication Technology Index. Source: author's calculations as shown in Appendix 1.

Table 3: Correlation Matrix

(a) A Sample of 93 Countries

	$\ln y(2003)$	$\text{Ln}(s_k)$	$\ln(s_h)$	$\ln(s_c)$	$\ln(n+g+\delta)$	$\ln y(85)$
$\ln y(2003)$	1.00					
$\ln(s_k)$	-0.14	1.00				
$\ln(s_h)$	0.65	-0.03	1.00			
$\ln(s_c)$	0.89	-0.10	0.77	1.00		
$\ln(n+g+\delta)$	-0.25	-0.10	-0.55	-0.36	1.00	
$\ln y(85)$	0.89	-0.20	0.69	0.85	-0.33	1.00

(b) MENA Countries

	$\ln y(2003)$	$\text{Ln}(s_k)$	$\ln(s_h)$	$\ln(s_c)$	$\ln(n+g+\delta)$	$\ln y(85)$
$\ln y(2003)$	1.00					
$\ln(s_k)$	-0.12	1.00				
$\ln(s_h)$	0.61	0.04	1.00			
$\ln(s_c)$	0.82	-0.19	0.67	1.00		
$\ln(n+g+\delta)$	0.31	-0.16	0.03	0.37	1.00	
$\ln y(85)$	0.96	-0.07	0.54	0.74	0.50	1.00

(c) OECD Countries

	$\ln y(2003)$	$\ln(s_k)$	$\ln(s_h)$	$\ln(s_c)$	$\ln(n+g+\delta)$	$\ln y(85)$
$\ln y(2003)$	1.00					
$\ln(s_k)$	-0.33	1.00				
$\ln(s_h)$	0.78	-0.21	1.00			
$\ln(s_c)$	0.90	-0.30	0.82	1.00		
$\ln(n+g+\delta)$	-0.20	0.18	-0.35	-0.28	1.00	
$\ln y(85)$	0.88	-0.49	0.67	0.78	-0.31	1.00

(d) A Sample of Developing Countries

	$\ln y(2003)$	$\ln(s_k)$	$\ln(s_h)$	$\ln(s_c)$	$\ln(n+g+\delta)$	$\ln y(85)$
$\ln y(2003)$	1.00					
$\ln(s_k)$	-0.11	1.00				
$\ln(s_h)$	0.44	0.02	1.00			
$\ln(s_c)$	0.79	-0.05	0.65	1.00		
$\ln(n+g+\delta)$	-0.01	-0.16	-0.49	-0.21	1.00	
$\ln y(85)$	0.79	-0.17	0.54	0.73	-0.17	1.00

Table 4: Estimation of the Textbook Slow Model

Dependent Variable: Log GDP per working-age person (PPP) in 2003				
Sample	MENA	OECD	DEVELOPING	ALL
Observations	17	29	64	93
CONSTANT	8.2*** (2.09)	13.05*** (1.53)	8.58*** (1.43)	4.64*** (1.63)
$\ln(s_k)$	0.07 (0.65)	-0.98** (0.49)	-0.15 (0.28)	-0.41 (0.33)
$\ln(n+g+\delta)$	0.57 (0.54)	0.004 (0.09)	0.09 (0.48)	-1.34*** (0.54)
$\overline{R}^2$	0.07	0.13	0.03	0.07
Restricted Regression				
CONSTANT	9.51*** (0.85)	10.13*** (0.37)	8.73*** (0.30)	8.90*** (0.38)
$\ln(s_k)$ - $\ln(n+g+\delta)$	-0.30 (0.37)	-0.02 (0.09)	-0.13 (0.22)	0.09 (0.28)
$\overline{R}^2$	0.04	0.03	0.01	0.01
Test of Restriction				
p-value	0.50	0.06	0.92	0.01

Note. Standard errors are in parentheses. $(g+\delta)$ is assumed to be 0.05. *** statistically significant at $P \le 0.01$ level; ** statistically significant at $P \le 0.05$ level; * statistically significant at $P \le 0.1$ level.

Table 5: Estimation of the Augmented Slow Model: Impact of Human Capital

Dependent Variable: Log GDP per working-age person (PPP) in 2003				
Sample	MENA	OECD	DEVELOPING	ALL
Observations	17	29	64	93
CONSTANT	-5.85 (3.99)	11.94*** (0.99)	11.97*** (1.51)	11.37*** (1.64)
$\ln(s_k)$	-0.15 (0.47)	-0.51 (0.32)	-0.02 (0.25)	-0.14 (0.27)
$\ln(s_h)$	0.46*** (0.12)	0.73*** (0.12)	0.21*** (0.05)	0.64*** (0.09)
$\ln(n+g+\delta)$	0.46 (0.39)	0.05 (0.06)	0.96** (0.48)	0.69 (0.53)
$\overline{R}^2$	0.45	0.62	0.22	0.38
Restricted Regression				
CONSTANT	7.47*** (1.90)	14.08*** (1.29)	7.32*** (0.96)	5.13*** (0.71)
$\ln(s_k)$ - $\ln(n+g+\delta)$	-0.84 (0.58)	-1.30*** (0.41)	-0.37 (0.29)	-0.62** (0.27)
$\ln(s_h)$ - $\ln(n+g+\delta)$	0.93 (0.77)	1.29*** (0.41)	0.68* (0.40)	1.78*** (0.30)
$\overline{R}^2$	0.01	0.22	0.07	0.27
Test of Restriction				
p-value	0.01	0.00	0.00	0.00

