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# The impact of ICT capital and use on economic growth

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## The impact of ICT capital and use on economic growth

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### Keywords:

ICT, economic growth, panel data analysis

### Abstract

*This paper investigates how ICT capital and usage affects economic growth which is currently received considerable attention in the information society and its potential impacts on the economic growth. A sample of MENA and OECD countries including developing, emerging, and developed countries is used in this study to determine the impact of ICT on economic growth during the last 15 years using panel data analysis.*

*This research provides statistical evidence for the impact of labor and capital on economic growth as reported in several previous studies. However, this impact differ between regions and level of development. It is observed that the impact of ICT on economic growth for OECD, emerging and advanced economies is higher than its impact in MENA and developing countries. This is contradicting to the impact of non-ICT capital where the impact of non-ICT capital on economic growth for OECD and advanced economies is much smaller than its value for MENA and developing countries. In addition, both mobile service and fixed broadband service as a measures for ICT usage show positive and significant impact on economic growth. This impact appears in OECD countries and advanced economies only but not appears in MENA countries and developing economies.*

## **1. Introduction**

The Information and Communication Technology (ICT) development not only become very clear in our daily life in the last three decades but also considered as a key driver in productivity and economic growth.

ICT can be defined as a combination of electronics, telecommunications, software, networks, computer stations, and the integration of information media (Granville, et.al., 2000). Also, Dedrick et al. (2000) define ICT as all communication equipment including radio and TV, consequently ICT investment includes investments in computer and telecommunication networks and services and their related infrastructure including hardware and software.

The investments in ICT is currently considered as a key driver for economic development. It can affect economic growth directly through producing more communication products and services and consequently increasing the demand of these products and services or indirectly through potential benefits of ICT such as enhancing communication means among individual and enterprise, reducing transaction costs, and improving the quality of services of other sectors including but not limited to energy, transportation, health, and education sectors.

There are several studies aim to determine the contribution of ICT on economic growth. However, the results of these studies are different; some studies report a significantly positive impact of ICT such as Sridhar & Sridhar (2007), Dahl, Kongsted & Srensen (2011), while other studies didn't record this impact Dewan and Kraemer (2000), Lee et al. (2005). In our opinion, the reason is due to the discrepancy of selected countries, variables, estimation methodologies, and time periods among different studies. In addition, it is noticed that the empirical studies aim to assess the impact of ICT on economic growth for developing countries are very limited when compared to those studies focus on developed countries due to the lack of data for many developing countries especially for ICT, human capital and labor data.

Accordingly, this study aims to fill this gap and adds to the current literature by analyzing empirically the impact of ICT capital and the use of ICT on economic development in developing countries. Moreover, the impact of ICT in developing countries is compared to other developed economies in order to extract some policy recommendations for the developing countries.

## 2. Literature Review

Economic growth determinants is one of the most significant issues that economists have examined. In the 1950s, Solow's neoclassical growth model uses an aggregate production function and assumes that technological progress has permanent impact on economic growth besides human and physical capital (Solow, 1956). Then, an extensive researches aim to investigate the relation between ICT as one of the main technological development in the recent decades and the economic growth from different perspective such as firms / business level, industry / sectorial level, and macroeconomic / national level.

Earlier studies focus on developed countries and most of them didn't find significant impact of ICT on economic growth before mid 1990s while its impact start to appear after that period. Jorgenson & Stiroh (2000) and Oliner & Sichel (2000) focus on US economy and prove positive and significant impact of ICT on productivity. By comparing US and European countries, Inklaar et al. (2005) find that the impact of ICT in US is higher than its impact on Europe. Schreyer (2000), Daveri (2000), and Van Ark et al. (2002) also confirm that the gains from ICT capital in Europe are behind their corresponding in US.

Then, the scope of this area of research extends to include developing and emerging countries which raise an important question about how far these developing countries are benefiting from ICT as compared to developed countries. The theoretical literature provides mixed answers to this question. Antonelli (1991) suggests that developing countries may benefit more from ICT than developed countries because ICT can create several opportunities to developing and less industrialized countries that make them catch and even leapfrog the developed countries, also Steinmueller (2001) points out that ICT can support the development strategy of leapfrogging in developing countries by increasing productivity and bypassing some of the processes of accumulation of invested capital and human capabilities in order to narrow the gap between developed and developing countries. This is also reported by United Nation (2011) where ICT services can enable better access to information, reduce transaction costs, and encourage innovations. However, the leapfrogging effect depends on the absorptive capacities of emerging and developing countries which defined by Kneller (2005) as the ability and effort of individuals in developing countries to use and apply new ICT technologies.

