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CONSIDERATION THE RELATIONSHIP BETWEEN INFORMATION COMMUNICATIONS TECHNOLOGY AND ECONOMIC GROWTH IN TOP 10 ECONOMIC

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ABSTRACT

In this paper, we examine the relationship between information and communications technology (ICT) development and economic growth in top 10 economic, using panel cointegration, and panel-based error correction models from annual data covering the period of 1980 to 2010. The empirical results support of a short-run cointegration relationship after allowing for the heterogeneous country effect. The long-run relationship is estimated using a full-modified OLS. The evidence shows that short run causalities run from ICT to GDP and vice versa. This means that an increase in ICT directly affects economic growth and that economic growth also stimulates further ICT. The direction of causation between ICT and economic growth has significant policy implications.

Keywords: ICT, Economic growth, Panel cointegration, Causality.

INTRODUCTION

The original member countries of the top 10 are Sweden, Finland, Denmark, Netherlands, Norway, New Zealand, Canada, Germany, Australia and Switzerland (*Source:* KAM 2012, www.worldbank.org/kam). The economic impact of ICT is closely linked to the extent to which different ICT technologies have diffused in these economies. This is partly because ICT is a network technology; the more people and firms that use the network, the more benefits it generates. The diffusion of ICT currently differs considerably in top 10 countries, since some countries have invested more or have started earlier to invest in ICT than other countries.

Economic growth theories predict that economic growth is driven on investment in Information and Communication Technology (ICT). However, empirical studies of this prediction have produced mixed results, depending on the research methodology employed and the geographical configuration considered. Over the past decade, the development of information and communications technology and the investment in the ICT sector has been increasing rapidly in many countries. The fast growth of ICT infrastructure can be explained by a number of factors, such as advancements in ICT related technologies and services and market demand. In particular, over the past decade, many countries have seen explosive growth in mobile communications.

Mobile communications are experiencing accelerated growth rates in both developing countries and developed countries in recent years. The diffusion of mobile ICT services has not only facilitated market competition but also attracted a lot of domestic and foreign investment into the ICT sector. During the past decade, world economic output has also been growing at a fast rate, and in particular (Wan, 2011; Sadr and Gudarzi, 2012).

Early macro level studies, going back to late 1980s and early 1990s, indicated that ICT's share in productivity and economic growth was very small. However, later macroeconomic studies showed that investments in ICT had a considerable effect on the productivity of labor force and on economic growth. Gordon (2000) attributes productivity growth of the 1995-2000 period to business cycles. Results sometimes diverge due to different methodologies employed (Wan, 2011). Economic growth is the increasing ability of a nation to produce more goods and services. The use of ICT can enable the production of goods in a short amount of time and services are also provided more efficiently and rapidly. Growth can occur in many different ways, for example, the increased use of land, labor, capital and business resources and increased productivity of existing resources use by using ICT. ICT investment can also increase economic growth in many ways. ICT networks provide the framework for the delivery of different services, improves communications between firms, spreads to other industries and contributes to their profits affecting overall economic growth. The increased economic importance of ICT raises new questions for governments regarding the best policy frameworks to adopt for encouraging both ICT investment and ICT-led growth. The rapid diffusion of ICT in the past decades also introduces new policy issues for consideration, such as the effect of ICT on the distribution of economic activity and the influence of ICT on productions. Does the development of ICT infrastructure lead the increase of economic growth? Or does the increase of economic growth lead the development of ICT infrastructure? It is a vital question to explicitly disentangle the effect of ICT development and investment on economic growth. For this reason, the causal relationship between ICT development and economic growth has long been a subject of interest for empirical investigation. To date, a large number of studies have focused on explaining the economic impact of ICT development on economic growth and the issue has ranked among the active research fields since the issue has received considerable regulatory and public policy attention in many countries. ICT-led economic growth tends to occur when ICT demonstrates a stimulating influence across the overall economy. Although many studies find ICT development is one of the factors that affect economic growth, its contribution to the overall economy has varied between countries at different stages of development (Wan, 2011).

