

Knowledge, Technological Catch-up and Economic Growth: A Dynamic Panel Data Analysis for MENA and Latin America

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Abstract

This paper aims to investigate the role of various knowledge indicators (human capital, research and development, information and communication technologies and trade) in the economic growth and catch-up performance of the Middle East and North Africa (MENA) region during the 1980-2014 period, by utilizing dynamic panel data techniques. The empirical results suggest a positive impact of knowledge indicators on the economic growth performances these countries and that there is convergence to the common long-run equilibrium in the MENA region. Moreover, to see whether the role of various knowledge indicators have the same effect in the economies of countries with relatively similar characteristics in other regions we have analyzed the economic growth and catch-up performance of Latin America during the same period and have found similar results.

Keywords: economic growth, catch-up, knowledge, productivity, dynamic panel data, MENA and Latin America.

JEL Classification: O11, O33, O40, O47, O50

1. Introduction

The classical economists believed that the poor countries would eventually converge to income levels of the rich countries because they could freely benefit from the available technological improvements. On the other hand according to the “technology-gap” theorists the *technological differences* were the prime cause of the differences between the income levels of countries and argued that the follower countries were trying to “catch-up” the

technology of the leading country¹ so as to achieve higher growth rates. However, as argued by the technology-gap theorists, by time the follower countries established the necessary infrastructure for the production of the old technology, the leading countries with their more advanced research and development (R&D) structures moved forward to new technological frontiers. So, with the exception of a few countries, in general rather than converging, the economic growth gap between the rich and poor countries in the world has increased.

Benhabib and Spiegel (1994), in line with the spirit of Nelson and Phelps (1966) and the new growth theories -that emphasize the endogenous nature of technological progress-introduced education as the main and the only determinant of the ability of the follower country to use the technology from the leading country and the rate at which the technological gap between the leader and follower countries would close. Moreover, while Benhabib and Spiegel (1994) and Nelson and Phelps (1966) modeled the role of human capital in economic growth through total factor productivity (Nelson and Phelps Approach), seminal empirical studies such as Bosworth and Collins (2003), Inklaar and Timmer (2013) and Senhadji (2000) emphasized that it is important to consider human capital as an additional input along with capital in the production function (Lucas Approach).

In our paper following Utku-İsmihan (2016) we derived an augmented framework where human capital enters the model as an additional input together with capital stock with an aim to capture the role of human capital accumulation in the growth process and also included the other critical knowledge variables as a shift factor in the production function and measured the impact of knowledge indicators (such as trade, information and communication technologies (ICTs) and research and development (R&D)) on the long run growth performance of countries in the Middle East and North Africa (MENA) region. Compared to the other regions in the world this study has been challenging in terms of two issues; the heterogeneous structures of countries situated in this region and the data availability problem.

The MENA region is composed of countries that are heterogeneous in terms of socio-economic structure, natural resources and political structure. Most of these countries are dependent on natural resources (i.e. oil) and primary goods. Thus, they are extremely vulnerable to the fluctuations in the world markets that are directly reflected on their economies.

¹ In general the leader country is assumed to be USA (see for example, Benhabib and Spiegel (1994; 2000) and others).

During the last two decades due to political and social instability or never ending conflicts between various neighboring countries, the growth rates of the majority of countries in this region have been remarkably volatile.

In our analysis due to data constraint 20 MENA region countries Algeria, Bahrain, Egypt, Israel, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, Turkey, United Arab Emirates and Yemen have been included. Moreover due to the data constraint, to our knowledge, there are only few studies that have analyzed the convergence in the MENA region, such as Guetat and Serranito (2007) and Andreano and Savio (2012).

Moreover, we also wanted to compare the MENA region with another region that had similar structure, namely Latin America. Thus, for the same period we have investigated the role of knowledge variables in the economic growth and catch-up performance of 18 Latin American countries; Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Suriname, Uruguay and Venezuela.

In order to measure the impact of knowledge on the long run growth performance, following Bosworth and Collins (2003) among others we utilize a production function with a skill adjusted labor input (human capital). Additionally, in line with Griliches (1979) and Eberhardt et al. (2013), we include the other critical knowledge variables as a shift factor in the production function without affecting the returns to inputs.