However, there are empirical evidences that don't support the leapfrog argument. One of the early researches in this regard is the study of Dewan and Kraemer (2000) who find positive and significant effect of ICT capital in developed country but insignificant impact in developing ones during the period 1985-1993. In addition, Lee et al. (2005) and Edquist (2005) find significant impact of ICT on growth rates in new industrialized economies and developed countries but this impact is not found in developing countries. Similarly, Papaioannou and Dimelis (2007) find that the impact of the ICT capital stock on labor productivity growth is higher in developed than in developing countries. The mentioned studies explain these findings due to lack of rapid diffusion of ICT and lack of ICT enhancing factors in developing countries such as educational level and human skills.

Although most of the studies focus on the impact of ICT investment on economic growth, other studies concentrate on ICT use and diffusion as an important measure for ICT impact on economic performance. ICT use can be measured by the number of subscribers or penetration levels of different ICT services. For example, Roller and Waverman (2001) find that wireline penetration has positive effect on GDP in OECD countries while Czernich et al. (2011) and Koutroumpis (2009) prove the positive impact of broadband penetration on growth in the same region. In addition, the positive and significant impact of mobile telecommunication on economic growth is reported by Waverman et al. (2005), Gruber & Koutroumpis (2010), and Saglam (2018). Moreover, Czernich et al. (2011), Jin and Cho (2015), and Bertschek et al. (2015) provide empirical evidence about the significant impact of internet on economic growth.

In contrast to the above literature, another direction of studies finds negative effects of ICT on economic growth. For example, Stiroh (2002) and O'Mahony & Vecchi (2005) find negative impact of ICT measures on manufacturing industries in US and UK respectively. In addition, Hofman et al. (2016) find low impact of ICT on productivity and growth in Latin America. In addition, Kiley (1999) and Jacobsen (2003) show negative impact of computer on economic growth. Recently, Yousefi (2011) finds insignificant impact of ICT capital investment on output growth for developing countries during the period 2000 to 2006.

### **3. Data and Methodology**

#### **3.1. Samples and Data Sources**

This research covers two regions; Middle East and North Africa (MENA) and the Organisation for Economic Co-operation and Development (OECD) during the period 2001-2016.

The MENA region is represented by 15 Countries; Algeria, Egypt, Morocco, Tunisia, Bahrain, Iran, Israel, Jordan, Kuwait, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, and Yemen. On the other hand, OECD region is represented by 32 countries; Japan, Estonia, Hungary, Latvia, Lithuania, Poland, Slovak Republic, Slovenia, Turkey, Chile, Mexico, Canada, United States, Australia, New Zealand, Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and United Kingdom.

Due to unavailable data on capital and labor for Sudan, Iraq, Armenia, Azerbaijan, Iceland, and Czech Republic, these countries are excluded from this research. In addition, there are other missing values due to lack of data in some countries for one or more year(s). These missing observations are dropped because handling such missing data with any estimation method will be misleading due to its high size, this results in total of complete 685 observations.

The data is collected from different sources; The Conference Board Total Economy Database™ (TED) is the main source of data. The TED is a comprehensive database with annual data covering Gross Domestic Product (GDP), population, employment, total working hours, labor quality, capital services, labor productivity, and total productivity factor for 123 countries. In addition, other data sources are used including the International Telecommunication Union (ITU), the World Bank, and the United Nations Conference on Trade and Development (UNCTAD).

#### **3.2. Data and Research Variables**

The dependent variable is the Gross Domestic Product (GDP) as a measure of output in a country. The available GDP data in the Conference Board Total Economy Database™ (TED) is collected from national statistics offices on national currencies and in order to consider the price differences across countries the purchasing power parities (PPPs) is used for normalization and converting GDP into common denominator.

The independent variables or the regressors of this research can be grouped into three main groups. First, labor figures can be dis-aggregated into labor quantity measures such as employment rate and working hours as well as labor quality measures such as the composition of workers in terms of educational attainment.

Second, capital measures are used from the Conference Board Total Economy Database<sup>TM</sup> (TED) which distinguish between ICT and non-ICT capital. ICT capital measure is calculated from the investment aggregated to ICT assets which consists of hardware, software and communication equipment while non-ICT capital measure is aggregated from the investment on non-ICT assets such as residential and non-residential structures, transport equipment and all other non-ICT machinery categories. Such data provides us with a good basis that fit the objective of this paper because it allow us to assess separately the impact of ICT investments as important contributor on economic growth (Jorgenson and Vu, 2013).

Moreover, this research include another set of variables that assess the usage of ICT services across countries. Fixed landline telephony, mobile, fixed broadband, and internet usage are used as measures for ICT usage. This data is collected from the International Telecommunication Union database. Table (1) shows the definition of research variables and their data source.

