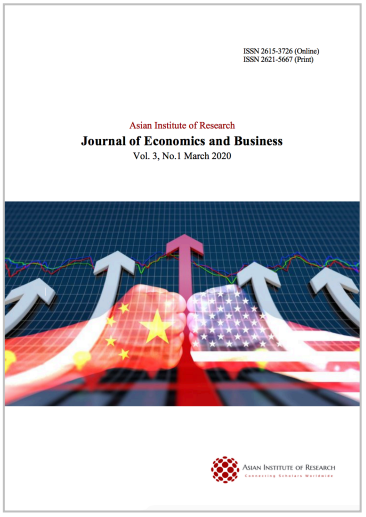

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The Cointegration Relationship and Causal Link of Internet Penetration and Broadband Subscription on Economic Growth: Evidence from ASEAN Countries

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Abstract
This study explores the cointegration relationship and causal link of internet penetration and broadband subscription to economic growth from the 10 countries of ASEAN for the period 2000-2016. A pooled multiple regression model with GDP growth as a function of internet penetration and broadband subscription was developed. The Johansen-Fisher panel cointegration was applied to determine the presence of a long-run equilibrium relationship among the three variables and the direction of causality was identified by estimating the panel-based vector error correction model (VECM). Results from cointegration test indicate a long run equilibrium relationship between internet penetration, broadband subscription and economic growth. The causality test reveals there is long run causality running from internet penetration and broadband subscription to economic growth. In the short-run, broadband subscription causes economic growth in the ASEAN countries. However, internet penetration has no causal link with economic growth in the short-run during the period 2000-2016. The findings are supportive of the claim that internet penetration and broadband connections are engine of economic growth and are rapidly transforming ASEAN economies. Based on these findings, this study recommends that ASEAN governments should be supportive on policies that promotes better internet and broadband infrastructure to achieved short and long-run economic growth.

Keywords: ASEAN, Broadband Subscription, Causality, Economic Growth, Internet Penetration, Panel Cointegration

1. Introduction

Modern theories of endogenous growth acknowledge that adoption of new technologies (i.e., digital technologies) enhance the innovative capacities of the economy through knowledge spillover, development of new products and processes, and business models to promote growth. Thus, the dramatic expansion of digital technologies has facilitated searching, matching, and sharing of information and contributed to greater organization and collaboration among economic agents—influencing how firms operate, people seek opportunities, and citizens

interact with their governments (Benhabib & Spiegel, 2005; World Bank, 2016; Kelly, Liaplina, Tan, & Winkler, 2017).

In particular, internet penetration and broadband subscription have vast potential for inclusive growth and socio-economic development because they increase productivity and contribute to the overall economic growth by connecting remote areas to markets, promoting access to social services, expanding educational opportunities, establishing platforms for innovation and enabling people's access to government services (Choi & Yi, 2009; Elgin, 2013; Zhang, 2013). During the 2000-2016 period, ASEAN countries have adopted policies that have led to the massive growth of the use of the internet in their countries. Governments of ASEAN have recognized the significant growth potential of the internet along with other ICT infrastructure (i.e., broadband) to their economies. Given the diversity of economic growth around ASEAN, perhaps it is not surprising that internet penetration and broadband subscription isn't evenly distributed across the region (see Figure 1).