The following section presents an overview of the literature followed by Section 3 which introduces our technological catch-up model, information regarding the data and the empirical results. Finally, the concluding remarks are provided in Section 4.

2. An Overview of Literature

The most important prediction of the neoclassical (Solow) growth model is the convergence hypothesis. According to this hypothesis, in the long run, due to their higher growth rate poor countries would eventually converge to the per capita income levels of the rich countries. However, in reality with the exception of few East Asian countries, the income gap between

the poor and rich countries have widened. Gerschenkron (1962) was one of the first economists who drew attention to the difficulty for follower countries to catch up with the leading countries. He underlined the institutional resistance to change and the high cost of factors of production, especially human capital which he refers to as the creation of industrial labor force which is "... a most difficult and protracted process..." (Gerschenkron, 1962:9). Thus in reality, by the time the follower countries transfer and use the existing technology, the leader country moves forward to a new technological frontiers (Forbes and Wield, 2000). Thus, the "technology-gap" theorists, led by Gerschenkron (1962), saw "technological differences as the prime cause for differences in GDP per capita across countries" (Fagerberg, 1994:1155). Additionally they pointed out that technology is not freely available to everyone and this is the major obstacle in the catch-up performances of countries.

Nelson and Phelps (1966) in their study emphasized that education (i.e. human capital) determines the ability of the follower country to adapt technology received from the leading country. Thus human capital determines the rate at which the technological gap between the leader and follower country would close.

The basic idea behind the Nelson and Phelps (1966) catch-up model is that the tacit (disembodied) knowledge flow from the leader to the follower and the followers' ability (i.e. education level) to acquire this knowledge determines the speed of the catch-up. That is, human capital accumulation (or education) enhances both the ability of a country to adapt frontier technologies.²

$$\frac{\dot{A}_t}{A_t} = c(h) \left[\frac{T_t - A_t}{A_t} \right] \quad (1)$$

where A is the total factor productivity, \dot{A}/A denotes the growth rate of A, h is the human capital and T_t is the theoretical level of technology.³

²That is, human capital as a factor of production (Lucas Approach) is not sufficient enough for catch-up (see Lucas (1988)); it is the ability of the human capital to develop and to implement the transferred knowledge that determines the speed of catch-up (Nelson and Phelps Approach).

³Nelson and Phelps (1966) define theoretical level of technology as "the best practice level of technology that would prevail if technological diffusion ... [is realized and] ... is a measure of the stock of knowledge or body of techniques available to innovators" (Nelson and Phelps, 1966:71).

Equation (1) indicates that the speed of convergence (i.e. the rate of closing the technological gap) depends on the level of human capital. That is, in the short run, the level of human capital determines the rate that theoretical knowledge will accumulate to catch-up with the edge technology, i.e. $\partial c/\partial h > 0$. Thus the main contribution of Nelson and Phelps (1966) is that education is not inserted directly into the production function since it “may constitute a gross misspecification of the relation between education and the dynamics of production” (Nelson and Phelps, 1966:75). However, in line with Solow’s model, theoretical knowledge is assumed to grow at a constant (exogenous) rate. This means that the growth rate of Solow’s residual (\dot{A}/A) reaches to that of the theoretical knowledge level in the long-run.

Later, in line with the spirit of the endogenous growth theories, Benhabib and Spiegel (1994) augmented the Nelson and Phelps’ approach by emphasizing the endogenous nature of technological progress. They endogenize the productivity by introducing “law of motion for productivity” where the change in productivity is a function of human capital and the technology gap.⁴ Benhabib and Spiegel (1994) also introduce a catch-up term which is created by interacting human capital with the technology gap. In line with Nelson and Phelps Model, in this set up there is a leading country and the followers are trying to catch-up its level of technology. The followers’ growth rate of total factor productivity (Solow residual) is as follows;⁵

$$\frac{\dot{A}_t}{A_t} = g(h_t) + c(h_t) \left[\frac{\max_j A_{jt} - A_t}{A_t} \right] \quad (2)$$

where A_{it} is the total factor productivity of the follower at time t , A_{jt} is the total factor productivity of the leader at time t , $g(h_t)$ is the “endogenous” growth rate and h_t is the followers level of human capital.

