METU TEKPOL

ODTÜ-TEKPOL
BİLİM VE TEKNOLOJİ POLİTİKALARI ARAŞTIRMA MERKEZİ

METU-TEKPOL
RESEARCH CENTER FOR SCIENCE AND TECHNOLOGY POLICIES

SCIENCE AND TECHNOLOGY POLICIES RESEARCH CENTER
TEKPOL Working Paper Series
STPS-WP-18/04

Knowledge and Economic Growth: A Dynamic Panel Data Analysis for OECD Countries

Fatma M. UTKU-İSMİHAN

TEKPOL | Science and Technology Policies Research Center
Middle East Technical University
Ankara 06800 Turkey
http://www.stps.metu.edu.tr

KNOWLEDGE AND ECONOMIC GROWTH: A DYNAMIC PANEL DATA ANALYSIS FOR OECD COUNTRIES

Fatma M. UTKU-İSMİHAN[1]
Department of Economics, METU and Ministry of Agriculture and Forestry

Abstract

This paper aims to investigate the role of knowledge in the economic growth convergence of the OECD member countries during the 1995-2011 period, by utilizing production function approach. In our augmented production function framework, in addition to human capital, we consider other important channels of knowledge (R&D, trade and ICTs) to understand how knowledge contributes to the growth performance and growth convergence of the OECD countries. Furthermore, in contrast to most of the existing studies which used traditional panel data analysis, this study utilizes the dynamic panel data techniques. This approach enables us to utilize the long-run information in the data and hence gives us the possibility to analyze the impact of knowledge indicators on economic growth by focusing on equilibrium relations over longer time horizon. The empirical results suggest a positive impact of knowledge indicators on the economic growth performances of OECD countries and that there is convergence to a common long-run equilibrium in OECD.

Keywords: economic growth, knowledge, productivity, OECD and pooled mean group analysis.

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

1. Introduction

For a long time the neoclassical economists led by Robert Solow argued that technological improvements were freely available to poor countries and their economies would eventually converge to the per capita income levels of the rich countries (Solow 1956). However, rather than converging the gap between the rich and poor countries persistently increased (see

[1] Middle East Technical University, Üniversiteler Mah. Dumlupınar Blv. No:1, 06800 Çankaya, Ankara, Turkey, e-mail: fismihan@metu.edu.tr; fmutku@yahoo.com.

Acemoglu (2008) for more detail). Later, studies based on endogenous (new) growth models emphasized the importance of knowledge diffusion channels, such as human capital, research and development (R&D) and information and communication technologies (ICTs), in improving the technological capabilities of countries and hence their economic growth performance.

In this paper following Bosworth and Collins (2003) among others we utilize a production function with a skill adjusted labor input (human capital) and in line with Griliches (1979) and Eberhardt et al. (2013), we also include the other knowledge variables (e.g. R&D, ICTs and trade) as shift factors in the production function without affecting the returns to inputs. Moreover, we utilized dynamic panel data, i.e. pooled mean group (PMG) analysis of Pesaran and Smith (1995). PMG provided us the possibility of utilizing long-run information in the data by focusing on the equilibrium relations.

The following section presents an overview of the OECD economy during the 1995-2011 period followed by section 3 which presents our augmented production function model. Section 4 provides the empirical results and the final section provides the concluding remarks.

2. An Overview of the OECD Economy during the 1995-2011 Period

OECD was established on 14 December 1960 by 20 countries which signed the convention on the Organisation for Economic Co-operation and Development. The aim of OECD is to promote policies aiming economic and social well being in the world. Since its establishment 14 countries have joined the OECD.[2]

Majority of the OECD members are high income countries that are the leading actors in the global economy. This can be also observed from Figure 1 which presents the time plot of the growth rate of OECD countries for 1995-2011 period.

[2]The OECD member countries are Australia, Austria, Belgium, Canada, Chile, Czech Repubic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States of America.