### **3.3. Econometric model**

The conventional neoclassical growth model (Solow 1956) proposes that the real GDP (Y) is function of labor (L), capital (K), and technological changes (A). ICT investment is used in many studies as one of the main technological changes during the current and last decads. Accordingly, the capital measure in Solow's model can be divided into ICT and non-ICT capital. In this research a modified version of this production function is used by inserting additional measures for ICT usage (S) as oone of the technological changes in order to assess the impact of using ICT services on economic growth as well as a lag indicator for GDP to accommodate for highly presistent series of output (Diebold & Rudebusch, 1989 ; Bond et al., 2001). Accordingly, the following econometric model is used:

$$Y_{it} = f ( Y_{i,t-1} , L_{it} , K_{it} , S_{it} ) \quad (1)$$

Taking the logs and differencing, equation (1) can be written as:

$$Y_{it} = \beta_0 + \beta_1 Y_{i,t-1} + \beta_2 l_{it} + \beta_3 k_{it} + \beta_4 s_{it} + v_i + \varepsilon_{it} \quad (2)$$

Where

$Y_{it}$ ,  $l_{it}$ ,  $k_{it}$ , and  $s_{it}$  represent the growth measured by log change in GDP, labor, capital, and ICT usage measures respectively for country (i) and Year (t).

$\beta_1$ ,  $\beta_2$ ,  $\beta_3$ , and  $\beta_4$  represent output elasticity or regression coefficients for lagged GDP, labor, capital, and ICT measures respectively.

$\beta_0$ ,  $v_i$ , and  $\varepsilon_{it}$  is the constant term, country specific effect, and the random error term respectively.

In order to investigate the impact of ICT capital and usage on economic growth, a multiple linear regression model – based on the above equation – is applied on a panel data of MENA and OECD countries during the period 2001-2016. Panel data (also known as longitudinal or cross-section time-series) is a data set contains observations on several countries where each country is observed across time with two or more observations. The main advantage of panel data is that it allows controlling for variables that vary across countries but don't vary over time (time-invariant) such as cultural and demographic factors as well as unobserved variables that can't be measured and so don't included in the regression model.

There are two ways to deal with panel data; the fixed effect model and the random effect model (Hsiao, 2003) where each of them treats the unobserved individual effect in different way. Fixed effect model assume that unobserved or country-specific effect is correlated with the independent variables and it is also assumed to be time invariant that has constant value for each individual across time periods, accordingly it could be added to the constant term, it also assumes difference in intercepts across countries or time period. However, the random effect model assumes that variation across countries (or country specific effect) is assumed to be uncorrelated with the independent variables, also the unobserved country specific effect is assumed to be randomly distributed not a fixed term as in fixed effect model. In addition, random effect explores the individual specific difference in error variance instead of intercepts and it is estimated using Generalized Least Square (GLS) method.



Our sample is regressed according to equation (2) with two different methods of estimation which are fixed and random effect estimators. In addition, the data is analyzed as a whole first, then analyzed separately according to the region (MENA and OECD) and also according to the level of development (developing, emerging, and advanced economies) based on World Bank classification (World Bank, 2015).

## **4. Results**

### **4.1. Correlation analysis**

Table (2) shows the correlation matrix between research variables, it is clear that labor quantity and capital measures for both ICT and non ICT assets are the highest three variables that are positively correlated with growth rate. All ICT usage measures are also positively correlated with GDP but with lower correlation coefficient. On the other hand, slightly negative correlation is observed between labor quality and GDP growth.

Moreover, the importance of correlation analysis appears when monitoring the correlation among the explanatory variables where high correlation among independent variables may result in existence of multicollinearity. Checking the correlation among independent variables shows low correlation coefficient and consequently the data set don't suffer from multicollinearity problem.

### **4.2. Selecting the Best Method of Estimate**

Before interpreting regression results in details, it is worth to decide which estimation method should be used especially in case of different results between the the fixed and panel effects models.

Accordingly, a series of diagnostic test is used to answer this question. First, testing for the presence of random effects is done by using Lagrange Multiplier test developed by Breusch and Pagan. This test is used to compare between random effect and pooled OLS with the null hypothesis that variance across countries is zero or there is no random effects [  $H_0: \text{var}(\mu) = 0$  ]. Significance p-value less than 5 percent enable us to reject the null hypothesis and therefore ensure that there is a random effect. Similarly, the presence of fixed effects is done by using a F-test that compares for the restricted pooled OLS model results with the results from the fixed effects. The

rejection of null hypothesis indicates that fixed effect is present. Then, in case of the presence of both fixed effects and random effects, Hausman test is used to decide whether to use fixed effects or random effects. The null hypothesis of Hausman test is that country specific effect is uncorrelated with the explanatory variables and therefore both random effects and fixed effects are the same while the alternative hypothesis is that only fixed effects is consistent. If the null hypothesis is rejected, the fixed effect should be used instead of random effects.