In Equation (2) the change in productivity depends on the stock of human capital. In this specification the level of education has two roles on the technological capabilities of a country. First it enhances the domestic capability of technological innovation and secondly it enables the adaptation and implementation of imported technology. Thus, the level of education determines the total productivity of the following countries.

⁴ Technology gap is the country’s distance to the technological frontier.

⁵ They utilize the following production function $Y_{it} = A_{it} K_{it}^\alpha L_{it}^\beta$.

The last term gives us the technology gap, country i 's (follower country) technology gap is the difference between the country j 's (leader country) productivity and the productivity of country i , divided by the follower's productivity.

Initially, the leading country is the one that has the highest TFP. However, if there is another country with a higher level of education, let's say Country B, then eventually Country B will become the leader, until it has lost its educational advantage to another country.

It is also assumed that in the long-run all countries grow at the same rate as they try to catch-up with the leading country that has the highest level of human capital. In general the countries with lower level of Solow residual have growth rates that are higher than the leader due to the catch-up effect. However, the ones which are close to the leader, in terms of both technology and educational level, have lower growth rates and hence the catch-up effect might become insignificant.

Benhabib and Spiegel (1994) used cross-country estimates of physical and human capital stocks of 60 countries between 1965 to 1985 period. First they found that human capital entered insignificantly in explaining per capita growth rates. Then they have specified an alternative model where the growth rate of total factor productivity is dependent on a nation's human capital stock level and found a positive result. As mentioned above by adapting the Nelson and Phelps (1966) framework they also analyzed the diffusion of technology between countries. They have found that countries with higher education level catch the leading country much faster than the ones that had relatively lower educational attainment.

3. The Augmented Model of Technological Catch-up

3.1.1. The Missing Channels in the Literature

According to Nelson and Phelps' approach (including Benhabib and Spiegel's contribution) the level of education alone –more broadly, human capital– determines the gap between the leader and the follower countries, and hence the speed of technological catch-up. Even though the potential of the catch-up growth rates of the followers that are way behind the technological frontier are higher than the ones that are straight behind the leader, some of them may not fulfill this potential due to the absence of other channels of knowledge that

facilitate the diffusion of technology. There are number of well known channels (or pillars) of knowledge that helps countries to speed up their technological catch-up and hence economic growth. For example, the economic structure (e.g. openness to foreign trade) of the economy (O), education (h), country's level of R&D stock (R) and country's information and communication infrastructure (I).⁶

Thus, in addition to (as well as interacting with) human capital, the diffusion of technology is affected by trade, ICTs and domestic R&D efforts. Now, we will provide a brief review of the related literature on these channels starting with the human capital.

Human capital channel. Based on our theoretical intuition and the empirical results in the literature we expect human capital to have positive impact on the growth rate of the country.⁷ For example, Cohen and Soto (2001) on their analysis 95 countries for 1960-2000 period found that education had a positive effect on economic growth. However, as noted by Kruger and Lindahl (2001), model specification and the measurement of human capital are highly important for assessing the role of human capital on economic growth with macro data.

R&D channel. R&D is both an important determinant of innovation and promoter of technology transfer by raising the absorptive capacity.⁸ There seems to be ambiguity with regards the impact of R&D on TFP. While some economists have found that R&D had significant positive impact on TFP and thus on growth performances of the economies (see for example, Coe and Helpman (1995)) some economists have found significant negative impact on TFP due to the uncertainty and ambiguity that R&D entails due to its nature (see for example, Cozzi and Giordani (2011)).⁹

Trade channel (Openness to Foreign Trade). Trade increases the innovation capability of a country through the transfer of embodied technology with the imported capital goods and

⁶ See Chen and Dahlman (2004) for more detail.

⁷ For example, Benhabib and Spiegel (1994, 2000 and 2005), Cohen and Soto (2001), Collins et al. (1996) and so on find that education has positive effect on economic growth.

⁸ See, for example, Griliches and Lichtenberg (1984), Griliches (1992) and Aghion and Howitt (1992) on R&D as the determinant of innovation and Geroski (2000) and Griffith et al. (2000) for R&D and absorptive capacity.