Figure 1. Growth Rate in OECD (% Change in Real GDP)[3]

During the early years of the new millennium there has been serious decline in the economic activity of the high income countries (mainly due to 9/11), especially the European Union members and the USA. However, as can be seen from Figure 1 the major crisis during the 1995-2011 period occurred in 2008-2009. The global financial crisis of 2008-2009 was triggered by the mortgage crisis in the USA. The annual GDP growth rate in OECD dropped severely from an average of around 3% during 1995-2007 period to -4% (2009). However a year later from the crisis (2010) the annual GDP growth rate once again reached to 2%.

The improvements in transportation and communication technologies (as well as decrease in their costs) along with special agreements among some countries (such as increasing regional economic integrations, free trade agreements and so on) that shaped the current global structure have all contributed to the increase in the volume of trade in the world and even more so for OECD countries. As can be seen from Figure 2 the share of trade (export plus import) in GDP has increased from 73% (1995) to approximately 100% (2011) during the 1995-2011 period albeit temporary falls during the turbulent times.

[3] Computed by using WDI data.

Figure 2. OECD Trade (% of GDP)[4]

Research and development (R&D) is considered to be one of the key determinants of economic growth. In order to increase their competitiveness, all countries including the high income and middle high income countries are increasing their expenditures on R&D. Figure 3 provides the share of R&D expenditure in GDP for OECD. The R&D expenditure to GDP ratio in OECD has increased from 1.5% (1995) to 2.06% (2011) (see Figure 3). However, the R&D expenditure to GDP ratio in OECD countries is between 1% and 4%. For instance, Israel with average R&D to GDP ratio of approximately 4% during the 1996-2011 period is the leading country followed by Sweden, Finland and South Korea with a R&D to GDP ratio above 3.5%.

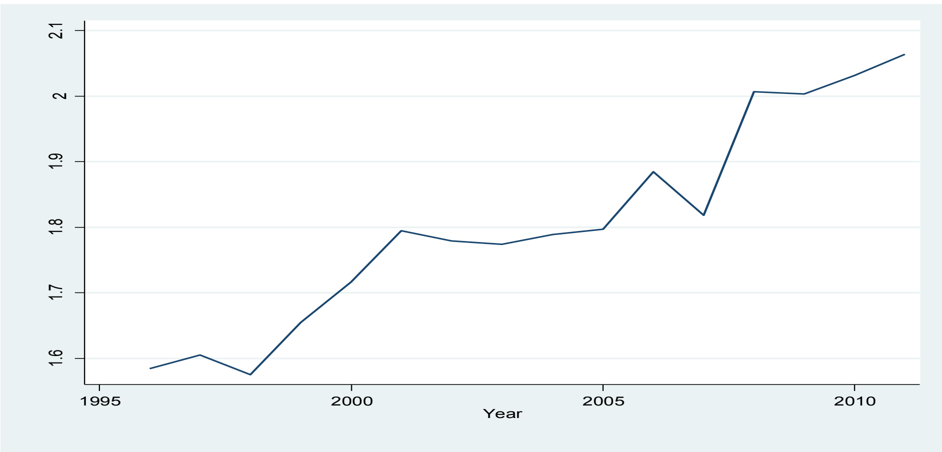

Figure 3. R&D Expenditure (% of GDP) in OECD[5]

[4] Computed by using WDI data.

[5] Computed by using WDI data.

When we analyze the human capital we see that the index of human capital per person[6] has been steadily increasing in OECD (see Figure 4).

The improvements in the information and communication technologies (ICTs) during the late 20th and 21st century have changed and shaped the current world structure. Communication and information are the essentials of daily life in the current century. Never in the history of mankind has there been so much information available to everyone in the world, at virtually zero cost, once the necessary infrastructure to use ICTs has been built.

