EMPIRICAL EVIDENCE OF CAUSALITY BETWEEN INFORMATION COMMUNICATIONS TECHNOLOGY AND ECONOMIC GROWTH IN CHINA, JAPAN AND SOUTH KOREA

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ABSTRACT

This study examines the causal relationship between information and communications technology (ICT) development and economic growth in three of the Northeast Asian countries: China, Japan and South Korea. The Granger causality test is performed following the cointegration approach to reveal the direction of causality between ICT development and economic growth. Test results indicate two things; 1) there is a long-run equilibrium relationship that runs from ICT development to economic growth in South Korea; and 2) a one-way directional causality of growth-led ICT development for China is evidenced. A discussion follows based on the empirical findings.

Keywords: Information and communications technology, infrastructure, economic growth, ICT-led growth hypothesis, Granger causality.

INTRODUCTION

Over the past decade, the development of information and communications technology (ICT) 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, in Northeast Asian countries such as China and South Korea. It has been widely recognized that the advancement of ICT is one of the driving forces of globalization and the rapid growth of the world new economy.

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. 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. It is therefore questionable to generalize from the study of one country to that of the world's largest emerging economies such as China.

This study thus examines a causal relationship between ICT development and economic growth in the three Northeast Asian countries: China, Japan and South Korea. 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.

LITERATURE REVIEW

Many studies have reported that there exists a positive correlation between ICT development and economic growth in the country level. For example, Thompson and Garbacz [1] reported that the development of ICT has a significant positive impact on productivity growth to the world as a whole, but particularly so for developing countries, by improving the efficiency of how these and other resources are used. Kraemer and Dedrick [2] and Dewan and Kraemer [3] reported that there exists a positive correlation between ICT development and economic growth in the Asia-Pacific region. Many studies have also reported that ICT investments contribute positively to economic growth in the country level, for example, in many OECD countries [4] [5] [6].

Many studies have reported that ICT development is one of the main drivers of better economic growth and sustainable economic growth [7] [8] and higher productivity [9] [10] in many developing countries. They reported that ICT development plays an important role in the economic growth of developing countries. Lee, Gholami and Tong [11] reported that ICT development contributes to economic growth in many developed countries and newly industrialized countries, but not in developing countries. For example, many empirical studies supported that there exists a one-way directional causal relationship from ICT development to economic growth in the United States [12] [13], in a group of OECD countries [14] [15] [16] [17]. In addition, many studies argued that there is not much evidence to indicate that ICT development leads to economic growth in developing countries [18], in China [19], in Taiwan [20]. On the contrary, Gordon [21] reported that ICT sector benefits from economic growth. Shiu and Lam [22] reported that there exists a one-way directional causal relationship that runs from economic growth to ICT development in China. The result is consistent with some of the previous studies which have found a limited impact of ICT development on economic growth, in particular, for developing countries [23] [24] [25].

On the other hand, Lam and Shiu [26] reported that there is a bidirectional relationship between ICT development and economic growth for European high-income countries. Many studies reported there exists a bidirectional causal relationship between ICT development and economic growth in South Korea [27]) and in 15 industrialized countries [28]. They found that although causality is generally in both directions, ICT development more strongly precedes the nations' economic growth. Chakraborty and Nandi [29] reported a bidirectional causal relationship, in both the short-run and long-run, between ICT development and economic growth in twelve developing countries in Asia. Munnell [30] and Gramlich [31] also reported a bidirectional relationship between ICT development and economic growth. They found that the effect of ICT development on economic growth is positive and the direction of causation runs from economic growth to ICT development as well.

Since the results of previous studies of the causal relationship between ICT development and economic growth have been mixed, this study suggests that the causal relationship between ICT development and economic growth may not be independent of the level of economic growth and ICT development of countries. Therefore generalizing from the study of one country to other countries should be a significant contribution to the body of literature in this domain. The empirical application of this paper uses the three largest Northeast Asian countries including China, Japan and South Korea, based on data availability and compatibility to test for the validity of the theoretical findings. Accordingly, the following hypotheses are considered:

Hypothesis 1: There is a long-run equilibrium relationship between ICT development and economic growth.

Hypothesis 2: ICT development leads to economic growth.

Hypothesis 3: Economic growth leads to ICT development.