To date, results of the causal relationship between ICT development and economic growth have been mixed. As a matter of fact, research results for the relationship between ICT development and economic growth are inconclusive. This study thus examines a causal relationship between

ICT development and economic growth in top 10 countries. This study aims to answer the following two questions: First, is there a long-run equilibrium relationship between ICT development and economic growth? Second, what is the direction of causality between the two variables in the short-run? This study aims to contribute to the literature testing the ICT-led economic growth hypothesis. This study employs cointegration tests to investigate a long-run equilibrium and Granger causality tests to investigate directional causality in the short-run between ICT development and economic growth.

This study differs from previous work on growth and the role of ICT as it considers a range of questions that were not explicitly addressed in the previous work by these countries. For example, why have some countries invested more in ICT than others? What characterizes firms that adopt ICT? Which technologies are they using and for which purpose? What factors help firms in seizing the benefits from ICT? The paper is organized as follows: In Section 2 we provide a brief discussion of The impact of ICT on economic growth and section 3 discuses about the panel unit root test and the panel cointegration procedure. Empirical results are provided in Section 4. Final section contains the conclusions.

The Impact of Ict on Aggregate Productivity Growth

The evidence presented above shows that ICT has had considerable impacts on productivity growth in the second half of the 1990s, and into 2010. These effects are threefold:

1. In several countries with strong growth performance, notably Australia, Canada and the United States, investment in ICT capital has supported labor productivity growth. The available evidence suggests that these impacts have not disappeared with the slowdown, as ICT investment is slowly recovering.
2. In a number of countries, notably Finland, Ireland and Korea, ICT production has provided an important contribution to aggregate labor and multi-factor productivity growth.

3. In a number of these countries, notably Australia and the Sweden, there is evidence that sectors that have invested heavily in ICT, notably service sectors such as distribution and financial services, have been able to achieve more rapid MFP growth. This link between ICT use and MFP growth is also visible at the aggregate level; countries that have invested most in ICT in the 1990s have often also seen the largest increase in MFP growth.

A key question is the extent to which these effects are still visible in aggregate productivity growth now the economies of many countries have slowed down and as parts of the ICT sector have entered a down-turn. While aggregate trends in productivity are influenced by a range of factors, ICT is commonly considered to have contributed to a structural improvement in certain these countries. Estimates of multifactor productivity growth are not available for many countries for the most recent years, as estimates of capital services are typically only available with some delay. The aggregate productivity trends therefore continue to point to a structural improvement in productivity growth in certain countries, e.g. Australia and Canada, all countries that are among the key examples of ICT-led growth. This suggests that the impacts of ICT on productivity could continue in the years to come and that ICT remains a key factor for overall growth performance.

METHODOLOGY

The Panel Unit Roots Test

In order to investigate the possibility of panel cointegration, it is first necessary to determine the existence of unit roots in the data series. For this study we have chosen the Im, Pesaran and Shin (IPS), which is based on the well-known Dickey-Fuller procedure. Investigations into the unit root in panel data have recently attracted a lot of attention. Levine and Lin (1993) proposes a panel-based ADF test that restricts parameters γ_i by keeping them identical across cross-sectional regions as follows:

$$\Delta y_{it} = \alpha_i + \gamma_i y_{it-1} + \sum_{j=1}^{k} \alpha_j \, \Delta y_{it-j} + e_{it} \qquad (1)$$

where t =1,. . ., T time periods and i =1,. . .N members of the panel. LL tests the null hypothesis of $\gamma_i = \gamma = 0$ for all i, against the alternate of $\gamma_1 = \gamma_2 \ldots = \gamma < 0$ for all i, with the test based on statistics $t_\gamma = \hat{\gamma}/s.e.(\hat{\gamma})$. One drawback is that c is restricted by being kept identical across regions under both the null and alternative hypotheses (Lee, 2005).