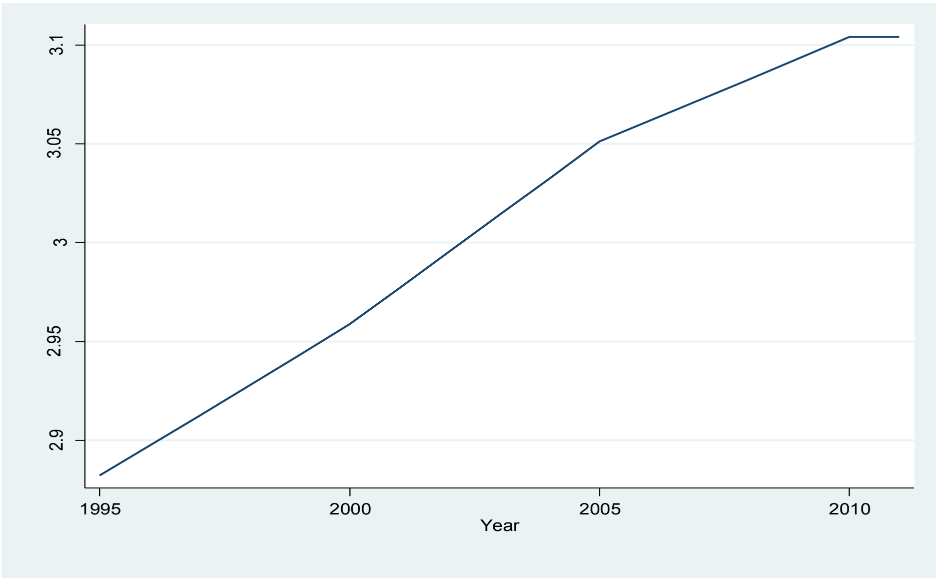

Figure 4. Human Capital in OECD[7]

The internet technology, initially developed for military communication, started to be used widely during the late 1990s. The speed of increase in the internet users has been quite significant during the last 15 years. As can be seen from Figure 5 the internet users in OECD

[6] The index of human capital per person is usually measured by using the Mincerian approach; in which human capital is calculated as a function of average years of schooling and returns to education. Following the literature in PWT 8, data on average years of schooling (Barro and Lee, 2012) and returns to education (Psacharopoulos, 1994) has been combined within a Mincerian approach to calculate the index of human capital per person (Inklair and Timmer, 2013:37).

[7] Computed by using PWT data.

have increased from 2.9 per 100 persons (1995) to 75.5 per 100 persons (2011). Usage of internet is fundamentally high in OECD countries compared to the rest of the world.[8]

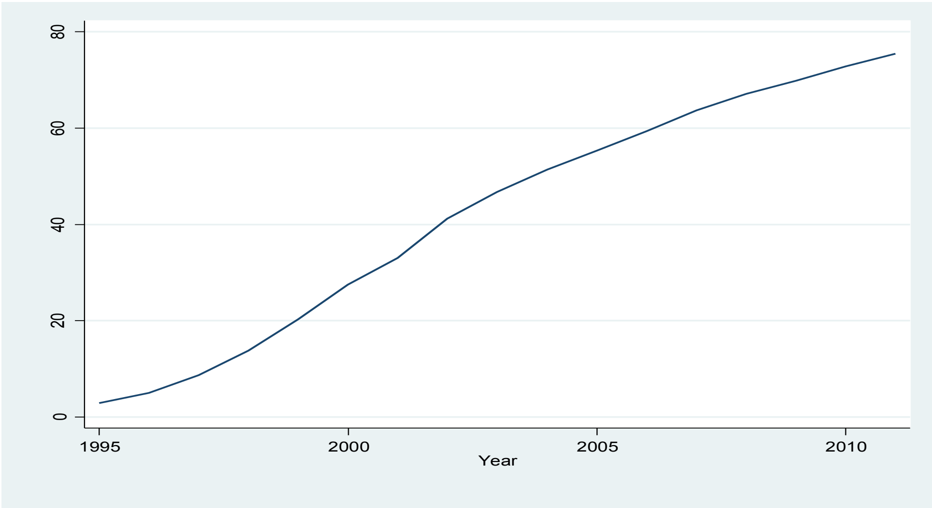

Figure 5. Internet Users (Per 100 People) in OECD[9]

In the following section we provide an overview of the augmented production function.