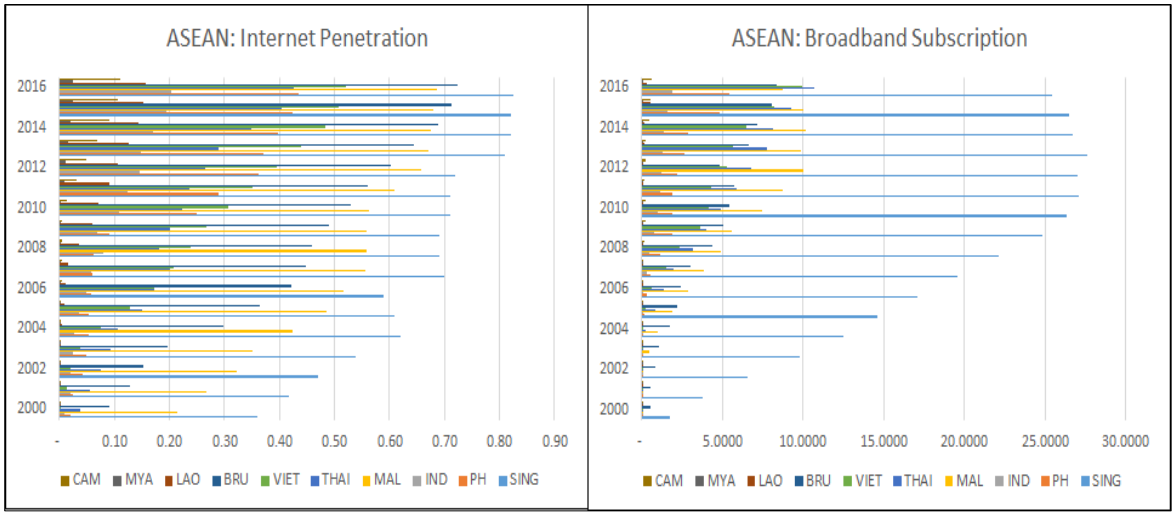

Figure 1. Digital Divide within ASEAN

ASEAN has to work harder to erase the digital divide and raise its game across the board to enhance intra-regional connectivity. The risk of a widening digital divide within ASEAN can undermine plans to turn the digital economy into an engine of growth. Thus, this study explores the cointegration relationship and causal link of internet penetration and broadband subscription to economic growth from the 10 countries of ASEAN for the period 2000-2016.

2. Method

This study used dataset of 10 ASEAN member countries for the period 2000 to 2016. The core variables used in the study were real GDP growth rate (%), internet penetration (% of population) and fixed broadband subscription (per 100 people). Data for these variables were obtained from the World Development Indicators (WDI) by the World Bank.

2.1. Panel Pooled Multiple Regression Model

A pooled multiple regression model with GDP growth (GDPGRW) as a function of internet penetration (IPEN) and fixed broadband subscription (BROAD) was developed. Thus, the economic growth equation in functional form is:

$$GDPGRW = f(IPEN, BROAD) \quad \begin{matrix}(+) & (+)\end{matrix} \qquad (1)$$

where:
GDPGRW = real GDP growth rate (%)
IPEN = internet penetration (% of population)
BROAD = fixed broadband subscription (per 100 people)

Intuitively, the above functional model means that economic growth is driven by internet penetration (IPEN) and broadband subscription (BROAD). Internet penetration and broadband subscription allows the generation and distribution of decentralized information and ideas in markets increasingly relying in information as an input. In light of this, economic growth is accelerated by facilitating the development and adoption of innovation processes. Internet and broadband subscription may accelerate the distribution of ideas and information and foster competition for and development of new products, processes, and business models, thereby further promoting long-run economic growth. In its stochastic form, it can be mathematically expressed as follows:

$$GDPGRW_{it} = \alpha_0+\alpha_1 IPEN_{it}+\alpha_2 BROAD_{it}+\varepsilon_{it} \quad (2)$$

where:
α_0, α_1, and α_2 = parameter estimates
ε_{it} = error term

The subscripts *i* and *t* represent ASEAN country (*i* = 1...10) and time period (2000-2016), respectively. The standard procedures required us to conduct panel unit root test, panel cointgration test, panel vector error correction model and Wald test.

2.2. Unit Root Test

This study uses the more reliable and well-behaved panel unit root tests such as those developed by Levin, Lin & Chu (2002) and Im, Pesaran & Shin (2003). An alternative approach to panel unit root tests applied in this study are the ADF (augmented Dickey-Fuller)-Fisher and ADF-PP (Philipps-Perron) to ensure comparison and validation of results with a view to further create consistency (Demetriades & Fielding, 2012).

2.3. Johansen-Fisher Panel Cointegration

Where the unit root test gives variables that are of order one integration I(1), then cointegration analysis was applied to determine the presence of a long-run equilibrium relationship among the three variables (real GDP growth rate, internet penetration and fixed broadband subscription). Madalla and Wu (1999) relied on the Johansen (1988) test for cointegration to consider the suggestion of Fisher (1932) to combine trace test and max-eigen statistics to test for cointegration in full panel by combining individual cross-sections for cointegration. Johansen-Fisher contegration test type aggregates p-values of individual Johansen maximum likelihood cointegration test statistics. Unlike Pedroni (2004) and Kao (1999) whose cointegration tests are residual based, the Johansen-Fisher contegration test is system based cointegration for the whole panel (Madalla & Kim, 1998).