Note. Standard errors are in parentheses. $(g+\delta)$ is assumed to be 0.05. *** statistically significant at $P \le 0.01$ level; ** statistically significant at $P \le 0.05$ level; * statistically significant at $P \le 0.1$ level.

Table 6: Estimation of the Augmented Slow Model: Impact of Information Technology

Dependent Variable: Log GDP per working-age person (PPP) in 2003				
Sample	MENA	OECD	DEVELOPING	ALL
Observations	17	29	64	93
CONSTANT	1.17 (4.52)	7.64*** (1.13)	11.65*** (1.11)	11.34*** (1.02)
$\ln(s_k)$	-0.22 (0.41)	-0.28 (0.24)	-0.01 (0.18)	-0.07 (0.17)
$\ln(s_h)$	0.31*** (0.11)	0.64*** (0.15)	0.10** (0.05)	0.48** (0.26)
$\ln(s_c)$	0.59** (0.24)	0.84*** (0.17)	0.59*** (0.08)	0.78*** (0.07)
$\ln(n+g+\delta)$	0.12 (0.36)	0.05 (0.04)	0.67* (0.36)	0.41 (0.33)
$\bar{R}^2$	0.60	0.80	0.56	0.76
Restricted Regression				
CONSTANT	8.94*** (1.35)	6.93*** (1.08)	10.43*** (0.60)	10.55*** (0.57)
$\ln(s_k) - \ln(n+g+\delta)$	-0.49 (0.41)	-0.35 (0.24)	-0.10 (0.17)	-0.12 (0.43)
$\ln(s_h) - \ln(n+g+\delta)$	-0.14 (0.59)	-0.73** (0.32)	-0.82*** (0.27)	-0.85*** (0.26)
$\ln(s_c) - \ln(n+g+\delta)$	0.86*** (0.21)	1.04*** (0.12)	0.63*** (0.07)	0.81*** (0.06)
$\bar{R}^2$	0.53	0.79	0.56	0.76
Test of Restriction				
p-value	0.1	0.1	0.19	0.36

Note. Standard errors are in parentheses. $(g+\delta)$ is assumed to be 0.05. *** statistically significant at $P \le 0.01$ level; ** statistically significant at $P \le 0.05$ level; * statistically significant at $P \le 0.1$ level.

Table 7: Tests for Unconditional Convergence

Dependent Variable: Log Difference GDP per working-age person 1985-2003: $\ln y(2003) - \ln y(85)$				
Sample	MENA	OECD	DEVELOPING	ALL
Observations	17	29	64	93
CONSTANT	1.66** (0.61)	2.12** (0.85)	2.88*** (0.58)	1.19*** (0.44)
$\ln y(85)$	-0.13* (0.07)	-0.14 (0.09)	-0.29*** (0.07)	-0.06 (0.05)
$\bar{R}^2$	0.14	0.04	0.20	0.01

Note. Standard errors are in parentheses. $(g+\delta)$ is assumed to be 0.05. *** statistically significant at $P \le 0.01$ level; ** statistically significant at $P \le 0.05$ level; * statistically significant at $P \le 0.1$ level.

Table 8: Tests for Conditional Convergence

Dependent Variable: Log Difference GDP per working-age person 1985-2003: $\ln y(2003) - \ln y(85)$				
Sample	MENA	OECD	DEVELOPING	ALL
Observations	17	29	64	93
CONSTANT	-2.67** (1.22)	3.00** (1.46)	4.21*** (0.97)	2.10*** (0.82)
$\ln y(85)$	-0.02 (0.06)	-0.06 (0.11)	-0.26*** (0.07)	-0.03 (0.06)
$\ln(s_k)$	-0.20 (0.14)	0.34 (0.30)	0.12 (0.19)	0.17 (0.18)
$\ln(n+g+\delta)$	-1.20*** (0.33)	0.38 (0.50)	0.50* (0.29)	0.32 (0.28)
$\bar{R}^2$	0.58	0.04	0.22	0.01

Note. Standard errors are in parentheses. $(g+\delta)$ is assumed to be 0.05. *** statistically significant at $P \le 0.01$ level; ** statistically significant at $P \le 0.05$ level; * statistically significant at $P \le 0.1$ level.