RESEARCH METHODOLOGY

Data

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 the countries in this study because they are universally measured and a consistent index collected by the international agencies and also, their longitudinal data availability corresponds well with that of real Gross Domestic Product (GDP).

The data on real GDP, real exchange rates relative to the US dollar, are used as a proxy of economic growth for the countries in this study. The information of GDP and mobile and fixed-line telephone subscribers (per 100 people) has been obtained from the world development indicators of the World Bank (http://data.worldbank.org/) and has been reported on an annual basis. The yearly time-series of the information were available from 1960 to 2009. To match the time period with ICT development, the GDP was chosen yearly from 1975 to 2009 (35 observations) for this study. Additionally, the two time-series are seasonally unadjusted and, therefore, transformed into a natural log form to minimize any possible distortions of dynamic properties of the data and thus to remove a heteroscedasticity problem from the model initially.

Unit root test

Most of economic time-series data are likely to be non-stationary. If a time-series is found to be non-stationary, a filtering mechanism such as the first difference of the variable can be employed to induce stationarity for univariate model estimation. Augmented Dickey–Fuller [32] and Phillips–Perron [33] tests are carried to test the null hypothesis of a unit root in the level and the first difference of the two variables. As Enders [34] indicated, the Augmented Dickey–Fuller (ADF) test assumes the errors to be independent and to have constant variance, while the Phillips–Perron (PP) test allows for fairly mild assumptions about the distribution of errors.

Results of both ADF and PP tests for stationarity are reported in Table 1. The null hypothesis of a unit root cannot be rejected in the level of the variables, but all null hypothesis of a unit root is rejected in the first difference of the variables. The results in Table 1 unanimously confirm that all variables are integrated of order one *I(1)*. The optimal lag in the ADF test is automatically selected based on the Schwarz Info Criterion (SIC) and the bandwidth for the PP test is selected based on the Newey-West estimator [35] using the Bartlett kernel function, and the numeric values are reported in Table 1.

Table 1. Results of unit root test

Country	ADF t-statistic (lag length)		PP t-statistic (bandwidth)	
	ΔlnGDP	ΔlnICT	ΔlnGDP	ΔlnICT
China	-4.810***(0)	-3.246** (0)	-4.811***(1)	-3.022** (6)
Japan	-3.891***(0)	-3.549** (2)	-3.860***(2)	-5.626***(3)
South Korea	-4.213***(0)	-5.152***(0)	-4.231***(1)	-5.152***(0)

Note: ln denotes the natural logarithm of the variable under consideration. Δ denotes the first difference of the variable under consideration. The test equations were tested by the method of least squares. The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) test equations include an intercept but no time trend. For both the ADF and PP t-statistics, the probability value for rejection of the null hypothesis of a unit root are employed at the 0.01 level (***, p-value < 0.01), the 0.05 level (**, p-value < 0.05) and the 0.1 level (*, p-value < 0.1) based on MacKinnon [36] one-sided p-values.

Cointegration test

According to Granger [37], cointegration means that the two non-stationary variables are integrated in the same order with the stationary of residuals. If the two variables are cointegrated, there exists a force that converges into a long-run equilibrium. In other words, if ICT development and economic growth are cointegrated, there is a force of equilibrium that keeps ICT development and economic growth together in the long-run. There are two test methods to identify the presence of a cointegrating relationship between two variables: (a) the Engle-Granger two-stage single equation method [38] and (b) the Johansen-Juselius cointegration test [39]. The Johansen method has two separate tests, the trace test and the maximum eigenvalue test. The Engle-Granger method obtains only one single cointegration relationship whereas it is possible to obtain more than one cointegration relationship with the Johansen method. Given this, the Engle-Granger method is Ordinary Least Squares (OLS) based test and the Johansen method is a maximum likelihood based test that requires a large sample.

For the Engle-Granger two-stage single-equation method in this study, the Augmented Dickey-Fuller (ADF) test equation includes an intercept but no time trend. The test

equations were tested by the method of least squares. The optimal lags are automatically selected for the ADF test based on the Schwarz Info Criterion (SIC). Based on the residual sequence of the ADF test, the null hypotheses of a unit root cannot be rejected for all countries in the study, except South Korea, which has proven having one cointegrating relationship between ICT development and economic growth in the country. Numeric values of the results of cointegration test by the Engle-Granger method are not reported in this study due to space limitation.