2.4. Panel Causality

The direction of causality was identified by estimating the panel-based vector error correction model (VECM) and used to conduct the causality of internet penetration and fixed broadband subscription on real GDP growth rate. The empirical model is represented by the following equations:

$$\Delta \boldsymbol{GDPGRW_{it}} = \boldsymbol{\lambda_{1j}} + \sum_{k=1}^{m} \boldsymbol{\varphi_{11ik}} \Delta \boldsymbol{GDPGRW_{it-k}} + \sum_{k=1}^{m} \boldsymbol{\varphi_{12ik}} \Delta \boldsymbol{IPEN_{it-k}} + \sum_{k=1}^{m} \boldsymbol{\varphi_{13ik}} \Delta \boldsymbol{BROAD_{it-k}} + \Psi_{1i}{}^{\varepsilon}{}_{it-1} + \mu_{1it} \quad (3)$$

$$\Delta \boldsymbol{IPEN_{it}} = \boldsymbol{\lambda_{2j}} + \sum_{k=1}^{m} \boldsymbol{\varphi_{21ik}} \Delta \boldsymbol{IPEN_{it-k}} + \sum_{k=1}^{m} \boldsymbol{\varphi_{22ik}} \Delta \boldsymbol{GDPGRW_{it-k}} + \sum_{k=1}^{m} \boldsymbol{\varphi_{23ik}} \Delta \boldsymbol{BROAD_{it-k}} + \Psi_{2i}\varepsilon_{it-1} + \mu_{2it} \quad (4)$$

$$\Delta \boldsymbol{BROAD_{it}} = \boldsymbol{\lambda_{3j}} + \sum_{k=1}^{m} \boldsymbol{\varphi_{31ik}} \Delta \boldsymbol{BROAD_{it-k}} + \sum_{k=1}^{m} \boldsymbol{\varphi_{32ik}} \Delta \boldsymbol{GDPGRW_{it-k}} + \sum_{k=1}^{m} \boldsymbol{\varphi_{33ik}} \Delta \boldsymbol{BROAD_{it-k}} + \Psi_{1i}\varepsilon_{it-1} + \mu_{1it} \quad (5)$$

where Δ = denotes first differences and k = the optimal lag length. Equations 3 to 5 allows to test the short-run and long-run causality which is determined by investigating the significance using the probability value on the coefficient, Ψ, of the error correction term, ε_{it-1}, in the equations.

3. Results and Discussion

3.1 Pooled Multiple Regression Model

The results of the regression in Table 1 shows that internet penetration (IPEN) has a significant and negative effect on GDP growth (GDPGRW) as indicated by the coefficient value of -9.1690 and t-statistic = 3.5327 in absolute term with probability = 0.0005. This means that a 1 percentage point increase in internet penetration lowers economic growth by 9.1690 percentage points. This negative effect can be attributed to the presence of a digital divide in ASEAN countries due to high income inequality (Noh and Yoo, 2008). The rapid expansion of internet usage has resulted in the creation of of social inequality- popularly known as digital divide - a phenomenon that have the potential to weaken growth and productivity (Doong & Ho, 2012; Bowles, 2012; Shahiduzzaman & Alam, 2013).

Table 1. Pooled Least Squares Regression Results

Variable	Coefficient	Std. Error	t-statistics	Prob.
C	7.2943	0.5828	12.5148	0.0000
IPEN	-9.1690	2.5955	-3.5327	0.0005
BROAD	0.1683	0.0983	1.7127	0.0888
AR(1)	0.4768	0.0686	6.9461	0.0000
R-squared = 0.4182		F-statistic = 37.3737	DW = 2.1428	
Adjusted R-squared = 0.4069		Prob. (F-statistic) = 0.0000		

As for broadband subscription, its positively and statistically influence GDPGRW at 10 percent level of significance. A 1-unit increase in the number of broadband subscription prompted an increase in economic growth by 0.1683 percentage points. The widespread adoption of broadband (i.e. a form of high speed internet) has been linked with economic growth and social wellbeing (Dwivedi, Alsudairi, & Irani, 2009; Holt & Jamison, 2009). The availability of high speed broadband for business and households is a well understood and significant factor to encourage rapid economic growth (Bowles & Wilson, 2010).

