The current issue and full text archive of this journal is available on Emerald Insight at:
https://www.emerald.com/insight/2515-964X.htm

Received 17 July 2020
Revised 23 September 2020
28 November 2020
6 January 2021
Accepted 31 January 2021

Analysis of the impact of information communication technology on economic growth: empirical evidence from Asian countries

Meta Ayu Kurniawati
Graduate school of International Relations, Ritsumeikan University, Kyoto, Japan

Abstract

Purpose – This study examines the causal relationship between information communication technology (ICT) and economic growth in high-income and middle-income Asian countries.

Design/methodology/approach – This study utilises a high-quality data from 25 Asian countries from 2000 to 2018. This study presents the robustness results by employing panel cointegration and estimation procedures to account for the endogeneity and cross-sectional dependence issues.

Findings – The results illustrate that high-income Asian countries have achieved positive and significant economic development from high Internet penetration. Additionally, the middle-income countries have started to benefit from ICT Internet. The findings show that the telephone line and mobile phone penetration is highly capable of promoting economic growth in middle-income Asian countries.

Practical implications – In high-income Asia countries, an appropriate ICT infrastructure policy will support feasible ICT penetration, which may drive the processes of economic development and innovation that contribute to economic growth. Moreover, in middle-income Asian countries, the establishment of better-quality ICT service and infrastructure is more critical. Policymakers should accommodate sufficient support to establish the ICT infrastructure and expand ICT penetration.

Originality/value – This study reveals that high-income Asian countries have been more proactive and effective than middle-income countries in embracing ICT to foster economic growth. Examining the case of high-income and middle-income Asian countries provides comprehensive insight for policymakers regarding the relevance of ICT in boosting economic growth through the advantages of technology expansion.

Keywords ICT, Economic growth, Asia, Panel data, Communication technologies

Paper type Research paper

1. Introduction

Recent investments have promoted considerable growth in the telecommunications industry and have become one of the significant drivers of economic growth in several other critical sectors. Information and communication technology (ICT) facilitates information exchange and influences modern society. Due to the effects of the ICT revolution, a paradigm shift is taking place in human development, which refers to the process of expanding the range of choices for society, such as education, healthy life and living standards (Yakunina and Bychkov, 2015).

The impact of innovation and technology expansion on economic development has long been recognised. ICT increases the availability of information, forms new communication

JEL Classification — L86, O40, O47

Journal of Asian Business and Economic Studies
Vol. 29 No. 1, 2022
pp. 2-18
Emerald Publishing Limited
2515-964X
DOI 10.1108/JABES-07-2020-0082

methods, reformats productive processes and improves the efficiency of many different economic activities. With the rapid development of ICT and telecommunications, Internet users continue to grow around the world. The Broadband Commission for Sustainable Development remarked that "half the world's population is expected to be connected to the internet by the end of 2019 at the latest" (International Telecommunication Union, 2018). Therefore, in less than two decades, societies have achieved broader connectivity than ever before (Lee *et al.*, 2017).

This study aims to examine the causal relationship between economic growth and three ICT indicators in Asia. The Asian countries were divided into two groups based on the World Bank's 2020 classification of countries according to their income levels, namely high-income and middle-income countries. The income categorisation allows for examining whether the results vary among income groups, leading to more specific policies and recommendations for each group. However, a notable difference between high-income and middle-income countries is that the high-income countries produce digital technologies while the middle-income countries are only users. High-income countries have already built a mature stock of physical infrastructure, human capital and relevant government institutions and policies that enhance and amplify the effects of ICT investments (Dewan and Kraemer, 2000).