Cheung and Lai [40] reported that the Johansen approach is more efficient than the Engle-Granger method because the maximum likelihood procedure has significantly large and finite sample properties [41]. The Johansen [42] procedure uses two ratio tests: (a) a trace test and (b) a maximum eigenvalue test, to test for a number of cointegration relationships. Both can be used to determine the number of cointegrating vectors present, although they do not always indicate the same number of cointegrating vectors. While doing the Johansen cointegration test, if there arises a different result between trace statistic and maximum eigenvalue statistic, the result of maximum eigenvalue test is preferred in this study due to the benefit of separate tests on each eigenvalue.

The results of the Johansen cointegration test in Table 2 show that the trace statistics and the maximum eigenvalue statistics are smaller than the critical values for China and Japan, except South Korea; therefore, the null hypothesis of no cointegration cannot be rejected at the 5 % significance level for the China and Japan cases.

Table 2. Results of the Johansen cointegration test

	Trace test		Maximum Eigenvalue test	
	r = 0	r ≤ 1	r = 0	r ≤ 1
China	7.922	0.430	7.491	0.430
Japan	13.289	2.200	12.089	2.200
Korea	18.908**	2.472	16.435**	2.472

Note: The test equations were tested by the method of least squares. For the Johansen cointegration test, the assumptions of cointegration test allow for leaner deterministic trend in data include an intercept but no time trend and test VAR. For the both trace and maximum eigenvalue test statistics, the probability value for rejection of the null hypothesis of no cointegration is employed at the 0.05 level (***, p-value < 0.01; **, p-value < 0.05; *, p-value < 0.1) based on the MacKinnon-Haug-Michelis [43] p-values.

The results indicate that there is no cointegration relationship between the two variables at the 0.05 level, except the South Korea case, which the trace statistic and the maximum eigenvalue statistic are greater than the critical values, the null hypothesis of no cointegration can be rejected at the 0.05 level. For the South Korea case, the results indicate the existence of one cointegrating equation between ICT development and economic growth in the country.

Therefore, this study concludes that Hypothesis 1 *"There is a long-run equilibrium relationship between ICT development and economic growth"* is not supported. In other words, there exists no long-run equilibrium between the two variables for the China and Japan cases. In this case the Granger causality test method by an unrestricted VAR model is the best option for testing directional causality of short-run dynamics.

Granger causality test

Engle and Granger [38] note that if two time-series variables are not cointegrated there may be unidirectional or bidirectional Granger causality in the short-run. Short-run causality is determined by test on the joint significance of the lagged explanatory variables, using an F-test or Wald test. The traditional practice in testing the direction of causation between two variables has been to use the standard Granger causality test (i.e. pairwise Granger causality tests for bivariate time-series). As an alternative, the short-run Granger causality can be tested by the Wald test. Under the Wald test, the maximum likelihood estimate of the parameters of interest is compared with the proposed value, with the assumption that the difference between the two will be approximately normal. Typically the square of the difference is compared to a chi-squared distribution. The Block Exogeneity Wald test in the VAR system provides chi-squared statistics of coefficients on the lagged endogenous variables, which are used to interpret the statistical significance of coefficients of the regressors. In this way, Wald test statistics can be used to find out the Granger causal effect on the dependent variable. In the VAR system, Granger causality is done to glimpse the short-run causality running from independent variables to a dependent variable, using asymptotic t-statistics that follow chi-squared distribution instead of F distribution. The hypothesis in this test is that the lagged endogenous variable does not Granger cause the dependent variable. For China and Japan, to answer the question regarding the direction of causation in the short-run, the Granger causality tests by unrestricted VAR models are performed.

Engle and Granger [38] and Granger [37] note that if two variables are cointegrated there always exists a corresponding error correction representation in which the short-run dynamics of the variables in the system are influenced by the

deviation from equilibrium. For the South Korea case, the existence of a long-run equilibrium relationship between ICT development and economic growth implies that the two variables are causally related, at least in one direction. The VECM implies that changes in one variable are a function of the level of disequilibrium in the cointegrating relationship, as well as changes in the other explanatory variable. The VECM is a technique that facilitates to capture both the dynamic and interdependent relationships of the said variables and is a special type of restricted VAR to correct a disequilibrium that may shock the whole system.