When applying these diagnostic tests for each regression model in the study, all models – except model (4) for developing countries – show that the best method of estimate is the fixed effect. However, we will still compare the results of both fixed and random effect methods of estimate as a natural test of robustness (Calvo & Robles 2001) but depending on fixed effect results in case of differences.

### **4.3. Regression Results**

There are 6 regression models to determine the impact of ICT capital and usage on economic growth. First, model (1) investigate this relation for all countries as a whole. Then, model (2) and model (3) differentiate between MENA and OECD countries separately. Moreover, models (4, 5, and 6) provide results when grouping the countries into developing, emerging, and advanced economies respectively using the classification of World Bank according to the level of development,.

All models are significance with p-value  $<.0001$  which is evidence to reject the null hypothesis that any model is not useful and none of the independent variables have a relationship with the dependent variable. This means that the selected multiple regression models are accepted and useful to investigate the relationship between the independent variables and economic growth. Regarding the explanatory power of the models, first the coefficient of determination is ranging from .43 to .67. This means that around 55-60 percent of variation in the economic growth can be explained by the selected set of explanatory variables.

Table (3) shows the results of regression analysis according to region. First, in model (1), we deal with all countries as a whole where both fixed and random effects shows significant and positive relationship between labor quantity, capital provided by ICT and non-ICT assets and economic

growth. In addition, fixed effect reports positive and significant relationship between only one measure of ICT usage which is mobile service usage and economic growth.

According to the fixed effect model, each one percent increase in labor quantity will lead to 0.34 percent increase in economic growth while the labor quality shows unexpected result of negative and significant relationship with GDP growth. Regarding the capital measures, each one percent increase in growth of capital services provided by ICT assets results in 0.054 percent increase in GDP growth. Similarly, capital services provided by non-ICT assets has greater impact on economic growth where each one percent increase in it results in 0.62 percent increase in GDP growth. On the other hand, mobile services is the only ICT usage measure that shows significant impact on GDP where each ten percent growth of fixed mobile service usage leads to around 0.3 percent increase in economic growth.

Model (2) shows the regression results for MENA countries only where both fixed and random effects shows the positive and significant relationship of ICT and non-ICT capital on economic growth. Each ten percent increase in ICT capital results in 0.08 increase in GDP growth, and each one percent increase in non-ICT capital results in 0.87 increase in GDP growth. However, all other ICT usage measures don't have any impact on economic growth on MENA region.

In model (3), the results of OECD countries shows that every one percent increase in labor quantity results in 0.83 percent increase in GDP growth. In addition every one percent increase in ICT capital and non ICT capital results in 0.10 and 0.24 percent increase in GDP growth respectively. In addition, both of mobile and broadband service usage have significantly positive impact on growth where every ten percent increase in mobile service usage leads to 0.28 percent in GDP growth and similarly every ten percent increase in broadband usage leads to 0.05 percent increase in GDP growth.

By comparing the results of MENA and OECD countries, we find that ICT capital has positive impact on economic growth in OECD countries only. Also, no ICT usage measure has significant impact on growth in the MENA region while both mobile and broadband service usage have positive and significant impact on economic growth in the OECD countries.

In addition to the MENA and OECD classification, another classification is used based on the level of economic development provided by the World Bank. Table (4) shows three other regression

models for developing, merging and advanced economies. In model (4), only ICT capital and non-ICT capital have positive and significant impact on economic growth. Each one percent increase in ICT capital growth results in 0.09 percent increase in GDP growth, while each one percent increase in non-ICT capital growth results in 0.53 percent increase in GDP growth.

Similar to developing countries, the results for emerging economies are shown in model (5) where both ICT capital and non-ICT capital have positively and significant impact on GDP growth with almost the same values of regression coefficients. Each one percent increase in ICT capital results in 0.10 percent increase in GDP growth, and each one percent increase in non-ICT capital results in 0.50 percent increase in GDP growth. However, inconsistent with developing countries, labor quantity has positive and significant impact on economic growth where every one percent increase in labor quantity growth rate results in 0.74 percent increase in GDP growth.

Finally, model (6) reports the results of countries with advanced economy where labor quantity, ICT capital, and broadband service usage have positive and significant impact on GDP growth while labor quality and fixed service usage has negative impact. Each one percent increase in labor quantity results in 0.87 percent increase in economic growth, also each one percent increase in ICT capital results in 0.07 percent increase in economic growth and each one percent increase in non-ICT capital results in 0.08 percent increase in economic growth given all other variables are constant. In addition, each ten percent increase in broadband service usage results in 0.08 increase in economic growth. On the other hand, fixed telephony service shows negative and significant impact with economic growth, this finding may be due to the decline figures of fixed telephony worldwide.