There are three main motivations for this study. First, Asia is a vibrant region with high penetration potential for ICT diffusion and production. However, research examining the contributions of each ICT indicators to economic growth in high-income and middle-income countries has provided mixed results. Therefore, there is a need for studies based on income classification in Asian countries that use the latest data and robust econometric estimation. Second, according to prior literature, high-income Asian countries have been highly proactive and effective in embracing ICT to foster economic growth, while middle-income Asian countries are facing a knowledge- and information-divide, which leads to a technology gap. Examining the case of high- and middle-income countries can provide a comprehensive understanding of ICT's effects on growth, which come from ICT Internet penetration, mobile phone development and telephone landline establishment. Third, the alteration in the performance of Asia's ICT development provides valuable policy insights on the relevance of ICT in boosting economic growth through the advantages of technology expansion.

This paper is divided into five main sections. Section 2 reviews of the literature. Section 3 includes the detailed methodology used in the study. Section 4 provides the analysis and the results interpretation. The last section presents the conclusion, policy implications and recommendations.

2. Literature review

The expansion of information and communication technology (ICT) is continuing in the world economy. Recently, ICT plays a substantial role in driving globalisation and the growth of the economy as well as making communications and commerce more transnational (Maneejuk and Yamaka, 2020). Under the development of Industry 4.0, ICT establishes new ways in sustainable industrial manufacturing (Stock and Seliger, 2016).

ICT participates in two fundamental roles through capital deepening as a result of investment and contribution of all the productivity factors. Investment in ICT has assisted companies in reducing their communication and coordination costs. Additionally, ICT investment can accelerate efficiency and productivity (Erumban and Das, 2016).

The empirical literature proposes different ways for ICT to boost economic growth. Generally, it can accrue via direct and indirect manners: directly via enhanced productivity and growth in industries that produce ICT goods and services and indirectly via elevated quality of investment and productivity in industries that use ICT assets in their production (van Ark *et al.*, 2011). This increased productivity occurs in several ways. First, ICT enhances the demand for production inputs and reduces transaction costs (Roller and Waverman, 2001). Second, ICT raises labour productivity in ICT-using industries by increasing labour production outputs and efficiency (van Ark *et al.*, 2011). Third, ICT influences productivity through its forward and backward linkages with the economy. Besides, ICT can enhance economic performance by providing market information; facilitating information diffusion; and enhancing competition, entrepreneurial activities, job search processes and the distribution of ideas (Czernich *et al.*, 2011). Furthermore, the business usage of ICT has been promoted labour productivity (Evangelista *et al.*, 2014) and increased competitive advantage and efficiency, which boosting business growth (Henry and Stephen, 2010).

Both empirical and theoretical studies have confirmed the contribution of telecommunication technology to economic growth. In the case of country-specific studies, several researchers have highlighted the relevance of ICT in enhancing economic growth, for example, Adedoyin *et al.* (2020) for the USA; Chakpitak *et al.* (2018) for Thailand; Kumar *et al.* (2016) for China; Agarwal *et al.* (2018) for India; Salahuddin and Gow (2016) for South Africa; Ishida (2015) for Japan and Salahuddin and Alam (2015) for Australia.

The positive influence of ICT on economic growth also has been verified by numerous research projects at the cross-country level. For instance, Khan *et al.* (2020) for South Asia; Asongu and Odhiambo (2019) for Africa; Alshubiri *et al.* (2019) for Gulf Cooperation Council (GCC); Kurniawati (2020) for OECD; Ghosh (2017) for MENA; Zhang and Danish (2019) for Asia; and Donou-Adonsou and Lim (2018) for SSA. Besides, the results show that ICT has been documented to be particularly relevant in boosting economic growth in developed countries (Fernández-Portillo *et al.*, 2020; Kurniawati, 2020; Myovella *et al.*, 2020; Nair *et al.*, 2020) and developing countries (Bahrini and Qaffas, 2019; Donou-Adonsou and Lim, 2018; Maneejuk and Yamaka, 2020; Solomon and van Klyton, 2020; Zhang and Danish, 2019).