⁹ See Welch (1975), Bartel and Lichtenberg (1987), Coe and Helpman (1995), Caselli and Coleman (2001), Caselli and Wilson (2004), Xu (2000) and Benhabib and Spiegel (2005) for more detail.

ideas (patents and licenses) or feedbacks from exported goods.¹⁰ Moreover, by importing technologically intensive products the follower countries can increase quality of their products and their production efficiency. Thus, as argued by Coe et al. (1997) if trade involves positive externalities such as embodied knowledge then it would have positive impact. However, the impact of openness on economic growth depends significantly on the absorptive capacity of the country. For example, Fagerberg and Srholec (2008) in their analysis for 115 countries during 1992 -2004 period found that the trade (or “openness”) is influenced by the absorptive capacity of the country. That is, the absorptive capacity of the country determines the impact of trade on economic growth.¹¹ So, interactive effect of trade via catch-up efforts of the country on growth is an important issue.

ICT channel. ICTs on the other hand provide a channel for fast and effective flow of technological knowledge which also has a positive impact on the domestic productivity.¹² The impact of ICTs on productivity has been through various channels. For example, the continuously decreasing computer and software prices has led to the incentive of replacing other capital goods with them and this in turn contributed to higher total factor productivity growth. The computerization along with the developments in other ICTs, such as internet, made it much easier to acquire information from suppliers and/or customers to develop new products or processes. Some country specific studies have found that ICT usage had an important impact on TFP (see for example Jorgenson and Stiroh (2000)). Moreover, OECD (2012) in a recent report considers ICT to be a general purpose technology that changed the world drastically. This can be attributed to ICTs both direct and indirect affect on growth and productivity.

¹⁰ Coe and Helpman (1995) have found that this had a positive impact on domestic productivity.

¹¹ Fagerberg and Srholec (2008) use trade and foreign direct investments to proxy for openness of an economy and find that “...openness to imports and foreign direct investment seems to matter more for the richer economies ... poor countries due to lack of absorptive capacity are much less likely than other countries to benefit from foreign direct investments ... [a]lthough a positive correlation between openness and growth is reported ... [it is] sensitive to changes in the composition of the sample...it is among the richer economies that openness to trade and foreign direct investment seems to matter most for growth (Fagerberg and Srholec, 2008: 1422-1427)”.

¹² For example, the ICTs provide the opportunity of an efficient, continuous and permanent connection to the global markets, which increases the flow of information into the economy. This newly acquired information, in turn, contributes to productivity increase.

Based on theory it is expected that all ICTs would boost knowledge creation and have positive impact on TFP and thus economic growth of countries.¹³ However, there seems to be ambiguity in terms of empirical studies. For example, OECD (2012) in a study on the impact of internet in OECD countries has found that the impact of internet on the per capita income growth across the countries varied among countries, while there was positive impact in US, this did not hold for all the other OECD members (even in some of the European countries). In terms of the less developed countries since there is limited access for the capital required to build the internet infrastructure and impact of ICT does not seem to be significant.¹⁴ On the other hand, Choi and Yi (2009) in their study for 162 countries during 1991-2000 period found that the internet to have a positive and significant role in economic growth. Thus, taking into consideration the evidence provided by the empirical research just like in the case of openness we do not have a priori expectations with regards ICT.

Comin and Hobijn (2004) investigated the evolution of 25 technologies in 23 countries during a span of 200 years. They found that most new technologies originated in rich countries and the following countries were slow to adopt these new technologies. Comin and Hobijn (2004) found that the speed of adoption is positively related to per capita GDP, human capital, and openness to trade, and is also related to the type of government.

In the light of these arguments, the Nelson and Phelps' framework and Benhabib and Spiegel (2000) framework needs to be augmented by incorporating these additional channels that can help technological diffusion and catch-up. We will attempt to do this in the following subsection.

3.2. Knowledge and Technological Catch-up: The Augmented Approach

Utku-İsmihan (2016) developed an augmented model using Benhabib and Spiegel's (1994) specification to analyze the impact of knowledge variables in the economic growth and catch-up processes of the OECD countries during the 1995-2011 period via panel data analysis. However, the econometric results of her augmented model contradicted the theoretical

¹³See, for example Aghion and Howitt (1998) and Barro and Sala-i-Martin (2003).