As a conclusion, this research provide statistical evidence for the impact of labor and capital on economic growth as reported in several previous studies. However, this impact differ between regions and level of development.

Labour quantity has positive significant impact on economic growth in OECD region, emerging, and advanced economies (models 3, 5, and 6 respectively) and has positive but insignificant impact on economic growth in MENA region and developing countries (models 2 and 4 respectively). On the other hand, the sign of regression coefficient for labor quality is unexpectedly negative in all regression models and it is also significant in MENA, OECD, and advanced economies.

Regarding Capital measures, the capital provided by both ICT assets and non-ICT assets have positive and significant impact on economic growth in all regression models including MENA and OECD regions as well as different level of economies. We can observe that the impact of ICT on economic growth for OECD, emerging and advanced economies is higher than its impact in MENA and developing countries. This is contradicting to the impact of non-ICT capital where the impact of non-ICT capital on economic growth for OECD and advanced economies is much smaller than its value for MENA and developing countries.

Finally, regarding the ICT usage measures, both mobile service and fixed broadband service usages shows positive and significant impact on economic growth. This impact appears only in OECD countries and advanced economies (models 3 and 6 respectively) but not appears in MENA countries and developing economies (model 2, 4, and 5 respectively). It is also observed that the impact of mobile service usage is much higher than the impact of broadband, this may be due to that the fixed broadband didn't reach to the critical mass yet that could help in accelerating the potential benefits of broadband services and eventually contribute in the economic development in those countries. This would imply that positive growth effects might be subject to get certain threshold or critical mass in the number of subscribers utilizing ICT services. On the other hand, fixed telephony usage shows negative impact on economic growth in the advanced economies only (model 6).

#### **4.4. Diagnostic Tests, Limitations, and Future Work**

A series of diagnostic tests are applied to check assumptions of ordinary least square estimation methods. First, the collinearity problem is tested using variance inflation factors (VIF) to find if the explanatory variables or the regressors of this research are correlated. The mean VIF values appears in tables (3 and 4) for all regression models shows reasonable and small values (less than 4.0) which indicates that no multicollinearity problem appear in this data set.

In addition, the residual-versus-fitted plot is used to test for heteroscedasticity where nonconstant spread in this plot means heteroscedasticity. As shown in figure (1), the rvf plot shows constant spread which indicates no heteroscedasticity problem, However, by using another statistical test which is Breusch-Pagan/Cook-Weisberg test for heteroskedasticity with  $H_0$ : Constant variance, the results reject the null hypothesis in model 1, 2, and 4 which may indicate heteroscedasticity problem in these three models. Under heteroscedasticity, OLS estimators are unbiased and

consistent but no longer efficient, and the S.E. are biased. Accordingly, we use one of the options in Stata software to deal with heteroscedasticity which is white-estimators or robust option.

Moreover, to test the normality of data, normal probability plot for residuals in all regression models are shown in figure (2) which indicates nonnormality distribution of residuals. In addition, the statistical results of Shapiro-Wilk test for normality shows the nonnormality of data. Under nonnormality problem, the results of significance tests are invalid. However, the central-limit theorem assures that inferences are approximately valid in large samples. Different transformation was used to deal with nonnormality but none of them succeeded to overcome it.

Finally, besides the nonnormality of data shown from the diagnostic tests, the main limitation of this research is lack of several data specially for labor and capital measures in developing countries where data for advanced economies is generally in better quality compared to developing economies. Accordingly, additional analysis using other estimation methods such as Generalized Method of Moments (GMM) besides increasing the sample size to cover more geographical regions and time period could be considered in future work. Furthermore, complementary firm-level or sector specific studies can help to gain deeper understanding of the potential effect of ICT on economic development.

## **5. Conclusion and Policy consideration**

This research uses panel data analysis techniques to empirically study the impact of ICT capital and usages on the economic growth of MENA and OECD regions and to investigate if the ICT capital and usage measures has the same effect on economic growth among MENA and OECD regions. It is a statistical indication that developing countries are gaining more from investments in ICT than developed economies. Our results show a positive impact between ICT capital and usage on economic growth where the capital provided by ICT assets has positive and significant impact on economic growth in all regression models including MENA and OECD regions as well as different level of economies. We also find that the impact of ICT on economic growth for OECD, emerging and advanced economies is higher than its impact in MENA and developing countries. Moreover, ICT diffusion shows positive impact on economic growth in terms of mobile service and fixed broadband service in OECD countries and advanced economies but not appears in MENA

countries and developing economies. It is also observed that the impact of mobile service usage is much higher than the impact of fixed broadband. The findings of this research doesn't support the leapfrog argument that developing countries can benefit from ICT better than developed countries, this can be due to lack of rapid diffusion of ICT and ICT enhancing factors in developing countries such as educational level and human skills which can be investigated empirically in future studies.