The computed adjusted coefficient of determination (Adj. R-squared = 0.4069) shows that 40.69 percent of the total variation in the dependent variable are accounted for by the variation in the explanatory variables while 59.31 percent of the total variation in the GDPGRW is attributable to the influence of other factors not included in the regression equation. The F-statistic = 37.3737 is significant at 1 percent level. This implies that internet penetration and broadband subscription collectively influenced economic growth overtime. These findings are supportive of the claim that internet penetration and broadband connections are an engine of economic growth and rapidly transforming ASEAN economies. The computed DW statistic = 2.1428 indicates the absence of both positive and negative autocorrelations.

Figure 2 exemplifies the effect of internet penetration and broadband subscription on GDP growth of the 10 ASEAN countries. Based on the figure, the 17-year pooled least squares regression model appear to fit the actual behavior of the data. Moreover, the residuals of the series are stationary since the fluctuations are more or less on zero, indicating constancy of error variances.

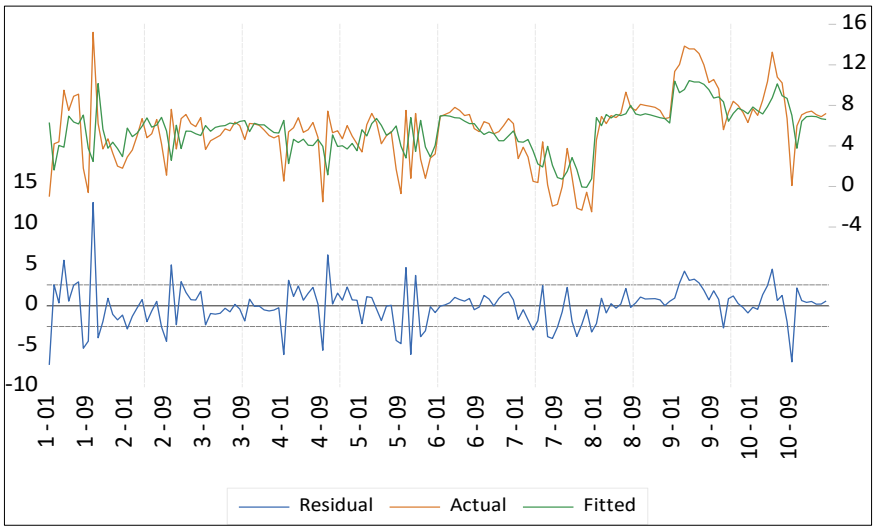

Figure 2. Plot of the Actual, Fitted and Residual for Pooled Regression

3.2 Unit Root Test

We first tested if the relevant variables were stationary as well as determining their order of integration. By looking at Figure 3 one can guess the stationarity or nonstationarity of a series. The nonstationary series GDPGRW, IPEN and BROAD were compared to their stationary series D(GDPGRW), D(IPEN) and D(BROAD). The graph of the series GDPGRW, IPEN and BROAD exhibits a trend suggesting nonstationarity. On the other hand, the graphs of D(GDPGRW), D(IPEN) and D(BROAD) shows pattern with no discernible upward nor downward trend, suggesting stationarity.