2. The Augmented Production Function Model

In the Solow growth model capital and labor are considered as the only factors of production, exogenous factors, i.e. technology and population growth, determine the growth performance of a country and time is the only variable that affects the level of productivity. That is,

$$Y = A(t)\ F(K, L) \tag{1}$$

where Y is the level of aggregate output, K is the level of the capital stock, L is the size of the labor force, A is total factor productivity and t is time.

[8] For example, the internet users in the world have increased from 0.04 per 100 persons (1995) to 32 per 100 persons (2011).

[9] Computed by using WDI data.

This simple growth model has become the staple of economic growth literature and has become the starting/derivation point of majority of studies in the economic growth literature. That is, researchers use this simple production function framework as a building block to present their arguments and thesis and this study is no exception to this trend.

The most strongly criticised aspects of the Solow model is its "optimistic" prediction about the high speed potential (or ability) of the lagging countries to catch-up with the more advanced countries. As time passed with the exception of few Asian countries unfortunately the gap between per capita income levels of the lagging and leading countries in the world increased. Some researchers considered education (for example, Nelson and Phelps (1966), Romer (1986) and Lucas (1986)) –more broadly, human capital– that determined the ability of the following countries to catch-up with the leading countries.

From late 20th onwards, the technologies that had been used in the production process required strong knowledge capital. Without any doubt the essence of knowledge accumulation is human capital. [10] But as country cases were analysed it was evident that several other factors such as R&D stock, ICTs and international trade appeared to be other factors that played important role in the capability of countries to accumulate knowledge and thus their economic growth performance.

In our model, following Bosworth and Collins (2003), Senhadji (2000) and Inklaar and Timmer (2013) human capital enters the model as input along with capital in the production function. Thus, it captures the role of human capital accumulation in the growth process (Lucas, 1988) as follows,

$$Y = AK^{\alpha}H^{\beta} \tag{2}$$

where Y is output, A is total factor productivity, K is capital stock and 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).

As we have indicated previously we include R&D, ICTs and trade as shift factors into our model. Many studies consider R&D as an important determinant of innovation and promoter of technology transfer.[11] But the uncertainty and ambiguity that R&D entails in its nature raises question marks about its impact on economic growth performance or productivity. For example,

[10] Romer (1986) and Lucas (1986) as the pivotal studies in this area.

[11] 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.

while Coe and Helpman (1995) found that R&D had significant positive impact on TFP Cozzi and Giordani (2011) found that R&D had significant negative impact on TFP. The improvements in ICTs have not only contributed to productivity performances of countries but have also shaped the current global world structure that we are living in. But studies on the impact of ICTs demonstrated ambiguities which generally pointed to the importance of ICTs related infrastructure.[12] In terms of trade, as argued by Coe et al. (1997), trade would have positive externality only if it embodied knowledge that the absorptive capacity of the importing country could digest. So when we integrate these knowledge indicators into our model we obtain the following augmented Cobb Douglas production function,

$$Y = K^{\alpha} H^{\beta} e^{\theta_0 + \theta_1 R + \theta_2 O + \theta_3 C} \tag{3}$$

where C represents ICTs, R represents R&D, O represents trade, $e^{\theta_0 + \theta_1 R + \theta_2 O + \theta_3 C}$ is total factor productivity (A) and all variables are defined as earlier.

In our model we included R, C and O as a shift factors in the production function without affecting the returns to inputs and following Bosworth and Collins (2003) and Senhadji (2001) constant returns to scale assumption (α+β=1) is imposed and thus Equation (3) is transformed into per efficient worker form (Y/H and K/H) as follows,

$$\left(\frac{Y}{H}\right) = \left(\frac{K}{H}\right)^{\alpha} e^{\theta_0 + \theta_1 R + \theta_2 O + \theta_3 C} \tag{4}$$

where all variables are defined as earlier.

We obtain the following equation by taking the log of Equation (4)

$$y_{it} = \theta_0 + \theta_1 R_{it} + \theta_2 O_{it} + \theta_3 C_{it} + \alpha k_{it} \tag{5}$$

where y=ln(Y/H), $\ln A_t = \theta_0+\theta_1 R+\theta_2 O+\theta_3 C$, k=ln(K/H) and all other variables are as defined earlier.