The evidence of the effect of ICT capital on economic growth suggests several policy implications. Countries should promote ICT services in their national and strategic plans by encouraging innovation and facilitating investments in ICT infrastructure and next generation networks through business friendly environment and efficient public private partnership programs. Moreover, considering the finding of the positive effect of mobile and broadband penetration on economic growth suggest that promoting the diffusion of these services should be on the top priorities of governments and regulatory bodies through fair competition policies and equal playing field regulations that encourage competition and reduce cost of ICT services and consequently increase its diffusion to reach a critical mass that accelerates the potential benefits of ICT on economic development.

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**Table 1: Research Variables; Definitions, and Data Sources**

Variable	Symbole	Description	Source
Gross Domestic Product	GDP	Growth rate of GDP (measured in log change multiplied by 100)	Conference Board Total Economy Database™ (TED)
Lagged GDP	Lag_GDP	First lag (previous year measure) of GDP growth	WorldBank database
Labour Quntity	Lab_Quntity	Growth of labour quantity, log changed multiplied by 100	Conference Board Total Economy Database™ (TED)
Labour Quality	Lab_Qality	Growth of labour quality, log changed multiplied by 100	Conference Board Total Economy Database™ (TED)
ICT Capital	Capital <sub>ICT</sub>	Growth of capital services provided by ICT assets, log changed multiplied by 100	Conference Board Total Economy Database™ (TED)
Non ICT Capital	Capital <sub>non-ICT</sub>	Growth of capital services provided by non ICT assets, log changed multiplied by 100	Conference Board Total Economy Database™ (TED)
Fixed telephone services	Fixed_ICT	Growth of fixed telephone service usage, measured in log change multiplied by 100	International Telecommunication Union (ITU)
Mobile services	Mobile_ICT	Growth of fixed mobile service usage, measured in log change multiplied by 100	International Telecommunication Union (ITU)
Fixed broadband service	Broadband_ICT	Growth of fixed broadband service usage, measured in log change multiplied by 100	International Telecommunication Union (ITU)
Internet usage	Internet_ICT	Growth of internet service usage, measured in log change multiplied by 100	International Telecommunication Union (ITU)

**Table 2: Correlation Matrix**

	GDP	Lag_GD	Lab_Quntit	Lab_Qalit	Capital <sub>IC</sub>	Capital <sub>non</sub>	Fixed_IC	Mobile_IC	Broadband_IC	Internet_IC
		P	y	y	T	-ICT	T	T	T	T
GDP	1.000									
Lag_GDP	0.507	1.000								
Lab_Quntity	0.527	0.409	1.000							
Lab_Quality	-	-0.102	-0.112	1.000						
	0.116									
Capital <sub>ICT</sub>	0.454	0.455	0.327	-0.026	1.000					
Capital <sub>non-ICT</sub>	0.526	0.579	0.602	0.014	0.499	1.000				
Fixed_ICT	0.11	0.146	0.198	0.042	0.153	0.261	1.000			
	4									
Mobile_ICT	0.276	0.264	0.308	0.112	0.264	0.325	0.259	1.000		
Broadband_ICT	0.174	0.199	0.106	-0.026	0.244	0.159	0.126	0.509	1.000	
Internet_ICT	0.225	0.206	0.239	0.069	0.254	0.313	0.236	0.507	0.509	1.000