¹⁴See, Kenny (2003) for more detail. Also several other studies have negative impact of ICT on economic growth especially for the developing countries (Dewan and Kraemer (2001) and Satti and Nour (2003)).

expectations. That is, majority of the results of her panel data estimation with the traditional techniques (e.g. fixed effects model) were either theoretically inconsistent or statistically insignificant. As a result of her investigation Utku-İsmihan (2016) found that there were serious limitations of the specification used by Benhabib and Spiegel (1994). In their model Benhabib and Spiegel (1994) followed Nelson and Phelps (1966), who have emphasized role of human capital in adaptation of new technology and hence improving total factor productivity. Thus, human capital enters the model only via total factor productivity. So, accordingly in her specification she followed this line of reasoning and hence introduced the knowledge indicators into the model through total factor productivity.

In the Benhabib and Spiegel (1994) framework (Equation 2) the technology gap is a function of human capital (h_i). They emphasize the role of human capital for the growth process of countries through its impact on productivity growth. That is, the potential for catching up of countries, with a technology gap, depends on the country's absorptive capacity which is proxied by human capital and human capital is considered as a factor in productivity however considerable empirical literature (e.g. Bosworth and Collins (2003), Senhadji (2000) and Inklaar and Timmer (2013)) considers human capital as an input (a la Lucas) in the production function. On the other hand, when human capital enters the model as an additional input of production it captures the role of human capital accumulation in the growth process (Lucas, 1988). Therefore, by following those studies we consider the following production function with a skilled adjusted labor (human capital) input,

$$Y = A K^\alpha H^\beta \quad (3)$$

where Y is output (real GDP), K is capital stock and A is total factor productivity, H is human capital and it is also called adjusted labor input ($H=hL$, where h is human capital per labor and L is total employment).

Griliches (1979) emphasized that it is important to consider knowledge as an additional input to the traditional inputs, such as labor and capital, in the production function. More formally, he considers the following production function,

$$Y = f(L, K, R) \quad (4)$$

where L is labor and R is the R&D stock and the rest of the variables are as defined before.

Additionally, we also consider the role of ICTs and openness as important knowledge indicators in our model.

Thus when we combine Griliches's approach and Lucas's approach with our above argument on the role of ICTs and openness we can obtain an augmented production function. More specifically, we use the following Cobb Douglas production function,

$$Y = K^\alpha H^\beta R^\gamma C^\phi O^\varsigma \quad (5)$$

where C represents ICTs, O represents openness and all variables are defined as earlier.

Following Bosworth and Collins (2003) and Senhadji (2001) among others we impose constant returns to scale assumption ($\alpha+\beta=1$) and hence we transform Equation (5) to per efficient worker form (Y/H and K/H) as follows,

$$\left(\frac{Y}{H}\right) = \left(\frac{K}{H}\right)^\alpha R^\gamma C^\phi O^\varsigma \quad (6)$$

where all variables are defined as earlier.

We obtain the following equation by taking the log of Equation (6)

$$\hat{y}_{it} = \alpha \hat{k} + \gamma r + \phi c + \zeta o \quad (7)$$

where $\hat{y} = \ln\left(\frac{Y}{H}\right)$, $\hat{k} = \ln\left(\frac{K}{H}\right)$, $r = \ln(R)$, $c = \ln(C)$ and $o = \ln(O)$.

Therefore, in line with Griliches (1979) and Eberhardt et al. (2013) we included the knowledge variables as a shift factor in the production function without affecting the returns to inputs. We will use Equation (7) as the main theoretical specification of our model in the following section.

3.3. Data and the Empirical Results

3.3.1. The Definitions and the Sources of Data

The main variables that are used in the model are output (Y), capital stock (K), human capital per worker (h), R&D stock (R), openness (O), and ICT term (I). While the former three are obtained from PWT 8, the others are from the WDI database.^{15,16}

Output (Y) is the real gross domestic product (GDP) at constant 2005 national prices (in mil. 2005US\$)

Capital stock (K) is the capital stock at constant 2005 national prices (in mil. 2005US\$). In the PWT 8 data, capital stocks are “estimated based on cumulating and depreciation past investments using the perpetual inventory method” (Inklaar and Timmer, 2013:5).