Thus, we will use Equation (5) as the main theoretical specification of our model in the following section.

[12] See, Kenny (2003) for more detail.

3. EMPIRICAL MODEL AND RESULTS

The most commonly used alternative methods to analyze multi-country estimation that allow for parameter heterogeneity across countries are, in general, mean group (MG), pooled mean group (PMG) and dynamic fixed effects (DFE) model within the domain of dynamic panel data analysis.

In our analysis we have preferred to use the PMG which is in between MG and DFE. Because, PMG will provide us the possibility of having intercepts, short run coefficients and the error correction terms differ across countries, while the long run slope coefficients are restricted to be the same across countries.

We re-state Equation (5) for empirical purpose in stochastic form as follows,

$$y_{it} = \theta_0 + \theta_1 R_{it} + \theta_2 O_{it} + \theta_3 C_{it} + \alpha k_{it} + \varepsilon_{it} \tag{6}$$

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

The above (augmented) log linear production function can be thought as a long-run equilibrium relationship between factor inputs, knowledge variables and output (in per efficient worker form).

Pesaran 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. In the PMG estimator, only the long run coefficients are same across countries and the short run coefficients vary. For this exact reason, as noted by Eberhardt et al. (2013), the PMG estimators are preferable when we have small set of similar countries (as in the case of OECD) rather than large diverse macro panels. Thus, when we analyze group of countries such as the OECD, by following Pesaran et al. (1999), we could reasonably expect a common long-run equilibrium relationship. That is, we can estimate common long run coefficients for the augmented production function for the OECD countries. Therefore, following Pesaran et al. (1999) we use the following error correction model in our empirical analysis,

$$\Delta y_{it} = \varphi_{it} + \omega_{it}\Delta k_{it} + \zeta_{it}\Delta R_{it} + \psi_{it}\Delta O_{it} + \varpi_{it}\Delta C_{it}$$

$$+\lambda_i(y_{it-1}-\theta_0-\theta_1 R_{it-1}-\theta_2 O_{it-1}-\theta_3 C_{it-1}-\alpha k_{it-1})+\varepsilon_{it} \quad (7)$$

where ω_{it}, ξ_{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.[13]

Pesaran et al. (1999) also suggested an alternative group estimator, called mean group (MG) estimator, which estimate the long-run parameters by averaging the corresponding parameters from the individual ARDL models (see Asteriou and Hall, 2011 for more detail). Thus, the alternative pooled estimates for the knowledge production function of OECD countries with no restrictions, Mean Group (MG), and with common long-run effects (PMG) are provided in Table 1. As can be 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.

The sign and magnitude of the error correction term (-0.36514) of the PMG estimates is statistically significant and confirms our a priori expectation of convergence of growth in OECD. That is, this result implies that the OECD countries, taken together, converge to a common long-run equilibrium represented by the augmented knowledge production function.

According to our results (based on PMG estimates) a 1% increase in capital stock per efficient worker increases output per efficient worker by 0.28%. A 1% increase in R&D stock, ICT and trade increases output per efficient worker about 0.16%, 0.03% and 0.04%, respectively. Thus, these findings imply that among the knowledge variables R&D contributes more to economic growth performances and to the convergence of OECD countries in the long run. Considering that the member countries of OECD are high income and middle high income countries this is not surprising since during the last decade the high income and middle high income countries have been continuously increasing their expenditures on R&D. The R&D expenditure to GDP ratio in OECD has increased from 1.5% (1995) to 2.06% (2011). However,

[13] It should be noted that while long run coefficients are same across (OECD) countries short run coefficients are allowed to vary.

the R&D expenditure to GDP ratio for OECD countries varies between 1% and 4%. For instance, Israel with an average of 4% during the 1996-2011 period is the leading country followed by Sweden, Finland and South Korea who have R&D to GDP ratio above 3.5% (World Bank).