**Table 3: Regression results according to region**

Dependent Variable is GDP (3)	(1)		(2)			
	All countries		MENA		OECD	
	FE	RE	FE	RE	FE	RE
Lag_GDP	.0427 (.0397)	.2127*** (.0371)	.0957 (.0841)	.2575*** (.0783)	-.1218*** (.0367)	-.0032 (.0360)
Lab_Quantity	.3389*** (.0412)	.3015*** (.0402)	.0688 (.0801)	.0791 (.0797)	.8331*** (.0432)	.8001*** (.0443)
Lab_Quality	-.5414*** (.1466)	-.2900** (.1377)	-.5497* (.3161)	-.1989 (.2900)	-.2262* (.1336)	-.0237 (.1304)
Capital <sub>ICT</sub>	.0537** (.0237)	.1079*** (.0203)	.0078* (.0480)	.0947** (.0398)	.1022*** (.0237)	.1002*** (.0211)
Capital <sub>non-ICT</sub>	.6194*** (.0988)	.1993*** (.0661)	.8767*** (.2040)	.4822*** (.1545)	.2402*** (.0924)	.1178** (.0591)
Fixed_ICT	-.0088 (.0208)	-.0316 (.0195)	-.0038 (.0454)	-.0057 (.0444)	-.0233 (.0187)	-.0432** (.0173)
Mobile_ICT	.0272** (.0127)	.0166 (.0125)	.0307 (.0236)	.0271 (.0234)	.0283** (.0149)	.0342** (.0151)
Broadband_ICT	3.06e-06 (.0035)	.0008 (.0035)	-.0088 (.0096)	-.0097 (.0094)	.0052* (.0029)	.0042 (.0029)
Internet_ICT	.0120 (.010)	.0028 (.0101)	.0274 (.0225)	.0155 (.0222)	.0119 (.0089)	.0158* (.0093)
Const.	-1.480 (.956)	-.8297*** (.2989)	-1.175 (1.553)	-2.169** (.866)	-.2957 (.7171)	-.5676** (.2619)
# of observation	685	685	177	177	508	508
F statistics (prob. F)	12.40 (.0000)		7.42 (.0000)		23.56 (.0000)	
R-square	.5153	.4307	.5015	.4308	.6746	.5966
Adjusted R-square	.4738		.4339		.6459	
mean VIF	2.28		2.13		2.70	
FE vs. pooled OLS (F-test)	2.45 (.0000)		1.83 (.047)		3.49 (.0000)	
RE vs. pooled OLS (Breush Pagen LM test)		chi2 =3.34 Prob>chi2 = (.067)		chi2 =0.00 Prob>chi2 = (.987)		chi2 =41.96 Prob>chi2 = (.0000)
Hausman test		chi2 = 116.27 Prob>chi2 = (.0000)		chi2 = 27.39 Prob>chi2 = (.0012)		chi2 = 1755.65 Prob>chi2 = (.0000)

Standard errors in parentheses, \* p <.10, \*\* p <.05, \*\*\* p <.01

¥ chi2<0 ; model fitted on these data fails to meet the asymptotic assumptions of the Hausman test;

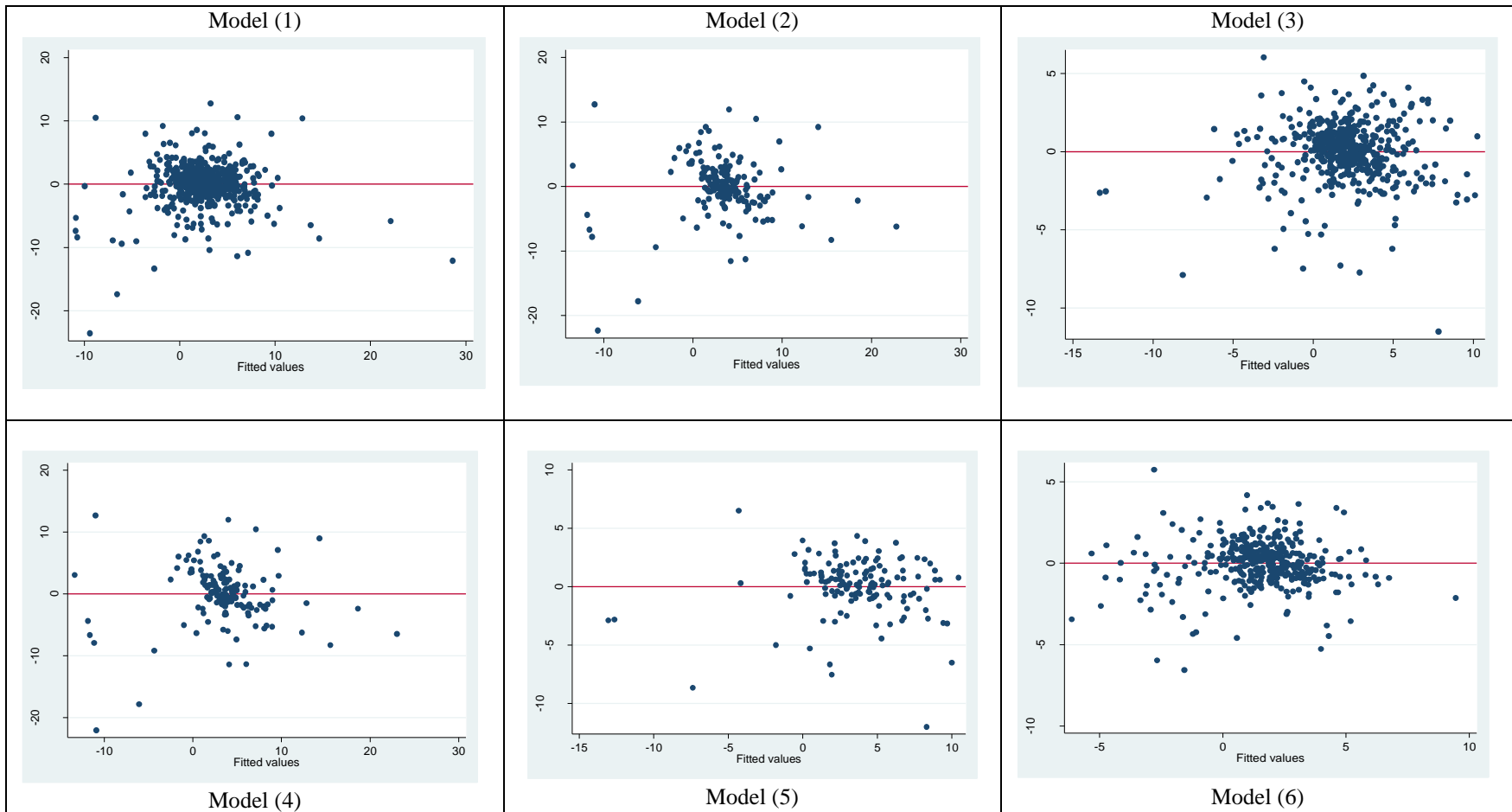
**Table 4: Regression results according to level of development**