When considering the linkage between ICT and economic growth, the role of other explanatory variables cannot be neglected. Researchers have noticed that economic growth can be positively affected by capital (Adeleye and Eboagu, 2019; Muhammad and Khan, 2019), labour (Kim and Park, 2020; Solarin, 2020), financial development (Raheem *et al.*, 2020; Salahuddin and Gow, 2016), foreign direct investment (FDI) (Adedoyin *et al.*, 2020; Asongu and Odhiambo, 2020; Sinha and Sengupta, 2019) and trade openness (Ahmed, 2017; Kurniawati, 2017).

3. Data and methodology

3.1 Model specification

To capture the effects of ICT mobile, ICT Internet, innovation and macroeconomic variable on economic growth, this study estimates an econometric model of the following form from current research:

$$\mathrm{GDP}_{it} = \beta_{0i} + \beta_{1i}\mathrm{CAP}_{it} + \beta_{2i}\mathrm{LAB}_{it} + \beta_{3i}\mathrm{ICT}_{it} + \beta_{4i}\mathrm{FD}_{it} + \beta_{5i}\mathrm{TRD}_{it} + \beta_{6i}\mathrm{FDI}_{it} + \varepsilon_{it} \quad (1)$$

Here, $\varepsilon_{it} = \mu_i + \nu_{it}$, while $\mu_{i\approx}(0, \sigma^2\mu)$ and $\nu_{it\approx}(0, \sigma^2\nu)$ are independent of each other; and μ_i and ν_{it} denote country-specific fixed effects and time-variant effects, respectively. The subscripts i and t represent the country ($i = 1 \ldots 24$) and time period (2000–2018), respectively. The coefficients $\beta_1, \beta_2, \ldots \beta_6$ represent the long-run elasticity estimates of economic growth concerning to capital, labour, ICT, financial development, trade and FDI.

3.2 Data descriptions

This study employed 2000–2018 panel data from 25 Asian countries, which was obtained from the World Development Indicators 2020, and classified the countries into 12 high-income and 13 middle-income countries (World Bank, 2020). The high-income countries were Bahrain, Brunei Darussalam, Cyprus, Israel, Japan, South Korea, Kuwait, Oman, Qatar, Saudi

Arabia, Singapore and the United Arab Emirates. The middle-income countries were Bangladesh, Bhutan, China, India, Indonesia, Malaysia, Mongolia, Myanmar, Pakistan, Sri Lanka, Thailand, Turkey and Vietnam. Besides, to corroborate the main findings, this study classified the observation period into pre-crisis (2000–2009) and post-crisis (2010–2018) for the estimation test.

The variables in this study include economic growth which was gross domestic product (GDP) per capita (US$ Constant 2010), labour (LAB) which represented total labour participation, capital (CAP) which presented the gross fixed capital formation to the GDP. ICT was divided into three main variables, namely telephone lines (ICTTel) as fixed telephone lines per 100 inhabitants; mobile phone subscribers (ICTMob) as mobile phone users per 100 inhabitants; and Internet use (ICTNet) as Internet users per 100 inhabitants. Trade openness (TRD) was the sum of exports and imports of goods and services measured as a share of GDP. Furthermore, financial development (FD) was proxied by a domestic credit to the private sector to the GDP. Lastly, foreign direct investment (FDI) represented the percentage of foreign direct investment net inflows to the GDP. The variables in this study employed in their natural logarithms form to reduce the data heterogeneity.

3.3 Estimation techniques

First, to estimate the degree of integration, this study used the Levine–Lin–Chu (LLC) test (Levin *et al.*, 2002) as a homogeneous panel unit root test and the Wu-Fisher Augmented Dickey–Fuller (ADF) test (Maddala and Wu, 1999) as a panel heterogeneous unit root tests. These first-generation of panel unit root tests (LLC and ADF) assume cross-sectional independence. Therefore, to account for cross-sectional dependence, this study employed CIPS (Pesaran, 2007) the second-generation panel unit root test.

Second, this study analysed the cointegration relationship of the variables with panel cointegration tests developed by Pedroni (1999) that account for country size and heterogeneity. However, since the number of countries (m) is 25 and the number of study years (y) is 19 (2000–2018), hence the results of countries' heterogeneity may bias as $m < y$. Therefore, the limitation of this study is not addressing cross-country heterogeneity.