The long-run causality is implied through the significance of the t-statistics of the lagged error correction terms. In this case, it estimates the asymptotic variance of the estimator, and then the t-statistics will have asymptotically the standard normal distribution. Therefore, asymptotic t-statistics in this test can be interpreted in the same way as t-statistics, which are used to interpret the statistical significance of coefficients of the lagged error correction terms, which contain the long-run information because it is derived from the long-run cointegrating relationship. The short-run Granger causality can be tested by the Wald test. The Block Exogeneity Wald test in the VECM system provides chi-squared statistics of coefficient on the lagged endogenous variables, which are used to interpret the statistical significance of coefficients of the regressors. In this way, Wald test statistics can be used to find the Granger causal effect on the dependent variable. The hypothesis in this test is that the lagged endogenous variable does not Granger cause the dependent variable.

Table 3. Results of Granger causality tests (Block Exogeneity Wald tests)

	"Y"	ΔlnGDP		ΔlnICT	
Country	Method, "X"	ΔlnICT (H2)	ECT	ΔlnGDP (H3)	ECT
China	VAR	1.699	n.a	6.483**	n.a
Japan	VAR	1.007	n.a	3.416	n.a
South Korea	VECM	0.427	3.449**	0.786	1.156

Note: The coefficients of regressors have been estimated by VAR or VECM. Numbers in the cells of the independent variable ("X") are chi-square statistics and numbers in the cells of ECT are asymptotic t-statistics, which are used to interpret the statistical significance of the parameters. The probability value for rejection of the null hypothesis is employed at the 1% significant level (***, p-value < 0.01), the 5% significant level (**, p-value < 0.05) and the 10% significant level (*, p-value < 0.1).

Table 3 displays the results of Granger causality tests with annual data. The null hypothesis regarding no causation leading from ICT development to economic growth in the short-run cannot be rejected for all the three countries. The null hypothesis regarding no causation leading from economic growth to ICT development in the short-run can be rejected only for China at the 5% significance level. The results are consistent with different lag selections, but the numeric values of the results of different lag selections are not reported in this study. Considering the results of the Granger causality test in Table 3, this study concludes that Hypothesis 2 *"ICT development leads to economic growth"* is not supported for all the three countries in this study. Hypothesis 3 *"Economic growth leads to ICT development"* is supported only for the China case. In other words, due to the presence of one-way directional causal relationship from economic growth to ICT development for China this finding suggests that economic growth leads to ICT development in China.

DISCUSSION AND CONCLUSION

Unlike the empirical findings of the previous studies, the Granger causality test in this study does not support the hypothesis of ICT-led economic growth in the short-run for all the three countries in this study. Given that China, Japan and South Korea have been showing relatively export-led growth economies, in terms of ratios of economic growth compared to that of ICT development; it is rational to believe that the ICT development of such countries is strongly affected by the industrial structures in such conditions. The results of this study also find a one-way causal relationship from economic growth to ICT development for China. Some of the possible reasons why the growth-led ICT development hypothesis is true for China are that economic development would be beneficial for ICT development in China and ICT development is strongly affected by growth of the Chinese economy in such conditions.

Considering that the findings of this empirical study differ among the three countries, the inconsistent results may indeed be a reflection of the specific countries' stage of economic development. Because countries could be different in terms of both the weight of the ICT industry in the overall economy and the size and openness of the economy, therefore the ICT-led growth hypothesis could also differ from one country to another. The diverse relationships between ICT development and economic growth

in different country settings found in existing empirical studies further support that country-specific conditions influence the results. Therefore, a careful empirical analysis is desirable for any country that may want to focus on the ICT industry as part of its national economic development strategy. The analysis will verify if the common notion that the ICT-led growth is in fact applicable to that particular country. Based on the results of this study, decisions on the ICT-led economic growth strategy can be adjusted or altered for such factors as the overall ICT investments and ICT infrastructure budget, approval of private or governmental ICT projects, and so forth.

In sum, the results of the causality test can help the government set priorities regarding where and how to use limited resources for national economic growth. If empirical results support the ICT-led growth hypothesis in the short-run, more resources should be allocated to the nation's ICT industry as a priority rather than to other sectors. This allocation of resources is appropriate in the case of South Korea since ICT-boosting policies as a means of economic growth will be fully effective in the long-run. If an economic growth-led ICT development holds true, the government should allocate resources to leading industries and not to ICT directly so that the overall economy will be improved and the ICT industry will benefit from economic growth, which is appropriate in the case of China.