For the above reason, Im *et al.* (1997) relax the assumption of the identical first-order autoregressive coefficients of the LL test and allow γ varying across regions under the alternative hypothesis. IPS test the null hypothesis of $\gamma_i = 0$ for all i, against the alternate of $\gamma_i < 0$ for all i. The IPS test is based on the mean-group approach, which uses the average of the t_{γ_i} statistics to perform the following $\bar{Z}$ statistic:

$$\bar{Z} = \sqrt{N}(\bar{t} - E(\bar{t}))/\sqrt{Var(\bar{t})} \qquad (2)$$

Where $\bar{t} = (\frac{1}{N}) \sum_{i=1}^{N} t_{\gamma_i}$, the terms E($\bar{t}$) and Var($\bar{t}$) are, respectively, the mean and variance of each t_{γ_i} statistic, and they are generated by simulations and are tabulated in Im *et al.* (1997). The $\bar{Z}$ converges to a standard normal distribution. Based on Monte Carlo experiment results, IPS demonstrates that their test has more favorable finite sample properties than the LL test.

Hadri (2000) argues differently that the null should be reversed to be the stationary hypothesis in order to have a stronger power test. (Hadri, 2000) Lagrange multiplier (LM) statistic can be written as (Lee, 2005):

$$\widehat{LM} = 1/N \sum_{i=1}^{N} \left(\frac{\frac{1}{T^2} \sum_{t=1}^{T} S_{it}^2}{\hat{\sigma}_{\varepsilon}^2} \right), \quad S_{it} = \sum_{j=1}^{t} \widehat{\varepsilon_{ij}} \qquad (3)$$

where $\hat{\sigma}_{\varepsilon}^2$ is the consistent (Newey and West, 1987) estimate of the long-run variance of disturbance terms. The next step is to test for the existence of a long-run cointegration among GDP and the independent variables using panel cointegration tests suggested by Pedroni (1999)Pedroni (2004). The panel cointegration tests Pedroni (1999) considers the following time series panel regression

$$y_{it} = \alpha_{it} + \delta_{it}\, t + X_i B_i + e_{it} \qquad (4)$$

where y_{it} and X_{it} are the observable variables with dimension of $(N * T) \times 1$ and $(N * T) \times m$, respectively. He develops asymptotic and finite-sample properties of testing statistics to examine the null hypothesis of non-cointegration in the panel. The tests allow for heterogeneity among individual members of the panel, including heterogeneity in both the long-run cointegrating vectors and in the dynamics, since there is no reason to believe that all parameters are the same across countries (Lee, 2005).

Two types of tests are suggested by Pedroni. The first type is based on the within dimension approach, which includes four statistics. They are panel υ-statistic, panel ρ statistic, panel PP-statistic, and panel ADF-statistic. These statistics pool the autoregressive coefficients across different members for the unit root tests on the estimated residuals.

The second test by Pedroni is based on the between-dimension approach, which includes three statistics. They are group ρ statistic, group PP-statistic, and group ADF-statistic. These statistics are based on estimators that simply average the individually estimated coefficients for each member. Following Pedroni (1999), the heterogeneous panel and heterogeneous group mean panel cointegration statistics are calculated as follows (Lee, 2005).