Third, this study employed the fully modified ordinary least squares (FMOLS) method developed by Pedroni (2000) as the estimation test. FMOLS is a non-parametric approach that considers the possible correlation between the error term and the first differences of the regressor (Pedroni, 2000) and accounts for the intercept and the endogeneity problem (Pedroni, 2001).

Furthermore, to manage the presence of cross-sectional dependence, this study used the cross-sectional dependence (CD) test proposed by Pesaran (2004). The CD test includes four separate tests: the Lagrange multiplier (LM) test (Breusch and Pagan, 1980), the scaled CDLM and general CD tests (Pesaran, 2004) and the bias-adjusted LM test (Breusch and Pagan, 1980). To examine the robustness of estimation results, this study employed the common correlated coefficient (CCE) estimation procedure proposed by Pesaran (2006), which addresses cross-sectional dependence in estimation and accounts for unobserved dependencies between countries in the panel.

Finally, the Dumitrescu Hurlin (DH) panel causality test proposed by Dumitrescu and Hurlin (2012) was used to examine the causal relationship of panel variables. The DH panel causality analysis evaluates unbalanced panel data and to account cross-sectional dependency between countries.

4. Results and analysis

4.1 Empirical results

Table 1 presents the descriptive statistics for high- and middle-income countries. Compared to middle-income countries, the mean GDP per capita is 34,742.52 USD and about ten times

Table 1.
Descriptive statistics

Variables	Mean	Maximum	Minimum	Std. Dev	Observations
High-income					
GDP	34,742.52	69,679.09	15,104.52	14,218.84	228
Capital	23.72	46.02	0.00	7.41	228
Labour	9,906,023	68,358,370	157,089	18,529,551	228
ICTNet	55.41	100.00	0.00	28.39	228
ICTMob	109.24	212.64	6.66	44.68	228
ICTTel	30.60	63.10	8.71	15.31	228
FD	84.97	255.31	0.00	54.13	228
FDI	10.21	280.13	−3.15	33.66	228
Trade	117.93	437.33	0.00	83.57	228
Middle-income					
GDP	3,497.15	15,068.98	342.14	3,287.68	247
Capital	28.57	69.67	0.00	11.52	247
Labour	124,000,000	785,000,000	245,167	220,000,000	247
ICTNet	19.04	81.20	0.00	19.71	247
ICTMob	62.16	180.18	0.00	47.97	247
ICTTel	8.83	29.45	0.38	7.63	247
FD	56.42	161.14	3.12	41.72	247
FDI	2.87	43.91	−37.15	5.07	247
Trade	76.92	220.41	0.00	50.29	247

higher than the average GDP per capita of middle-income countries. The average ICT Internet in high-income countries is 55.41 and approximately threefold that of middle-income countries. Besides, the number of mobile subscriptions and telephone infrastructures are higher compared to middle-income countries. They record a mean of 109.24 and 30.60, respectively. The highest average gross fixed capital formation (% of GDP) occurs in middle-income countries at 28.57%, followed by high-income countries at 23.72%. A huge difference concerns total labour participation, which is on average 124,000,000 in middle-income countries, whereas it is only about 9,906,023 in high-income countries. The average financial development in high-income countries is 84.97 and approximately twice that of middle-income countries. The average percentage of foreign direct investment (FDI) net inflows to the GDP in middle-income countries is only one-third as high as the percentage of FDI in high-income countries. It is also obvious that trade openness as a share of GDP is higher in high-income countries relative to middle-income countries.

Table 2 reports the correlation matrix results. The results indicated that Internet users, mobile phone subscriptions and telephone lines are positively and significantly correlated with economic growth in high- and middle-income countries. Besides, capital, labour, financial development and trade openness have a positive correlation with economic growth while the FDI is negatively correlated with economic growth in both regions.