To detect the causal relationship, this study performed Granger causality tests following the cointegration approach, which has been the typical method favored in studies of this kind. The current study discovered mixed results between ICT development and economic growth in the three Northeast Asian countries. Note that empirical results on the causal relationship between the two variables have been inconsistent in the past. The mixed results indicate that the direction of causality between ICT development and economic growth may be determined by various factors of the country. In conclusion, factors for each country such as the degree of dependence on the ICT industry, the usage of ICT and the level of economic development may each be considered individually as important determinants.

The mixed results of this study further point to several research directions for the future. First, the simple bivariate VAR and VECM models were used in this study. The important and critical roles that other microeconomic factors play in model specifications were not fully considered. This can be improved by adopting an approach of using multivariate Granger causality tests to include important variables such as foreign direct investment, exports and some socio-economic factors. Second, the limitations of this study may be related to data availability. Instead of using a series of mobile and fixed-line telephone subscribers (per 100 people) information, the more accurate measure of ICT development generated from economic impact data, so called credible instruments, will produce more precise causal relations.

REFERENCES

[1] Thompson Jr., H.G. & Garbacz, C. "Mobile, fixed line and Internet service effects on global productive efficiency," *Information Economics and Policy*, 2007, 19(2), 189-214.

[2] Kraemer, K.L. & Dedrick, J. "Payoffs from investment in information technology: lessons from the ASIA-PACIFIC region," *World Development*, 1994, 22(12), 1921–1931.

[3] Dewan, S. & Kraemer, K.L. "International dimensions of the productivity paradox," *Communications of the ACM*, 1998, 41(8), 56–62.

[4] Colecchia, A. & Schreyer, P. "ICT investment and economic growth in the 1990s: Is the United States a unique case? A comparative study of nine OECD countries," *Review of Economic Dynamics*, 2002, 5(2), 408-442.

[5] Oliner, S.D. & Sichel, D. "The resurgence of growth in the late 1990s: Is information technology the story?," *Journal of Economic Perspectives*, 2000, 14, 3–22.

[6] Whelan, K. "Computers, obsolescence, and productivity," *Review of Economics and Statistics*, 2002, 84, 445–461.

[7] Daveri, F. & Silva, O. "Not only Nokia: what Finland tells us about new economy growth," *Economic Policy*, 2004, 19(38), 117-163.

[8] Lipsey, R.G. & Carlaw, K.I. "Total factor productivity and the measurement of technological change," *Canadian Journal of Economics*, 2004, 37(4), 1118 -1150.

[9] Laursen, K. "New and old economy: the role of ICT in structural change and economic dynamics," *Structural Change and Economic Dynamics*, 2004, 15(3), 241-243.

[10] Plepys, A. "Sustainability in the information society: The grey side of ICT," *Environmental Impact Assessment Review*, 2002, 22(5), 509-523.

[11] Lee, S-Y.T., Gholami, R. & Tong, T.Y. "Time series analysis in the assessment of ICT impact at the aggregate level – lessons and implications for the new economy," *Information & Management*, 2005, 42(7), 1009-1022.

[12] Duggal, V., Saltzman, C. & Klein, L. "Infrastructure and productivity: An extension to private infrastructure and IT productivity," *Journal of Econometrics*, 2007, 140(2), 485–502.

[13] Greenstein, S.M. & Spiller, P.T. "Modern telecommunications infrastructure and economic activity: An empirical investigation," *Industrial and Corporate Change*, 1995, 4(4), 647–665.