Panel υ-statistic:

$$Z_{\upsilon} = \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2}\, \hat{e}_{it-1}^2 \right)^{-1}$$

Panel ρ-statistic:

$$Z_{\rho} = \left(\hat{\sigma}^2 \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2}\, \hat{e}_{it-1}^2 \right)^{-1/2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \left(\hat{e}_{it-1} \Delta \hat{e}_{it} - \hat{\lambda}_i \right)$$

Panel ADF-statistic:

$$Z_t^* = \left(\hat{s}^{*2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\,\hat{e}_{it-1}^{*2}\right)^{-1/2}\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\,\hat{e}_{it-1}^{*}\,\Delta\hat{e}_{it}^{*}$$

Group ρ-statistic:

$$\tilde{Z}_\rho = \sum_{i=1}^{N}\left(\sum_{t=1}^{T}\hat{e}_{it-1}^{2}\right)^{-1}\sum_{t=1}^{T}(\hat{e}_{it-1}\Delta\hat{e}_{it} - \hat{\lambda}_i)$$

Group PP-statistic:

$$\tilde{Z}_t = \sum_{i=1}^{N}\left(\hat{\sigma}^2\sum_{t=1}^{T}\hat{e}_{it-1}^{2}\right)^{-1/2}\sum_{t=1}^{T}(\hat{e}_{it-1}\Delta\hat{e}_{it} - \hat{\lambda}_i)$$

Group ADF-statistic:

$$\tilde{Z}_t^* = \sum_{i=1}^{N}\left(\sum_{t=1}^{T}\hat{s}_i^{2}\hat{e}_{it-1}^{*2}\right)^{-1/2}\sum_{t=1}^{T}(\hat{e}_{it-1}^{*}\Delta\hat{e}_{it}^{*})$$

Here, $\hat{e}_{it}$ is the estimated residual from Eq. (4) and $\hat{L}_{11i}^{2}$ is the estimated long-run covariance matrix for $\Delta\hat{e}_{it}$. Similarly, $\hat{\sigma}_i^{\,2}$ and $\hat{s}_i^{\,2}$ ($\hat{s}_i^{\,*2}$) are, respectively, the long-run and contemporaneous variances for individual i. The other terms are properly defined in Pedroni (1999) with the appropriate lag length determined by the Newey–West method. All seven tests are distributed as being standard normal asymptotically. This requires a standardisation based on the moments of the underlying Brownian motion function. The panel m-statistic is a one-sided test where large positive values reject the null of no cointegration. The remaining statistics diverge to negative infinitely, which means that large negative values reject the null. The critical values are also tabulated by Pedroni (1999) (Lee, 2005). In the presence of unit root variables, the effect of superconsistency may not dominate the endogeneity effect of the regressors if OLS is employed. Pedroni (2000) shows how FMOLS can be modified to make an inference in being cointegrated with the heterogeneous dynamic. In the FMOLS setting, non-parametric techniques are exploited to transform the residuals from the cointegration regression and can get rid of nuisance parameters (Lee, 2005).

EMPIRICAL RESULTS AND DISCUSSION

Our study uses annual time series for these countries. Annual data for real GDP (2000=100), though various indicators of world ICT development are reported periodically by International Telecommunication Union, the periodic instability among the most commonly used measurements deter the need to rely on a single superior measure. Moreover, as good as the indicators may appear, the paucity of data in the ICT development in many developing countries poses a serious problem for the adoption of many of the indicators due to limited data availability and comparability. In this reason, different researchers have employed different indicators in their measurement of ICT development. Therefore, the accuracy of a proxy has not been subject to careful statistical scrutiny. Despite these facts, mobile and fixed-line subscribers (per 100 people), were used as a proxy of ICT development for these countries in this study because they are universally measured and a consistent index collected by the international agencies and also, real gross capital formation (2000=100) are obtained from World Development Indicators (World Bank, 2011). The unit is expressed in US dollars. The empirical period depends on the availability of data, where the time period used is 1980–2010. All variables used are in natural logarithms.

Table 1 presents the panel unit root tests. At a 5% significance level, all statistic of the level model confirm that three series have a panel unit root. Using these results, we proceed to test GDP, EC, and K for cointegration in order to determine if there is a long-run relationship to control for in the econometric specification. Table 1, presents the results of the panel unit root test at level indicating that all variables are $I(1)$ in the constant plus time trend of the panel unit root regression. Therefore, we can conclude that most of the variables are non-stationary in with and without time trend specifications at level by applying the Panel unit root test which is also applied for heterogeneous panel to test the series for the presence of a unit root. The results of the panel unit root tests confirm that the variables are non-stationary at level.