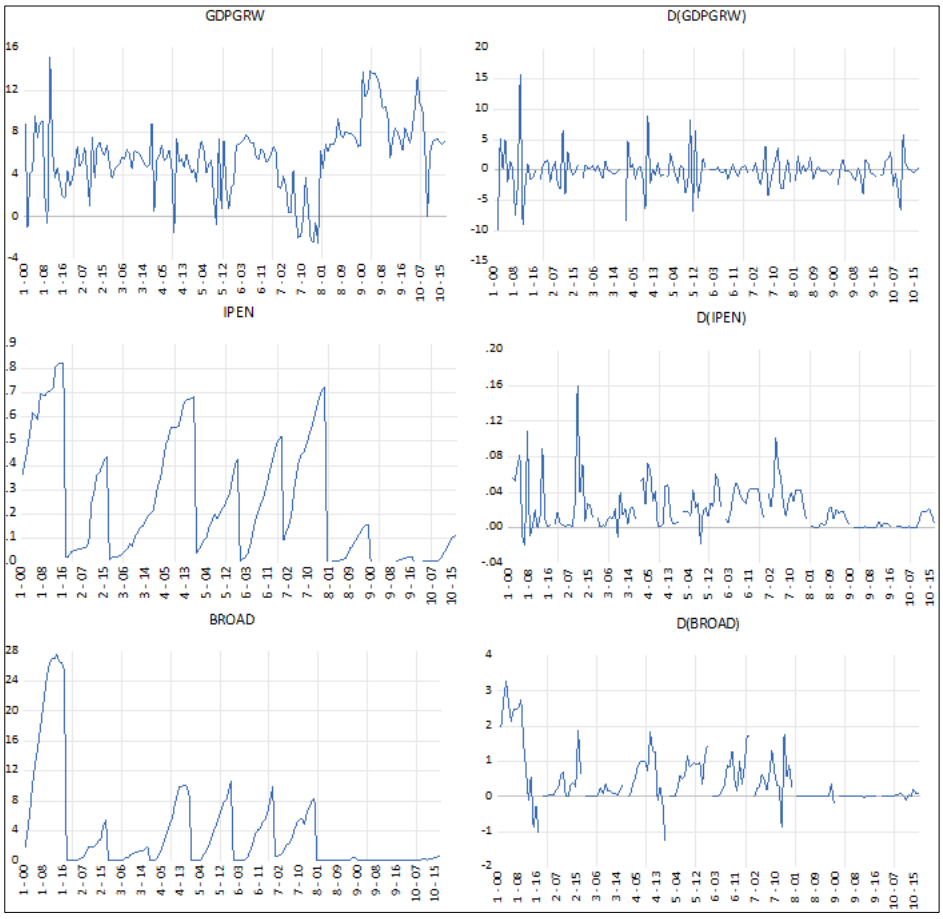

Figure 3. Nonstationary and Stationary Series Plot

The summary of the panel unit test results is presented in Table 2. The results are significant for GDPGRW at levels I(0) signifying the absence of unit root. In the case of IPEN and BROAD are non-stationary at I(0) and must be tested at first difference I(1). All the tests, show that the relevant variables are stationary in first differences, mostly at the 1% level of significance. That is, at I(1) all variables (i.e., D(GDPRW), D(IPEN) and D(BROAD)) are stationary for all the approaches employed signifying absence of unit root at order 1 and meeting the conditions for testing for long-run cointegration tests.

Table 2. Panel Unit Root Results

	Levin, Lin & Chu		Im, Pesaran & Shin		ADF-Fisher		PP-Fisher	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
	At Levels I(0)							
GDPGRW	-5.93	0.00	-4.56	0.00	58.58	0.00	58.81	0.00
IPEN	-0.76	0.99	3.09	0.99	17.47	0.62	18.40	0.56
BROAD	4.03	1.00	7.90	1.00	8.59	0.98	7.52	0.99
	At First Difference I(1)							
D(GDPGRW)	-15.09	0.00	-12.18	0.00	138.86	0.00	162.88	0.00
D(IPEN)	-5.12	0.00	-4.56	0.00	56.21	0.00	47.54	0.00
D(BROAD)	-3.16	0.00	-3.27	0.00	51.37	0.00	40.78	0.00

Note: the tests for panel unit roots were specified with individual effects only.

3.3 Johansen-Fisher Panel Cointegration

Table 3 below presents Johansen-Fisher panel cointegration test for potential cointegrating relationships among the variables in level form and first difference. As can be readily seen, both the trace and max-eigen tests suggests that there is a strong cointegrating relationship among these variables. Thus, at least 2 cointegrated relationships can be detected. The null hypothesis of no cointegration is rejected at the 1 percent and 5 percent levels of significance. The findings indicate that there is a cointegration relationship between economic growth and each of the independent variables, internet penetration and broadband subscription, in ASEAN countries. When a cointegration relationship is present, it means that economic growth (GDPGRW), internet penetration (IPEN) and broadband subscription (BROAD) share a common trend and long run equilibrium relationship.