Table 1. Pooled Estimates of Augmented Production Function

VARIABLES	MG	PMG
Capital per efficient worker (k)	2.06726	.27698***
R&D	-.90317	.15651***
ICT	.01957	.02796***
Trade	-.19542	.04446***
Error correction term	-.78879***	-.36514***
Observations	544	544
Number of code	34	34
Hausman	[Prob>chi2= 0.9171]	

*** p<0.01, ** p<0.05, * p<0.1

Trade and ICTs both seem to increase the output per efficient worker in OECD. However, the magnitude of the coefficient of trade is comparatively higher for trade. Thus, according to our analysis in the long run trade seem to play more important role than ICTs in the growth performance of OECD.

In sum, the results provided in Table 1 indicates that in the long run, knowledge variables, especially R&D, plays an important role in the economic growth performance of OECD and there is significant convergence among the OECD member countries.

4. Conclusion

This paper has attempted to analyse the impact of several knowledge indicators on the growth performance of OECD member countries during the 1995-2011 period. In our model we introduced human capital as an additional input together with capital stock and the knowledge variables as shift factors in the production function. We named this production function as the augmented knowledge production function.

Following, Pesaran et al. (1999) we used mean group estimators such as PMG estimator where only the long run coefficients are same across countries and the short run coefficients are allowed to vary. One advantage of PMG method is that it takes into account the nonstationary that is commonly observed in macroeconomic data. Considering the aim of this study another advantage of this framework is that in this 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 augmented production function were both theoretically and statistically significant. That is, our analysis of 34 OECD countries for 1995-2011 period indicates that knowledge variables as a whole have positive impact on the economic growth performances of OECD countries and these countries seem to be converging to the common long-run equilibrium represented by the augmented knowledge production function. It is important to note that among these knowledge variables R&D has significantly higher impact on the economic growth performance of OECD which clearly demonstrates the importance attributed to R&D by OECD member countries.

REFERENCES

Aghion, P. - Howitt, P. (1992): A model of growth through creative destruction. *Econometrica*, 60(2): 323–351.

Asteriou, D. - Hall, S. G. (2011): Applied Econometrics 2nd Edition, Macmillan, USA.

Barro, R. J. - Lee, J. W. (2012): A New Data Set of Educational Attainment in the World, 1950–2010. http://barrolee.com/papers/Barro_Lee_Human_Capital_Update_2012April.pdf

Bosworth B. - Collins S. M. (2003): The Empirics of Growth: An Update, Brookings Institution.

Coe, D. T. - E. Helpman (1995): International R&D Spillovers. *European Economic Review*, 39: 859-87.

Cozzi, G. - Giordani, P. (2011): Ambiguity attitude, R&D investments and economic growth. *Journal of Evolutionary Economics*, 21(2): 303-319.

Eberhardt, M. - Helmers, C. - Strauss (2013): Do Spillovers Matter When Estimating Private Returns to Trade. *The Review of Economics and Statistics*, 95(2): 436-448.

Feenstra, R. C. - Inklaar, R. - Timmer, M. P. (2015): The Next Generation of the Penn World Table. *American Economic Review*, 105(10): 3150–3182.

Geroski, P.A. (2000): Models of technology diffusion. *Research Policy*, 29: 603–625.

Griffith, R. - Redding, S. - Van Reenen, J. (2000): Mapping the two faces of R&D: Productivity growth in a panel of OECD industries. *CEPR Discussion Paper*, 2457.

Griliches, Z. (1992): The Search for R&D Spillovers. *Scandinavian Journal of Economics*, 94: 29-47.

Griliches, Z. - Lichtenberg, F. (1984): R&D and productivity growth at the industry level: Is there still a relationship. In: Griliches, Z. (Ed.), R&D, Patents and Productivity. NBER and Chicago University Press, Chicago, IL.

Griliches, Z. (1979): Sibling Models and Data in Economics: Beginnings of a Survey. *Journal of Political Economy*, 87(5): 37-64.

Inklaar, R. - Timmer, M. (2013): Capital, labor and TFP in PWT 8.0. http://www.rug.nl/research/ggdc/data/pwt/v80/capital_labor_and_tfp_in_pwt80.pdf.

