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Empirical Inspection of Broadband Growth Nexus: A Fixed Effect with Driscoll and Kraay Standard Errors Approach

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Abstract

Broadband has become an integral part of digital infrastructure of countries around the globe even in developing regions. Accordingly, this paper investigates the broadband growth nexus for 24 Asian countries for period 2001-2011. Using fixed effects with Driscoll and Kraay standard errors, the effect of broadband on economic growth is found positive. Recommendations include the policy step to bring the skills of human capital in these countries at par with developed countries that have benefitted substantially from broadband technology.

Keywords: broadband, economic growth, fixed effects estimation, digital infrastructure, Asian region.

1. Introduction

Time has brought much technological advancement that has reshaped our socio-economic lives. One of the technological advancements that brought a significant breakthrough in the field of information technology (IT) is the introduction of high speed internet viz.: broadband. Since it got commercialized from late 90s fast generation and dissemination of large batches of information and ideas to markets have become possible. Later, the scope of broadband has been upgraded from an advanced technology to an enabler of structural change in the economy via its increasing effects on sectors and industries. Broadly speaking, there are two types of effects that accrue from broadband technology. One is the direct effect that results from the investment in broadband technology and from the rolling out the infrastructure of its coverage. Second indirect effect is that comes from impact of broad band on factors driving growth such as competition, innovation, efficiency and globalization. Broadband has hotfooted the development of technologically advanced goods and services. It can be termed as the life blood of

services based knowledge economy. Digital services like e-health, e-commerce and e-banking etc. are a few promising instances of its catalytic effects on other sectors of economy. Accordingly, this research paper assesses the role of broadband in determining the economic growth in Asian region.

2. Objectives of the Research

This research aims the empirical scrutiny of impact of broadband and economic growth for a panel of selected Asian countries. Accordingly, the hypothesis is built as follows:

- H_1 **:** *There is positive relationship between broadband and economic growth in selected Asian countries*

A brief review of literature on broadband and economic growth relationship is furnished as follows.

3. Literature Review

Research on Information technology impact on economic growth has been in fashion since 1987's Solow's Paradox, but the research on advanced IT (broadband) started during 1990's. For instance, the study by Lehret al. (2006) is one of the initial researches to focus on the topic. He notes that broadband technologies are new and continue to evolve. His study particularly focused on broadband impact on the communities of US. Continuing research in similar veins, Crandall and Jackson (2002) tried to quantify the broadband technologies to economic growth.

Support for the positive association between broadband and economic performance is also found in Rappoport, Kridel & Taylor (2002).A comparison can be made between telecommunications and broadband industry from the researches Aschauer (1989), Alicia (1992) & Edward (1994). As per their findings, the telecommunications industry is primarily affected by the infrastructure while the important spillovers of broadband networks result in externalities in the other sectors of the economy.

Deployment of broadband in Korea positively affects economic performance as Lee, Ho and Shim (2005) conduct empirical analysis for Korea. Duggal, Saltzkan & Klein (2007) used non-linear production function to estimate IT contribution to growth. This may seem a gross exaggeration but this held true for the Korean economy, as it was in a state of recession and an investment in IT sector contributed positively to lift the economy.

For Asian region, Mehmood & Siddiqui (2013) inspected the long-run link between economic growth and investment in telecommunication for 1990-2010. The statistical methodology included panel unit root (Levin, et al., 2002; Im, et al., 2003, and Maddala and Wu, 1999) and panel cointegration tests (Pedroni, 1997, 1999). Using these sophisticated tools, they find lack of causality from GDP per capita to investment in telecom. They suggest that improvement in macroeconomic performance does not inevitably raise the level of investment in telecom sector only. In addition, an empirical study that investigates the role of ICT as a cause of economic convergence is found in Mehmood & Azim (2013). Besides ICT, demographic features, electricity consumption and human development are included to complete the regression. Authors chose System GMM estimator to estimate convergence for time period 2001-2010. Their findings reveal significant role of ICT in bringing about economic convergence. Support is also found for demographic features, electricity consumption and human development as contributors to economic convergence.

Comprehension of these studies highlights the gap in ICT (broadband)-growth nexus literature from Asian perspective. It is so despite the fact that data on Broadband is now available to a good extent and a few Asian countries have become leading users of broadband technology as well. Therefore, this paper tries to fill this gap in broadband-growth literature.

4. Theoretical Considerations

As per 'The Broadband Commission 'broadband is a high speed internet connection that is characterized by: '***always-on*** service' (not needing to make a new connection to a server each time a user wants to go online), and '***high-capacity'***: able to carry lots of data per second, rather than the particular arrival speed of the data. The practical result is that broadband enables the '***combined provision'*** of voice, data and video at the same time. From an economic point of view, it enables to instantaneous flow of economically meaningful information. Internet and computers are most common examples of 'General purpose technologies' GPTs. Distinguishing feature of GPT's is that they have multiple uses and can create spillovers to increase productivity of those firms causing a spur in inventions and innovations. Broadband does not only acts as a facilitator of innovation but also has an influence on firms' operations and processes.