Table 3 presents the panel unit root test results, which indicated that the panel contains a unit root and that all the variables are I(1). Since all the variables were stationary when first differenced, the next step is to ascertain if the variables were cointegrated using the panel cointegration test.

Table 4 illustrates the results of the panel cointegration test. The statistics were significant at the 1% level, which confirms that all variables were cointegrated. Therefore, this study rejected the null hypothesis of no cointegration.

The FMOLS estimation results for high-income countries are reported in Table 5. The coefficients of ICT mobile, Internet and telephone were statistically significant to economic growth, which corresponds with previous results (Hong, 2017; Kurniawati, 2020; Pradhan

Variables	GDP	Capital	Labour	ICTNet	ICTMob	ICTTel	FD	FDI	Trade
High-income									
GDP	1.00								
Capital	0.15**	1.00							
Labour	0.08*	0.10	1.00						
ICTNet	0.43***	0.23***	0.28***	1.00					
ICTMob	0.21**	0.09	−0.08	0.73***	1.00				
ICTTel	0.36**	0.05	0.46***	0.17***	−0.15**	1.00			
FD	0.01***	−0.02	0.52***	0.37***	0.13**	0.68***	1.00		
FDI	−0.05*	−0.13**	−0.14**	0.04	0.10	0.19***	0.54***	1.00	
Trade	0.43**	0.10	−0.36***	0.14**	0.22***	0.05	0.03	0.14**	1.00
Middle-income									
GDP	1.00								
Capital	0.02**	1.00							
Labour	0.05***	0.29***	1.00						
ICTNet	0.14***	0.12*	0.05	1.00					
ICTMob	0.48***	0.12*	−0.07	0.76***	1.00				
ICTTel	0.59***	0.10	0.23***	0.41***	0.27***	1.00			
FD	0.45***	0.18***	0.39***	0.68***	0.52***	0.45***	1.00		
FDI	−0.01**	0.15**	−0.04	0.05	0.13**	0.05	0.09	1.00	
Trade	0.26***	0.16***	−0.28***	0.45***	0.33***	0.25***	0.57***	0.26***	1.00

Note(s): ***p < 0.01; **p < 0.05; *p < 0.1

Table 2.
Correlation matrix

Variables	LLC Level	LLC First dif	ADF Level	ADF First dif	CIPS Level	CIPS First dif	Inferences
High-income							
GDP	4.47	−8.02***	12.32	116.73***	1.45	2.54***	I [1]
Capital	0.65	−11.71***	11.44	162.02***	1.85	2.69***	I [1]
Labour	2.93	−5.56***	8.67	37.09***	1.82	3.24***	I [1]
ICTMob	8.53	−8.56***	3.33	116.86***	1.51	2.43***	I [1]
ICTNet	3.90	−9.83***	1.80	123.44***	1.58	3.74***	I [1]
ICTTel	2.13	−6.95***	27.43	91.84***	1.73	2.21***	I [1]
FD	0.12	−13.19***	12.99	174.83***	1.31	3.04***	I [1]
Trade	1.11	−12.15***	8.32	163.53***	1.20	2.73***	I [1]
FDI	0.13	−4.25***	10.38	22.25***	1.70	3.20***	I [1]
Middle-income							
GDP	1.00	−7.27***	31.32	74.30***	1.44	2.12***	I [1]
Capital	4.76	−11.39***	8.62	157.74***	1.12	2.56***	I [1]
Labour	5.21	−3.59***	2.57	45.94***	1.64	2.68***	I [1]
ICTMob	1.74	−9.49***	15.32	113.93***	1.19	3.50***	I [1]
ICTNet	4.83	−8.06***	12.09	99.73***	1.44	3.78***	I [1]
ICTTel	2.39	−4.96***	23.43	59.87***	1.62	2.38***	I [1]
FD	4.42	−8.79***	4.69	127.22***	1.71	2.26***	I [1]
Trade	1.13	−3.22***	20.03	44.02***	1.33	2.61***	I [1]
FDI	1.20	−4.68***	32.94	77.39***	1.56	4.44***	I [1]

Note(s): ***p < 0.01

Table 3.
Results of panel unit root tests

et al., 2016). Interestingly, the ICT coefficient with the highest magnitude was Internet users, followed by mobile phone subscriptions and telephone lines. These suggest that higher Internet penetration contributes to a high-income economy.