Table 3. Johansen-Fisher Panel Cointegration Results

Hypothesized No. of CE(s)	Trace Test		Max-Eigen Test	
	Stat.	Prob.	Stat.	Prob.
	At Levels I(0)			
None	107.80	0.00	80.16	0.00
At most 1	52.95	0.00	39.65	0.00
At most 2	44.66	0.00	44.66	0.00
	At First Difference I(1)			
None	104.20	0.00	85.18	0.00
At most 1	43.64	0.00	38.47	0.01
At most 2	31.46	0.05	31.46	0.05

3.4 Panel Causality

From Table 4, the coefficient of ECM (1) is negative 0.219000 and its t-statistic is 3.848640 in absolute term with p-value = 0.0001 which is significant 0.01 level of significance. A negative and significant coefficient of the ECM indicates that any short term fluctuations between the independent variables (i.e., IPEN, BROAD) and the dependent variable GDPGRW will give rise to a stable long-run relationship between the variables. Moreover, we can also say that when C(1) is negative and significant this implies long-run causality running from internet penetration and broadband subscription to economic growth. The speed of adjustment is 0.2190, means that the

whole system is going back to long run equilibrium at the speed 21.90 percent annually. This implies that there has been some disequilibrium in previous years that is now been corrected at the speed of adjustment stated.

Table 4. Vector Error Correction Estimates

	Coefficient	Std. Error	t-statistic	Prob.
C(1)	-0.219000	0.056903	-3.848640	0.0001
C(2)	-0.373024	0.084560	-4.411376	0.000
C(3)	-0.250394	0.075331	-3.323941	0.0010
C(4)	-10.42205	8.874030	-1.174443	0.2409
C(5)	-4.917418	8.706510	-0.564798	0.5725
C(6)	0.083445	0.458752	0.181895	0.8558
C(7)	1.071901	0.490627	2.184760	0.0295
C(8)	-0.306351	0.303335	-1.009942	0.3131
Determinant residual covariance		0.000500		
Equation: D(GDPGRW) = C(1)*(GDPGRW(-1) + 6.57120030813*IPEN(-1) + 0.395384523504*BROAD(-1) - 9.07691329997) + C(2)*D(GDPGRW(-1)) + C(3)*D(GDPGRW(-2)) + C(4)*D(IPEN(-1)) + C(5)*D(IPEN(-2)) + C(6)*D(BROAD(-1)) + C(7)*D(BROAD(-2)) + C(8)				

3.5 Wald Short-run Causality

Table 5 reports the Wald short run causality results. It shows that broadband subscription causes economic growth in the ASEAN countries. That is, there is short-run causality running from BROAD to GDPGRW. However, internet penetration has no causal link with economic growth in the short-run.

Table 5. Wald Short-run Causality

	Chi-square		
	Value	df	Prob.
IPEN ➔ GDPGRW	2.4464	2	0.2943
BROAD ➔GDPGRW	11.1492	2	0.0038

4. Conclusion

This paper explored the cointegration relationship and causal link of internet penetration and broadband subscription to economic growth from the 10 countries of ASEAN for the period 2000-2016. A pooled multiple regression model with GDP growth as a function of internet penetration and broadband subscription was developed. The Johansen-Fisher panel cointegration was applied to determine the presence of a long-run equilibrium relationship among the three variables and the direction of causality was identified by estimating the panel-based vector error correction model (VECM). Internet penetration and broadband subscription collectively influenced the economic growth of the ASEAN countries during the period 2000-2016. The findings indicate that there is a long-run equilibrium relationship between economic growth and each of the independent variables, internet penetration and broadband subscription, in ASEAN countries. Moreover, we can also say that there is long run causality running from internet penetration and broadband subscription to economic growth. In the short-run, broadband subscription causes economic growth in the ASEAN countries. However, internet penetration has no causal link with economic growth in the short-run during the period 2000-2016. Based on these findings, this study recommends that ASEAN governments should be supportive on policies that promotes better Internet and broadband infrastructure to further boost economic growth. Likewise, ASEAN governments need to work closely with industry leaders to find ways to proactively promote the growth of internet interconnectivity of the region.

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