Human capital per worker (h) is obtained by calculating the index of human capital per person based on years of schooling (Barro and Lee, 2012) and returns to education (Psacharopoulos and Patrinos, 1994). Education is an important indicator of the capacity of the labor force to use the available information. Barro and Lee (2012) use a combination of data sources to infer the percentage of each country's adult population (aged twenty-five and older) the particular level of education they obtained for each year. Census data provide direct measures of a country's stock of education but, especially, in developing countries such data are only available for selected years. Barro and Lee (2012) use enrollment data and data on literacy rates to interpolate between census years to fill the missing data.

Labor (L) is represented with the number of persons engaged in employment (in millions).

Research and development Stock (R) due to lack of data by utilizing total patent and total trademark we have calculated R&D index. Since these two variables are in different units and have different ranges (minimums and maximums), we used the Human Development Index

¹⁵The World Development Indicators (WDI) data set of World Bank and recent version (July 2013) of the Penn World Tables (PWT 8) are used in this study.

¹⁶It is important to mention that PWT 8.0 provides two set of data for capital and output as well as productivity for cross country comparison and for country specific analysis. Since this essay is based on a cross country comparison we use the data set relevant for our analysis. See Feenstra et al. (2015) and Inklaar and Timmer (2013) for more detail.

(HDI) methodology to obtain a common range for them. That is, a minimum and a maximum bound is set to each of the four indicators and a number (index value) is obtained for each of these indicators between 0 and 1. After this process all of the raw variables turned into unit free indices, between 0 and 1, that can be added together. With this conversion the two variables become dimension indices which are labeled as ITC and IPC. The two dimension indices are calculated as follows:

$$IT_t = \frac{T_t - \text{Min}(T)}{\text{Max}(T) - \text{Min}(T)} \quad (8)$$

$$IP_t = \frac{P_t - \text{Min}(P)}{\text{Max}(P) - \text{Min}(P)} \quad (9)$$

where T_t and P_t , LNE_t LNO_t represents total trademark and total patent, respectively. $\text{Min}(X)$ is the minimum value and $\text{Max}(X)$ is the maximum value of variable X during the time interval that is being investigated. The minimum and maximum values of each variable during the 1980-2014 period.

After normalizing the indicators and obtaining the dimension indices next we calculate the R&D Index (RDI) as a weighted average of the two sub-indices, as follows:

$$RDI = w_1 IC + w_2 IT \quad (10)$$

where w_i 's denote weights of the respective dimension indices.

HDI used simple average methodology to determine the weights of each dimension index simply because all three dimensions were considered to be equally important. That is, the three dimension indices (Life expectancy index, Education index and GNI index) were considered to have equal weights (1/3 each). We also used this methodology since trademarks and patents are equally important (1/2 each).

Openness (O) is measured by dividing total trade (exports plus imports) to GDP. It gives us information about the economic structure of the country, regarding the degree of integration to the world economy via foreign trade. That is, the share of trade (exports and imports) in GDP can viewed as an indicator of that countries level of globalization and competition in the

global economy. Foreign trade is also a channel for knowledge spillovers across national borders. That is, trade is a mean to access foreign knowledge which is embedded in the traded goods. Sometimes the imitation of this acquired new knowledge may spur innovation that will enhance economic growth.

However, it should be noted that “[d]espite the overwhelming popularity of the simple trade ratio measure, researchers should be aware that this measure is a measure of country size and integration into international markets rather than trade policy orientation ... [T]he five *least* open countries are (in order) Japan, Argentina, Brazil, the United States, and India ... While it is clear that these countries have trade restrictions in varying degrees, it is difficult to believe that they are the most restrictive countries in the world in terms of trade policies.” (David, 2007:9).

Information and Communication Technologies (I). Telephone lines, internet hosts/active Internet Protocol (IP) addresses, mobile phones, personal computers are the variables used to capture the levels and the growth rates of ICT.

In this study we will use mobile phone subscribers, which is measured on per 100 people basis for the entire country.