We can conclude that the results of panel unit root tests reported in Table1 support the hypothesis of a unit root in all variables across countries, as well as the hypothesis of zero order integration in first differences. At most of the 1 percent significance level, we found that all tests statistics in both with and without trends significantly confirm that all series strongly reject the unit root null. Given the results of IPS test, it is possible to apply panel cointegration method in order to test for the existence of the stable long-run relation among the variables.

We first implement the following equation:

$$GDP_{it} = \alpha_i + \delta_i t + \beta_i ICT_{it} + c_i K_{it} + \varepsilon_{it} \qquad (5)$$

Where it allows for cointegrating vectors of differing magnitudes between countries, as well as country (α) and time (δ) fixed effects. Table 2 reports the panel cointegration estimation results. For the all statistics significantly we cannot reject the null of no cointegration. Thus, it cannot be seen that the GDP, ICT, and K (capital) move together in the long run. That is, there is not a long-run steady state relationship between ICT and GDP for a cross-section of countries. The next step is an estimation of such a relationship.

Table 3 reports the results of the individual and panel FMOLS. The panel estimators with and without common time dummies are shown at the bottom of the table. The coefficients of ICT and K are statistically significant at the 5% level, and the effect is positive as expected by the theory.

The elasticity of ICT and capital stock with respect to GDP are significantly smaller than 1. This implies in short run, ICT is an important ingredient for economic development. The FMOLS estimates of the elasticity of ICT with respect to GDP range from 0.53 (Switzerland) to 0.91 (Sweden). The coefficient of capital stock is positive and statistically significant in all countries; that is, an increase in capital stock tends to promote GDP.

Once the three variables are cointegrated, the next step is to implement the Granger causality test. We use a panel-based error correction model to account for the long-run relationship using the two-step procedure from Engle and Granger (1987). The first step is the estimation of the long-run model for Eq. (5) in order to obtain the estimated residuals,

The second step is to estimate the Granger causality model with a dynamic error correction:

$$\Delta GDP_{it} = \alpha_{1j} + \sum_{i=1}^{k} \beta_{11ik} \Delta GDP_{it-k} + \sum_{i=1}^{k} \beta_{12ik} \Delta ICT_{it-k} + \sum_{i=1}^{k} \beta_{13ik} \Delta K_{it-k} + \delta_{1i} ECT_{it-1} + u_{1it} \quad (6)$$

$$\Delta ICT_{it} = \alpha_{2j} + \sum_{i=1}^{k} \beta_{21ik} \Delta GDP_{it-k} + \sum_{i=1}^{k} \beta_{22ik} \Delta ICT_{it-k} + \sum_{i=1}^{k} \beta_{23ik} \Delta K_{it-k} + \delta_{2i} ECT_{it-1} + u_{1it} \quad (7)$$

where Δ denotes first differencing and k is the lag length and is chosen optimally for each country using a step-down procedure up to a maximum of two lags. The capital stock equations are omitted, because they are not relevant. The sources of causation can be identified by testing for the significance of the coefficients of the dependent variables in Eqs. (6) and (7). First, the short-run effect can be considered transitory. For short-run causality, we can test $H_0\colon \beta_{12ik} = 0$ for all i and k in Eq. (6) or $H_0\colon \beta_{21ik} = 0$ for all i and k in Eq. (7). Next, the long-run causality can be tested by looking at the significance of the speed of adjustmentδ, which is the coefficient of the error correction term, ECT_{it-1}. The significance of k indicates the long-run relationship of the cointegrated process, and so movements along this path can be considered permanent. For long-run causality, we can test $H_0\colon \lambda_{1i} = 0$ for all i in Eq. (6) or $H_0\colon \lambda_{2i} = 0$ for all i in Eq. (7). Finally, we can use the joint test to check for a strong causality test, where variables bear the burden of a short-run adjustment to re-establish a long-run equilibrium, following a shock to the system.