[14] Datta, A. & Agarwal, S. "Telecommunications and economic growth: A panel data approach," *Applied Economics*, 2004, 36(15), 1649–1654.
[15] Koutroumpis, P. "The economic impact of broadband on growth: A simultaneous approach," *Telecommunications Policy*, 2009, 33(9), 471-485.
[16] Röller, L-H. & Waverman, L. "The impact of telecommunications infrastructure on economic development," In Peter Howitt (Ed.), *The implications of knowledge-based growth for microeconomic policies* (pp. 363-387). Calgary: University of Calgary Press. 1996.
[17] Röller, L-H. & Waverman, L. "Telecommunications infrastructure and economic development: a simultaneous approach," *American Economic Review*, 2001, 91(4), 909–923.
[18] Avgerou, C. "How can IT enable economic growth in developing countries?," *Information Technology for Development*, 1998, 8(1), 15-28.
[19] Meng, Q. & Li, M. "New economy and ICT development in China," *Information Economics and Policy*, 2002, 14(2), 275-295.
[20] Wang, E.H.H. "ICT and economic development in Taiwan: analysis of the evidence," *Telecommunications Policy*, 1999, 23(3-4), 235-243.
[21] Gordon, R. "Does the "new economy" measure up to the great inventions of the past?," *Journal of Economic Perspectives*, 2000, 14, 49–74.
[22] Shiu, A. & Lam, P.L. "Causal relationship between telecommunications and economic growth in China and its regions," *Regional Studies*, 2008, 42, 705–718.
[23] Dewan, S. & Kraemer, K.L. "Information technology and productivity: Evidence from country-level data," *Management Science*, 2000, 46, 548–562.
[24] Jalava, J. & Pohjola, M. "Economic growth in the new economy: Evidence from advanced economies," *Information Economics and Policy*, 2002, 14(2), 189-210.
[25] Kenny, C. "The Internet and economic growth in less-developed countries: A case of managing expectations?," *Oxford Development Studies*, 2003, 31, 99–113.
[26] Lam, P-L. & Shiu, A. "Economic growth, telecommunications development and productivity growth of the telecommunications sector: Evidence around the world," *Telecommunications Policy*, 2010, 34(4), 185-199.
[27] Yoo, S-H. & Kwak, S-J. "Information technology and economic development in Korea: A causality study," *International Journal of Technology Management*, 2004, 27, 57–67.
[28] Dutta, A. "Telecommunications and economic activity: An analysis of Granger causality," *Journal of Management Information Systems*, 2001, 17, 71–95.
[29] Chakraborty, C. & Nandi, B. "Privatization, telecommunications and growth in selected Asian countries: An econometric analysis," *Communications and Strategies*, 2003, 52, 31–47.
[30] Munnell, A.H. "Policy watch: Infrastructure investment and economic growth," *The Journal of Economic Perspectives*, 1992, 6(4), 189–198.
[31] Gramlich, E.M. "Infrastructure investment: A review essay," *Journal of Economic Literature*, 1994, 32(3), 1176–1196.
[32] Dickey, D.A. & Fuller, W.A. "Likelihood ratio statistics for autoregressive time series with a unit root," *Econometrica*, 1981, 49(4), 1057–1071.
[33] Phillips, P. & Perron, P. "Testing for a unit root in time series regression," *Biometrica*, 1988, 75(2), 335–346.
[34] Enders, W. *Applied econometric time series* (2nd Ed.). New York: Wiley. 2004.
[35] Newey, W. & West, K. "Automatic lag selection in covariance matrix estimation," *Review of Economic Studies*, 1994, 61, 631-653.
[36] Mackinnon, J.G. "Numerical distribution functions for unit root and co-integration tests," *Journal of Applied Econometrics*, 1996, 11, 601-618.
[37] Granger, C.W.J. (1988). "Some recent developments in a concept of causality," *Journal of Econometrics*, 1988, 39, 199–211.
[38] Engle, R.F. & Granger, C.W.J. "Cointegration and error correction: representation, estimation and testing," *Econometrica*, 55, 251–276.
[39] Johansen, S., & Juselius, K. (1990). "Maximum likelihood estimation and inference on co-integration with application to the demand for money," *Oxford Bulletin of Economics and Statistics*, 1990, 52, 169–221.
[40] Cheung, Y.W. & Lai, K.S. "Finite-sample sizes of Johansen's likelihood ratio tests for cointegration," *Oxford Bulletin of Economics and Statistics*, 55, 313–328.
[41] Gonzalo, J. "Comparison of five alternative methods of estimating long-run equilibrium relationship," *Journal of Econometrics*, 1994, 60, 203–233.
[42] Johansen, S. "Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models," *Econometrica*, 1991, 59, 1551–1580.
[43] Mackinnon, J.G., Haug, A.A. & Michelis, L. "Numerical distribution functions of likelihood ratio tests for co-integration," *Journal of Applied Econometrics*, 1999, 14, 563-577.