As indicated before this chapter utilizes a dataset formed by merging WDI data set and PWT data sets. The WDI provides various indicators, ranging from demographic to environmental topics and it contains more than 800 indicators for 214 countries for the years 1960 to 2012, compiled from officially recognized sources. Whereas the PWT provides 30 variables on purchasing power parity and national income accounts indicators for 167 countries for the 1950-2011 period. The two datasets were matched at country level.

The descriptive statistics of the variables are presented for the MENA countries and Latin American countries separately in Table 1.

4.3.2. Empirical Results

To analyze the relationship between knowledge indicators and economic growth we use pooled mean group analysis.

Table 1. Descriptive Statistics of the Variables

Variable	MENA COUNTRIES					LATIN AMERICAN COUNTRIES				
	Obs	Mean	Std. Dev.	Min	Max	Obs	Mean	Std. Dev.	Min	Max
Growth Rate of Per Capita Output (Δy)	585	11.17254	1.312755	8.113461	13.34803	595	10.46395	1.807302	5.522836	13.96503
Growth Rate of Per Capita Capital (Δk)	585	12.09891	1.316722	8.848763	14.5102	595	11.46692	1.918922	6.481725	15.39318
Openness (O)	699	71.87869	42.43364	0	251.1389	630	62.91931	36.00298	0	187.144
Mobile Phone (I)	699	31.52002	48.46923	0	218.4303	630	28.92649	44.41444	0	180.6992
R&D Index (R)	699	0.041854	0.093456	0	0.669179	630	0.314921	0.503709	0	3.145739

We re-state Equation (7) for empirical purpose in stochastic form as follows,

$$\hat{y}_{it} = \phi + \alpha \hat{k} + \gamma r + \phi c + \zeta o + \varepsilon \quad (11)$$

where all the variables are as defined before, ϕ is constant term and ε is the error term.

Thus, the above (augmented) log linear production function can be thought as a long-run equilibrium relationship between factor inputs, knowledge variables and output.

Peseran and Smith (1995) argue that even though the dynamic specification is not common for all countries, in the long run the parameters might be common. Thus, they suggest

either averaging the individual country estimates, or by pooling the long run parameters, if the data allows, and estimating the model as a system ... [thus we can possess] the efficiency of pooled estimation while avoiding the inconsistency problem following from pooling heterogeneous dynamic relationships (Asteriou and Hall, 2011:436).

In the PMG estimator, only the long run coefficients are same across countries and the short run coefficients vary. For this exact reason, Bassanini et al. (2001) have used PMG estimators in their analysis of the long-run relationship between factor inputs and output in their sample of OECD countries over 27 years. Furthermore, as underlined by Asteriou and Hall (2011) another critical advantage of the PMG is that “the parameter estimates are consistent and asymptotically normal for both stationary [I(0)] and non-stationary I(1) regressors” (Asteriou and Hall, 2011:427).

Following Peseran et al. (1999) we use the following error correction model in our empirical analysis;

$$\begin{aligned} \Delta \hat{y}_{it} = & \varphi_{it} + \omega_{it} \Delta \hat{k}_{it} + \zeta_{it} \Delta r_{it} + \psi_{it} \Delta c_{it} + \varpi_{it} \Delta o_{it} \\ & + \lambda_i (y_{it-1} - \phi - \alpha k_{it-1} - \gamma r_{it-1} - \phi c_{it-1} - \zeta o_{it-1}) + \varepsilon_{it} \end{aligned} \quad (12)$$

where ω_{it} , ζ_{it} , ψ_{it} and ϖ_{it} are the short run parameters and λ_i is the error correction term. The term in the brackets represents the deviation from the long run relationship in the previous period.

It should be noted that while long run coefficients are same across countries short run coefficients are allowed to vary. Hence

“[t]he PMG method of estimation occupies an intermediate position between the MG method, in which the slopes and the intercepts are allowed to differ across countries, and the classical fixed effects method in which the slopes are fixed and the intercepts are allowed to vary” (Asteriou and Hall, 2011:436).

The alternative pooled estimates for the knowledge production function with no restrictions, Mean Group (MG), and with common long-run effects (PMG) are provided in Table 2.