Because all variables enter the model in stationary form, a standard F-test can be used to test the null hypothesis, which shows that none of the estimated country-specific parameters are significant. Table 4 shows the result of a panel causality test between GDP and ICT. We find that the ICT equations are not significant at the 1% level, implying a lack of long-run causalities. In addition, there are short-run causal relationships running from ICT to GDP and vice versa. The uni-directional causality shows that ICT may better in economic growth in developing countries regardless of being transitory or permanent.

CONCLUSIONS

This paper employs data on top 10 economic countries from 1980 to 2010 to examine the causal relationship between GDP and ICT. The panel cointegration and the resulting panel-based error correction models are conducted to answer the question. The full-modified OLS deals with the problem of endogeneity. Our evidence shows results suggesting that there is a short run and long run steady-state relationship between ICT and GDP for a cross-section of countries and vice versa. ICT is found to Granger cause GDP, and vice versa. The results of a bidirectional short-run causal relationship from ICT to GDP show that ICT leads economic growth. Our results support current as well as past changes in ICT that have a significant impact on a change in income in these countries. It is clear for these countries in general that in short run and long run ICT is an important ingredient for economic development.

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Table-1. Panel unit root tests

Variable	LL		IPS		Hadri	
	No time effects	Time fixed effects	No time effects	Time fixed effects	No time effects	Time fixed effects
GDP	-2.69	0.90	-1.32	-1.41	6.70	5.00
K	-2.29	-2.50	-2.29	-2.48	3.36	3.98
ICT	0.61	2.87	0.87	-1.29	5.56	3.70
ΔGDP	-4.85	-8.18	-6.49	-4.92	3.58	4.69
ΔK	-9.93	-8.33	-9.24	-7.62	3.45	21.94
ΔICT	-7.51	-9.54	-7.08	-6.30	0.40	3.73

Δ Denotes first differences. All variables are in natural logarithms.

Data Source: World Development Indicators (2011)

Table-2. Panel cointegration tests

	No time effects	**Time fixed effects**
Panel variance	1.12	1.38
Panel ρ	-1.02	0.73
Panel PP	-1.38	-1.01
Panel ADF	-2.04	-2.89
Group ρ	-0.63	1.47
Group PP	-1.12	-1.19
Group ADF	-2.69	-2.79

Statistics are asymptotically distributed as normal. The variance ratio test is right-sided, while the others are left-sided.

Table-3. Full modified OLS estimates (dependent variable is GDP)

Country groupings	ICT	K
Netherlands	0.78 (6.23)	0.52 (2.21)
Switzerland	0.60 (4.12)	0.49 (1.29)
Denmark	0.84 (5.32)	0.56 (2.29)
Finland	0.88 (4.48)	0.65 (2.63)
New Zealand	0.78 (4.18)	0.57(3.42)
Sweden	0.91 (10.11)	0.64 (3.38)
Norway	0.74 (2.69)	0.60 (2.83)
Canada	0.75 (3.12)	0.70 (3.23)
Germany	0.79 (2.53)	0.68 (2.90)
Australia	0.63 (4.70)	0.50(2.78)
Panel (without time dummies)	0.82 (37.28)	0.85 (13.19)
Panel (with time dummies)	0.72 (28.54)	0.88 (15.24)

Data Source: World Development Indicators (2011)

Table-4. Panel causality tests

Dependent variable	Source of causation (independent variable)				
	Short run		Long run		
	ΔGDP	ΔICT	ε	$\varepsilon/\Delta GDP$	ε/ΔICT
ΔGDP	-	0.00	0.25	-	0.01
ΔICT	0.02	-	0.18	0.04	-

Data Source: World Development Indicators (2011)