Kenny, C. (2003): The Internet and Economic Growth in Less-developed Countries: A Case of Managing Expectations?. *Oxford Development Studies*, 31 (1): 99-113.

Lucas, R. E. Jr. (1988): On the Mechanics of Economic Development. *Journal of Monetary Economics*, 22: 3-42.

Nelson, R. R. - Phelps, E. S. (1966): Investment in Humans, Technological Diffusion and Economic Growth. *American Economic Review*, 56 (2): 69-75.

OECD (2012): Measuring the Internet Economy: a Contribution to the Research Agenda, OECD, Paris.

Pesaran, H. - Shin, Y. - Smith, R. P. (1999): Pooled Mean Group Estimation of Dynamic Heterogeneous Panels. *Journal of the American Statistical Association*, 94(446): 622-634.

Pesaran, H. - Smith, R. P. (1995): Estimation of Long-Run Relationships from Dynamic Heterogeneous Panels. *Journal of Econometrics*, 68: 79-113.

Romer, P. M. (1986). "Increasing Returns and Long-Run Growth." Journal of Political Economy, 94, 1002-1037.

Schankerman, M. (1981): The Effects of Double-Counting and Expensing on the Measured Returns to R&D. *The Review of Economics and Statistics*, 63, 454-458.

Senhadji, A. (2000): Sources of Economic Growth: An Extensive Growth Accounting Exercise. *IMF Staff Papers*, Vol. 47, No. 1.

Solow, R. M. (1956): A Contribution to the Theory of Economic Growth. *Quarterly Journal of Economics*, 70: 65-94.

Table 1

APPENDIX

Data Definitions and Sources

The variables that are used in the model are output, capital stock, human capital, R&D, trade, and ICTs. While output, capital stock, human capital are obtained from PWT 8, the rest are from the WDI database.[14,15]

Output (Y) is the real gross domestic product (GDP) at purchasing power parities (PPPs) (in million 2005 US$). For international comparison GDP is converted to international dollars using the PPP rates.

Capital stock (K) is the real capital stock measured at current PPPs (in million 2005 US$).

Human capital (H) is the human capital adjusted labor input (H=hL, where h is human capital, educational attainment, per labor and L is total employment).

Research and development Stock (R) is calculated based on the perpetual inventory method following Griliches (1980) (in million 2005 US$). As underlined by Griliches (1980) and discussed in detail by Schankerman (1981) there are two important measurement problems when we use indicators such as research and development expenditure (% of GDP) as a proxy of R&D in our analysis. First, we face the problem of double counting because the conventional proxies of capital and labor include elements of R&D. For example, R&D workers are included in the labor force and also R&D investment is included in the total capital stock and the "failure to recognize the double-counting of R&D inputs and the expensing of R&D can be framed as an omitted variable problem" (Eberhardt et al. 2013:438). Secondly, in the value added calculation R&D is treated as intermediate expense. Thus, in order to avoid the problem of double counting and mutlicollinearity we have calculated the R&D stock for the OECD countries as follows,

[14]The World Development Indicators (WDI) dataset of World Bank and the Penn World Tables (PWT 8) are used in this study.
[15] See Feenstra et al. (2015) and Inklair and Timmer (2013) for more detail.

$$R_{it} = (1-\delta)R_{it-1} + RE_{it} \qquad \text{(A.1)}$$

where R_{it} is the R&D stock of country i at time t, RE_{it} is R&D expenditure of country i at time t and δ is the depreciation rate ($0 < \delta < 1$).

The depreciation rate is used as 0.15 following Griliches (1998) and Ruge-Leira (2015). The initial R&D stock (for 1995) is determined by following Ruge-Leira (2015). That is, the initial R&D stock is calculated as $R_{i,95}=RE_{i,95}/(g_i+\delta)$, where g is average growth rate of GDP of country i over 1995-2011 and as above δ is 0.15.

Trade (T) 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.

Information and Communication Technologies (C). In this study ICTs is proxied by using fixed broadband Internet subscribers, which is measured on per 100 people basis for the entire country.