As is seen from the last column PMG estimates of the production function is in line with theory and statistically significant. However, MG estimates are not consistent with the theory (in terms of signs and/or magnitudes of estimates) and statistically insignificant. The Hausman test statistic also prefers the PMG estimator. That is the efficient estimator under the null hypothesis (PMG) is not rejected.

As can be seen from Table 2, according to our results (based on PMG estimates) a 1% increase in capital stock increases output per efficient worker by 0.48% in the MENA region and by .82% in Latin America, this indicates that capital increases per efficient worker is nearly double in Latin America compared to the MENA region. In terms of R&D, interestingly the MENA regions performance is way much better then Latin American countries. The result of ICTs indicates that while it decreases the output per efficient worker in Latin America, it has positive effect in the MENA region. Openness increases the output per efficient worker in both regions. Thus, according to the results of our analysis in the long run, knowledge variables, especially the R&D stock, seems to play an important role in the economic growth performances and catch-up efforts of MENA countries compared to the Latin American countries.

Finally, the sign and magnitude of overall error correction term of the PMG estimates in both regions is in line with a priori expectations and it is statistically significant. This result implies that both regions, converge to their own common long-run equilibrium represented by the augmented knowledge production function. In other words, our results indicate that there is convergence among the MENA countries and Latin American countries in the long-run.

Table 2. Pooled Estimates of Augmented Production Function

	MENA Countries		Latin American Countries	
	MG	PMG	MG	PMG
Capital Stock (\hat{k}), α	-.16789	.46357***	.71104***	.81583***
R&D Stock (r), γ	15.39*	.20516***	.8621	.02115**
ICT (c), ϕ	-.00247	.00049***	.00012	-.00062***
Openness (o), ζ	.00476	.00411***	.00105	.00058*
ecm, λ	-.4884***	-.2305***	-.46589***	-.2796***
Observations	568	568	578	578
Number of countries	17	17	17	17
Log Likelihood		1000.9		1333.21
Hausman		[Prob>chi2= 0.7470]		[Prob>chi2= 0.4414]

5. Concluding Remarks

One of the widely used models in the economic growth and catch-up literature belongs to Nelson and Phelps (1966). In their seminal study Nelson and Phelps underlined the importance of human capital in adoption and imitation of technology. Later this model was taken one step further by Benhabib and Spiegel (1994) who introduced the catch-up term to analyze the role of human capital in the catch-up efforts of follower countries.

In their model Nelson and Phelps emphasize the role of human capital in adaptation/using new technology and hence improving total factor productivity. Thus, human capital enters the model via total factor productivity. In our specification we have also followed Nelson and Phelps and introduced our knowledge indicators (including human capital and R&D stock) into the model through total factor productivity.

However, as underlined by Lucas (1988) when human capital enters the model as an additional input it captures the role of human capital accumulation in the growth process. Following Lucas (1988) in our new model we introduced human capital as an additional input together with capital stock and also included the other critical knowledge variables as a shift factor in the production function (as suggested by Griliches (1979) and Eberhardt et al. (2013)). We named this production function as the augmented knowledge production function.

In contrast to Benhabib and Spiegel's (1994) static panel data analysis we also utilize dynamic panel data techniques which are more suitable for macro panel data. Our new framework also utilizes the long-run information in the data by focusing on the equilibrium relations. This was not possible with the previous analysis based on Benhabib and Spiegel approach which focused on the differenced form of production function which loses the valuable long run information. Following, Peseran et al. (1999) we used PMG estimator where only the long run coefficients are same across countries and the short run coefficients vary. One advantage of PMG method is that it takes into account non stationary cointegration that is commonly observed in macroeconomic analysis with panel data where there is large number of countries over short period of time. Considering the aim of this essay another advantage of this framework is that in this new set-up convergence or catch-up efforts can be tested directly, i.e. by testing the significance of the error correction term.

The results of the PMG estimation of our new production function were both theoretically and statistically significant. That is, our analysis of both the MENA region and Latin America for 1980-2014 period, indicates that knowledge variables as a whole have positive impact on the economic growth performances of the countries in these regions and they seem to be converging to the common long-run equilibrium (in their own regions) represented by the augmented knowledge production function.

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