Table 9: Tests for Conditional Convergence: Impact of Human Capital

Dependent Variable: Log Difference GDP per working-age person 1985-2003: $\ln y(2003) - \ln y(85)$				
Sample	MENA	OECD	DEVELOPING	ALL
Observations	17	29	64	93
CONSTANT	-1.91 (1.45)	6.23*** (1.53)	5.24*** (1.31)	3.51*** (1.18)
$\ln y(85)$	-0.07 (0.08)	-0.32*** (0.12)	-0.32*** (0.09)	-0.11 (0.07)
$\ln(s_k)$	-0.02 (0.14)	0.17 (0.26)	0.11 (0.19)	0.15 (0.18)
$\ln(s_h)$	0.37 (0.38)	0.70*** (0.14)	0.53 (0.46)	0.74* (0.44)
$\ln(n+g+\delta)$	-1.10*** (0.35)	0.71 (0.43)	0.68** (0.33)	0.56* (0.32)
$\bar{R}^2$	0.57	0.34	0.22	0.02

Note. Standard errors are in parentheses. $(g+\delta)$ is assumed to be 0.05. *** statistically significant at $P \le 0.01$ level; ** statistically significant at $P \le 0.05$ level; * statistically significant at $P \le 0.1$ level.

Table 10: Tests for Conditional Convergence: Impact of Information Technology

Dependent Variable: Log Difference GDP per working-age person 1985-2003: $\ln y(2003) - \ln y(85)$				
Sample	MENA	OECD	DEVELOPING	ALL
Observations	17	29	64	93
CONSTANT	-0.94 (0.96)	7.84*** (1.38)	7.36*** (1.21)	6.55*** (1.08)
$\ln y(85)$	-0.16*** (0.05)	-0.51*** (0.12)	-0.57*** (0.09)	-0.47*** (0.08)
$\ln(s_k)$	-0.11 (0.09)	0.14 (0.21)	0.05 (0.16)	0.07 (0.15)
$\ln(s_h)$	0.20** (0.09)	0.25*** (0.07)	0.33 (0.43)	0.44* (0.28)
$\ln(s_c)$	0.29*** (0.07)	0.51*** (0.16)	0.36*** (0.08)	0.46*** (0.07)
$\ln(n+g+\delta)$	-1.23*** (0.22)	0.60 (0.36)	0.53* (0.29)	0.41 (0.26)
$\bar{R}^2$	0.83	0.53	0.43	0.34

Note. Standard errors are in parentheses. $(g+\delta)$ is assumed to be 0.05. *** statistically significant at $P \leq 0.01$ level; ** statistically significant at $P \leq 0.05$ level; * statistically significant at $P \leq 0.1$ level.

Appendix 1: The Information Technology Index (ICTI)

For the construction of the Information and Communication Technology Index (ICTI), fixed minimum and maximum values have been established for each of its four components. An index for each component is calculated separately. For that, maximum and minimum values of the four basic variables are as follows in 2003:

Indicator	Maximum Value	Minimum Value
Personal Computers (per 1000 people)	708	1.41
Internet Subscribers (per 1000 people)	675	1
Fixed Phone Lines (per 1000 people)	727	2
Cell Phone Subscribers (per 1000 people)	1079	0

According to World Bank (2005) and UNDP (2005), Switzerland's ratio of personal computers (per 1000 people) of 708 is the maximum so far while Mali's ratio of 1.4 is the minimum. Similarly, Iceland has the maximum value of internet subscribers (per 1000 people) which is 675, according to UNDP (2005), while Ethiopia and Central African Republic share the minimum value of 1. The maximum value of 727 fixed phone lines (per 1000 people) was achieved again by Switzerland while the minimum value of 2 was achieved by Congo and Uganda. As for the number of cell phone subscribers (per 1000 people), we find that Hong Kong has the maximum value of 1079 while Eritrea has the minimum value of zero. For any component of the ICTI, individual indices are computed according to the general formula:

$$\text{Index} = \frac{Actual\ x_i\ value - Minimum\ x_i\ value}{Maximum\ x_i\ value - Minimum\ x_i\ value}.$$

The following example of Egypt may illustrate the above-mentioned steps for calculating the information and communication technology index.

<u>1. Computing Index:</u> Personal Computers (per 1000 people) in 2003 was 21.85, therefore, the computing index = (21.85-1.41) / (708-1.41) = 2.89

<u>2. Internet Index:</u> Internet Subscribers (per 1000 people) in 2003 was 44, therefore, the internet index = (44-1) / (675-1) = 6.38

<u>3. Cell Index:</u> Cell Phone Subscribers (per 1000 people) in 2003 was 84, therefore, the cell index = (84-0) / (1079-0) = 7.78.

<u>4. Phone Index:</u> Fixed Phone Lines (per 1000 people) in 2003 was 127, therefore, the phone index = (127-2) / (727-2) = 17.24.

<u>5. Calculation of ICTI:</u> ICTI is calculated as a simple average of the four indices as follows.

ICTI for Egypt =1/4(2.89+6.38+7.78+17.24) = 8.57.