Table 4.
Results of panel cointegration test

	ICT mobile		ICT internet		ICT telephone	
	Stat	Prob	Stat	Prob	Stat	Prob
High-income countries						
Panel *v*-statistic	−2.847	0.997	−1.981	0.976	−1.908	0.971
Panel rho-statistic	3.922	1,000	3.508	0.999	4.313	1,000
Panel PP-statistic	−5.795	0.000***	−5.447	0.000***	−2.490	0.000***
Panel ADF-statistic	−6.566	0.000***	−6.037	0.000***	−5.150	0.000***
Group rho-statistic	5.632	1,000	5.337	1,000	5.287	1,000
Group PP-statistic	−1.066	0.000***	−8.676	0.000***	−8.279	0.000***
Group ADF-statistic	−8.595	0.000***	−9.340	0.000***	−8.205	0.000***
Middle-income countries						
Panel *v*-statistic	1.552	0.000***	1.145	0.000***	3.851	0.000***
Panel rho-statistic	5.207	1,000	4.325	1,000	5.622	1,000
Panel PP-statistic	−1.134	0.128	−3.997	0.000***	0.845	0.801
Panel ADF-statistic	−6.461	0.000***	−3.748	0.000***	−3.740	0.000***
Group rho-statistic	5.671	1,000	5.438	1,000	6.364	1,000
Group PP-statistic	−3.573	0.000***	−4.063	0.000***	−2.131	0.000***
Group ADF-statistic	−5.474	0.000***	−3.829	0.000***	−3.212	0.000***
Inferences	Cointegrated		Cointegrated		Cointegrated	

Note(s): ***$p < 0.01$

Table 5.
Results of FMOLS estimation for high-income countries

	ICTMob		ICTNet		ICTTel	
	Coef	Prob	Coef	Prob	Coef	Prob
ICTMob	0.253	0.000***				
ICTNet			1.470	0.000***		
ICTTel				0.089	0.000***	
Capital	2.299	0.000***	2.284	0.000***	2.834	0.000***
Labour	0.704	0.003**	0.707	0.000***	0.760	0.000***
FD	1.829	0.000***	1.050	0.000***	1.631	0.000***
Trade	2.647	0.000***	2.297	0.000***	2.889	0.000***
FDI	0.728	0.000***	0.750	0.000***	0.781	0.000***

Note(s): ***$p < 0.01$; **$p < 0.05$

The capital coefficient had a positive and significant impact at the 1% level on per capita economic growth, in line with the results of Muhammad and Khan (2019). Labour was positively correlated with economic growth at the 1% significant level in three different ICT measurements. The influence of financial development on economic growth also appeared positive and significant. Besides, the results postulate that the effect of trade openness was significant in high-income countries, which means that higher trade openness elevates economic growth. The reduction of tariff rates in these countries caused a direct positive effect on imports and an indirect effect on exports. FDI also had a positive and significant impact on economic growth (Adedoyin *et al.*, 2020; Asongu and Odhiambo, 2020; Kurniawati, 2017).

Table 6 reports the FMOLS estimation for middle-income countries. The results illustrate that the three estimated models of ICT diffusion variables were consistently significant at the 1% level, meaning that the increased use of mobile devices, Internet and telephones has a significantly positive effect on economic growth (Erumban and Das, 2016; Pradhan *et al.*, 2017). The estimated elasticity for telephone penetration was the highest indicator that an increase in the number of telephone users has a greater stimulating effect on the middle-income countries' economic growth than other ICT indicators. These results support Sassi and Goaied (2013), which explain that the marginal impact of telephone penetration is greater than mobile penetration. In contrast, the effect of Internet penetration was lower than that of telephone penetration in middle-income countries (Erumban and Das, 2016).