Dependent Variable is GDP (6)	(4)		(5)			
	Developing		Emerging		Advanced	
	FE	RE	FE	RE	FE	RE
<b>Lag_GDP</b>	.0803 (.0927)	.2393*** (.0852)	-.0796 (.0769)	.0996 (.0708)	-.1941*** (.0413)	-.1319*** (.0411)
<b>Lab_Quantity</b>	.0713 (.0891)	.0840 (.0873)	.7427*** (.0828)	.6803*** (.0815)	.8725*** (.0514)	.8383*** (.0491)
<b>Lab_Quality</b>	-.7022* (.3871)	-.2049 (.3459)	-.1306 (.2835)	.1932 (.2612)	-.4238*** (.1303)	-.3779*** (.1257)
<b>Capital<sub>ICT</sub></b>	.0116 (.0529)	.0970** (.0429)	.1065* (.0603)	.1195** (.0496)	.0696*** (.0244)	.0355 (.0215)
<b>Capital<sub>non-ICT</sub></b>	.9146*** (.2324)	.5269*** (.1693)	.5032** (.2144)	.0044 (.1106)	.0830* (.1050)	.2299*** (.0778)
<b>Fixed_ICT</b>	-.0045 (.0496)	-.0072 (.0481)	-.0075 (.0392)	-.0412 (.0384)	-.0638*** (.0205)	-.0365** (.0171)
<b>Mobile_ICT</b>	.0279 (.0259)	.0292 (.0254)	.0487 (.0335)	.0382 (.0312)	-.0024 (.0166)	.0067 (.0161)
<b>Broadband_ICT</b>	-.0073 (.0114)	-.0089 (.0109)	.0014 (.0065)	.0049 (.0063)	.0078*** (.0029)	.0037 (.0029)
<b>Internet_ICT</b>	.0251 (.0254)	.0154 (.0248)	.0162 (.0173)	.0094 (.0179)	.0081 (.0103)	.0063 (.0104)
<b>Const.</b>	-1.041 (1.724)	-2.611** (1.029)	-1.405 (2.131)	-.3187 (.8700)	.9274 (.6100)	.2934 (.2442)
<b># of observation</b>	154	154	140	140	391	391
<b>F statistics (prob. F)</b>	6.44 (.0000)		9.38 (.0000)		18.04 (.0000)	
<b>R-square</b>	.5061	.4407	.6619	.5450	.6541	.5915
<b>Adjusted R-square</b>	.4275		.5913		.6179	
<b>mean VIF</b>	2.09		4.69		2.55	
<b>FE vs. pooled OLS (F-test)</b>	1.46 (.1490)		2.65 (.0018)		2.28 (.0003)	
<b>RE vs. pooled OLS (Breush Pagen LM test)</b>		chi2 = 0.11 Prob>chi2 = (.037)		chi2 = 2.58 Prob>chi2 = (.1080)		chi2 = 6.29 Prob>chi2 = (.0121)
<b>Hausman test</b>		chi2 = 18.20 Prob>chi2= (.0580)		chi2 = 52.59 Prob>chi2= (.0000)		chi2 = 1144.05 Prob>chi2= (.0000)

Standard errors in parentheses, \* p < .10, \*\* p < .05, \*\*\* p < .01

¥ chi2 < 0 ; model fitted on these data fails to meet the asymptotic assumptions of the Hausman test;

**Figure (1): residual vs. fitted plot for regression models as a test for heteroscedasticity**



**Figure (2): Normal probability plot for residuals as a test for normality**