The ICTs in many studies have expected to show an improvement in operational efficiencies and productivity gains within a firm (Shideler, Badasyan & Taylor, 2007; Breznik, 2012).Broadband allows for a greater geographical mobility for consumers and factors of production and allows for competitive prices and optimum allocation of resources in the global market over a wider range of possible locations.

Robert Solow (1956) contributed to growth empirics by developing a production function with 'residual – exogenous factor of technology'. However later studies tried to unravel the exogenous part into endogenous such as Romer (1994). Accordingly, both models consider technical change as a determinant of innovation which in term depends on expenditure on research and development ultimately leading to economic growth. Following researches affirm the same (Bar & Riis, 2000; Czernich et al., 2009; Brynjolfsson & Saunders, 2010 and Benkler, 2006).

5. Relationship between Broadband and Economic Growth

The importance of the information and communication technologies (ICT) for economic development has been widely acknowledged, after the controversy raised by Solow in 1987, also known as IT paradox. This research, however, focuses on only on broadband, one of the major components of ICT.

4.1 Estimable Model

In order to conduct empirical estimation of relationship between the variables we develop a function as follows:

$$GDY = f(BBS, FDI, SERT, POP, GVEX, TRD) \quad \ldots\ldots\ldots\ldots (1)$$

Here economic growth measured by the gross domestic income (GDY) in constant dollar, which is a function of broadband subscribers(BBS) and other control variables like foreign direct investment(FDI), tertiary school enrolment ratio (SERT), population (POP),government expenditure (GVEX) and trade openness (TRD) which are expected to be linked to economic growth.

Econometric specification of this function is as follows:

$$\ln(GDY_{i,t}) = \mu_i + \delta_t + \beta_1 \ln(BBS_{i,t}) + \beta_2 FDI_{i,t} + \beta_3 \ln(SERT_{i,t}) + \beta_4 \ln(POP_{i,t}) + \beta_5 \ln(GVEX_{i,t}) + \beta_6 \ln(TRD_{i,t}) + \varepsilon_{i,t} \quad \text{(1.e)}$$

Where number of observations: n = N × T (number of groups × temporal observations) ∀i ∈[1,N] and ∀ t∈[1,T]. $\boldsymbol{\mu_i}$ and $\boldsymbol{\delta_t}$ capture the unobserved country-specific effects and time-specific effects, respectively, and $\boldsymbol{\varepsilon_{i,t}}$ is the error term and is assumed to be i.i.d. null mean and variance equal to σ_ε^2.

4.2 Panel Data Estimation

For estimation of the panel dataset, following sequence of tests is followed in subsections below.

5.1Test for Multi-Collinearity

First econometric concern is to check the existence of multi-collinearity among the independent variables. As a general rule, if the variance inflation factors (VIFs) of variables exceed 10, which usually happen when R^2 exceeds 0.90, it shows the existence of severe multi-collinearity. VIF of the explanatory variables reported in the Table 1 are lower (less than 4.2) than the threshold level and thus it is less likely to have multi-collinearity in our estimation.

If there is heterogeneity among the countries (different characteristics like social and cultural behaviors etc.)OLS shall be incomplete specification and fixed/random effects model should be estimated. Following two tests are instrumental in making suitable estimation technique for panel data analysis.

5.2 Breusch and Pagan Lagrangian Multiplier Test for Random Effects or OLS

This post-estimation test helps in choosing between random effects regression and a simple OLS regression. The null hypothesis in the LM test is that variances across countries (σ_μ^2) is zero orno panel effect (significant difference across countries) exists. Here the significance of χ^2 indicates the presence of panel (fixed or random) effects.

5.3 Hausman Test

This post-estimation test allows choosing between fixed or random effects model. The results of both approaches have been estimated and then subjected to this test. The criteria for selecting the better of the two effects is comparison of probability value i.e. if p-value is less than 1%, 5% and 10% then fixed effects model is better specification for panel data estimation. The probability value of $\chi^2$is less than 0.05 which implies the test is significant and H_o is rejected and fixed (systematic) effects model is more suitable. Three tests in subsections 5.1, 5.2 and 5.3 are tabulated as follows:

<table>
<tr><th colspan="7">Table 1: Tests for Panel Data Estimation Technique</th></tr>
<tr><th colspan="3">Test for Multi-collinearity</th><th colspan="4">Schematic Selection of Panel Data Estimation Technique</th></tr>
<tr><td>Variable</td><td>VIF</td><td>1/VIF</td><td colspan="2" rowspan="2">Breusch-Pagan Lagrange multiplier (LM)</td><td colspan="2" rowspan="2">Hausman Test: Choice between Fixed or Random Effects</td></tr>
<tr><td>GVEX</td><td>4.19</td><td>0.238</td></tr>
<tr><td>BBS</td><td>3.36</td><td>0.297</td><td colspan="2" rowspan="3">[H_o: $\sigma_u^2 = 0$]
Null Hypothesis: No panel effect.</td><td colspan="2" rowspan="3">Hypothesis:
H_o: Difference in coefficients not systematic.
H_A: Difference in coefficients systematic.</td></tr>
<tr><td>SERT</td><td>2.04</td><td>0.490</td></tr>
<tr><td>TRD</td><td>1.99</td><td>0.503</td></tr>
<tr><td>POP</td><td>1.38</td><td>0.725</td><td>$\chi^2(01)$</td><td>869.42</td><td>Value</td><td>Decision</td></tr>
<tr><td>FDI</td><td>1.25</td><td>0.800</td><td rowspan="2">p-val > F</td><td rowspan="2">0.000</td><td rowspan="2">p-val>χ^2 = 0.000</td><td rowspan="2">Since p-val>χ^2> 0.05 as well as 0.01 fixed effects is preferred</td></tr>
<tr><td>Mean VIF</td><td>2.37</td><td>-</td></tr>
<tr><td colspan="3">STATA 12.0 VIF command</td><td colspan="2">STATA 12.0 xttest0 command</td><td colspan="2">STATA 12.0 xtreg and Hausman commands</td></tr>
</table>

On being affirmed about the estimation technique for panel data, the model established in subsection 4.1 is estimated and its results are tabulated and interpreted as under:

Table 2: Regression Model Estimations				
Dependent Variable is LGDY				
Regressors	**I**		**II**	
	Fixed Effects Estimation (Ordinary Least Square, OLS)		**Fixed Effects Estimation with Driscoll and Kraay standard errors**	
	Coefficient	**p-value**	**Coefficient**	**p-value**
Broadband Subscribers (BBS)	0.0500 (0.0039)	0.000	0.0499 (0.0066)	0.000
Foreign Direct Investment, in-flows (FDI)	0.0001 (0.0010)	0.903	0.0001 (0.0005)	0.897
Tertiary School Enrollment Ratio (SERT)	0.0800 (0.319)	0.981	0.0811 (0.0218)	0.872
Population (POP)	0.2900 (0.0834)	0.001	0.2901 (0.0795)	0.002
Government Expenditure (GVEX)	0.2409 (0.0389)	0.000	0.2410 (0.0570)	0.003
Trade Openness (TRD)	-0.0017 (0.0346)	0.960	-0.0020 (0.0312)	0.782
C	6.4117 (0.5013)	0.000	6.4117 (0.6262)	0.000
	R^2	0.755	R^2	0.834
	Adjusted R^2	0.749	Adjusted R^2	0.830
	F(6, 234)	196.33	Wald $\chi^2(6)$	1379.34
	p-val> F	0.000	p-val>χ^2	0.000
Model Specification Tests	Ramsey Test H_o**:** Model has no omitted variables		F(3, 109) = 112.16	p-val> F = 0.124
	linktest **(**Single-equation estimation**)**		_hat	p-val =0.196> 0.000
			_hatsq	p-val = 0.085> 0.000
Commands in STATA 12.0	xtreg [, fe]		xtscc [, fe]	

Notes:

i. Parentheses contain standard errors.

ii. Commands in STATA 12.0 **xtreg [, fe]** for Fixed Effects Estimation (Ordinary Least Square, OLS) **xtscc [, fe]** for Fixed Effects Estimation with Driscoll and Kraay standard errors.

5.4 Fixed Effects Estimates

In the estimates of fixed effects model (column I in table 2) broadband subscribers, population and government expenditures are statistically significant at 1% level of significance, while foreign direct investment, tertiary school enrollment ratio, and trade openness are not. A 10% increase in broadband penetration will lead to an increase in economic growth by 0.5%. 10% increase in tertiary school enrollment ratio, population, government expenditure shall lead to 0.8%, 2.9% and 2.4% increase in national income, respectively. These findings are in lines with standard theory and empirical literature.

An equal increase in trade openness shall decrease national income by 0.017%. Such indications are found in Dowrick and Golley (2004) who find that greater trade openness has a negative relation on income and growth in low income countries. Though in our sample not all countries are low income countries, but most are developing ones. 10 units increase in foreign direct investment shall increase national income by 0.1 units. R^2 is 0.755 showing that 75% of variation in the dependent variable is explained by explanatory variables and the remaining by variables not included in the model. For testing model specification, Ramsey test for possibility of omitted variables and link test for single equation model, are applied. Both Ramsey test statistic and estimated hat-square in link test are insignificant, implying correct specification of the model.

5.4.1 Test for Serial Correlation

Serial correlation in case of micro panels (with years less than 20) is usually not expected. In technical terms, serial correlation renders standard errors of coefficients smaller than their actual values and inflates R^2. This study deals with micro panel data ($t = 13 > 20$), this mitigates the likeliness of serial correlation test. But for the sake of exactness, test is applied. Interestingly, statistic in table 3 show that null hypothesis is rejected (p-value < 0.05 & p-value < 0.01) and it can be inferred that there is serial correlation among residuals. Consequently, OLS coefficients are likely to be biased, inconsistent and inefficient.

5.4.2 Test for Heteroskedasticity

The error term ε can be heteroskedastic if variance of the conditional distribution of ε_i given X_i [$var(\varepsilon_i|X_i)$] is non-constant for i = 1, 2,…, n, and specifically does not depend on X; else, ε ishomoscedastic." Heteroskedasticity can result in wrong estimates of standard errors for coefficients and hence of their t-values. While the estimates of OLS might not be biased in this case, standard errors do become wrong. Results show that null hypothesis is rejected (p-val < 0.05) and it can be concluded that residuals are not homogeneous. Consequently, the estimates of standard errors for coefficients and therefore their t-values are unlikely to be correct. Tests in subsections 5.4.1 and 5.4.2 are tabulated as follows:

Table 3: Tests for Serial Correlation and Heteroskedasticity in Fixed Effects Regression			
Wooldridge Test for Serial Correlation		**Modified Wald Test for Group Wise Heteroskedasticity**	
Wooldridge Test		**Modified Wald Test**	
H_o: No First Order Serial Correlation		$H_o: \sigma_i^2 = \sigma^2$ for all *i*	
F(1, 23)	537.061	χ^2 (24)	1594.96
p-val > F	0.000	p-val> χ^2	0.000
STATA 12.0 xtserial command		STATA 12.0 xttest3 command	

5.5 Fixed Effects Estimates with Driscoll and Kraay Standard Errors

Results of Wooldridge test for serial correlation and Modified Wald test for group-wise Heteroskedasticity call for the fixed effects regression with Driscoll and Kraay standard errors (S.E) as in column II in table 2. For a recent application see Mehmood, Shahid & Ahsan (2013). The error structure is supposed to be heteroskedastic, autocorrelated up to some lag and possibly correlated between the countries. The results reveal no upsetting change in results of fixed effects estimates and their statistical significance. However, R^2 has increased by 10.464%. The command in STATA for this variant of fixed effects regression is 'xtscc'. Under this program, the individual fixed-effects estimator is applied in two steps. Firstly, all variables $z_{it} \in \{y_{it}, x_{it}\}$ are within transformed using xtreg.

$$\ddot{z}_{it} = z_{it} - \bar{z}_{it} + \bar{\bar{z}}$$

$$\bar{z}_i = T_i^{-1} \sum_{t=t_{i1}} z_{it}$$

$$\bar{\bar{z}} = (\sum T_i)^{-1} \sum_i \sum_t z_{it}$$

It is known that within-estimator relates to OLS estimator of:

$$\ddot{y}_{it} = \ddot{x}_{it}'\theta + \ddot{\varepsilon}_{it}$$

Secondly, this regression is estimated by pooled OLS estimation with Driscoll and Kraay standard errors.

Furthermore broadband shows a positive relationship with economic growth and this finding is corroborated by studies of Lehr (2006) and Koutroumpis (2009). Trade and secondary school enrollment ratio have negative impact on economic performance. These results are realistic since in most of these Asian countries, the terms of trade are unfavorable and the quality of education suffers to an extent that it lacks the ability to contribute to economic performance. Rather it becomes a burden and appears with a negative coefficient.

6. Conclusion

It can be safely concluded from this research that there is a positive association between broadband and economic growth in Asian countries. This relationship is weak that is likely due to the abundance of developing countries in sample. Countries like Japan and India etc. that are at advanced stage of broadband adoption are a few. ICT policy can play an important role in attracting local and foreign investment. But the propitiation of negative aspects will be far less. Being a developing country there is strong need to expand the framework of broadband as there are great opportunities in this sector.

Currently there are many areas that are still un-explored in the field this sector which needs to be flourish. In particular, there needs to be greater focus on the role of broadband in supporting progress in developing countries and economies in transition. There are several indicators regarding internet technology and their influence on economic performance which are very significant and the need to be addressed. In broadband policy making all the stakeholders should be involved so the development network should be free of possible hazards.

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