The capital coefficient was positive and significant at the 1% level. Additionally, labour showed a greater positive impact on economic growth in middle-income countries than in high-income countries. The findings also illustrate that the financial development coefficients in middle-income countries were statistically significant. Therefore, it can be argued that financial development sufficiently enables resource mobilisation to promote economic growth (Raheem *et al.*, 2020; Salahuddin and Gow, 2016).

Trade openness was found to be positive and statistically significant in all model specifications. The openness of international trade generally favoured economic growth in middle-income countries. The FDI coefficient was also positive and statistically significant. In particular, there was evidence that FDI contributed to the host country's productivity when the technology gap was not significant and when a sufficient level of absorptive capacity existed in the host country. Hence, policies focused on improving FDI might lead to increased economic growth (Kurniawati, 2017; Muhammad and Khan, 2019; Sinha and Sengupta, 2019).

Table 7 presents the FMOLS estimation results for pre-crisis and post-crisis in high- and middle-income countries. The ICT coefficients were statistically significant to economic growth at a 1% level, which corresponds with previous results. According to high-income countries, the magnitude of ICT mobile and ICT telephone coefficients were significantly decreased from pre-crisis to post-crisis period. In contrast, the magnitude of the ICT Internet coefficient was escalated in the post-crisis period. Besides, the ICT Internet coefficient's size was the highest, followed by mobile phone and telephone for both periods.

Interestingly, according to middle-income countries, the ICT telephone coefficient's magnitude was changed from the highest ICT indicator in the pre-crisis period to the lowest ICT indicator coefficient in the post-crisis period. On the contrary, when the ICT mobile coefficient was the lowest in the pre-crisis period, its size was changed into the highest ICT indicator coefficient in the post-crisis period, which followed by the Internet and telephone. This evidence supports the results of the previous FMOLS estimations.

Finally, the Dumitrescu and Hurlin (2012) panel causality test results are presented in Appendix Table A1. According to the results, high-income countries illustrated a bidirectional causality between GDP and labour, GDP and ICT Internet, as well as between GDP and trade. Moreover, the results revealed a unidirectional causality running from the capital, ICT mobile and ICT telephone to GDP, whereas the latter Granger caused financial development and FDI. Furthermore, the findings for middle-income countries

	ICTMob		ICTNet		ICTTel	
	Coef	Prob	Coef	Prob	Coef	Prob
ICTMob	0.566	0.000***				
ICTNet			0.232	0.000***		
ICTTel				2.312	0.000***	
Capital	1.224	0.000***	1.913	0.000***	1.939	0.000***
Labour	1.666	0.000***	1.657	0.000***	0.907	0.000***
FD	0.560	0.000***	0.863	0.000***	0.445	0.000***
Trade	0.724	0.000***	0.845	0.000***	0.713	0.003**
FDI	0.535	0.000***	1.255	0.000***	1.122	0.000***

Note(s): ***$p < 0.01$; **$p < 0.05$

Table 6. Results of FMOLS estimation for middle-income countries

Table 7.
Results of FMOLS estimation for pre-crisis and post-crisis

	Pre-crisis ICTMob	Pre-crisis ICTNet	Pre-crisis ICTTel	Post-crisis ICTMob	Post-crisis ICTNet	Post-crisis ICTTel
High-income countries						
ICTMob	0.91***			0.37***		
ICTNet		1.06***			1.28***	
ICTTel			0.80***			0.27***
Capital	1.00***	1.92***	1.34***	1.23***	1.09***	1.74***
Labour	0.04***	0.05***	0.08***	0.06***	0.10***	0.13***
FD	0.74***	0.81***	0.73***	0.29***	0.10***	0.15***
FDI	0.31***	0.92***	0.22***	0.08***	0.09***	0.13***
Trade	0.67***	0.82***	0.81***	0.27***	0.32***	0.24***
Middle-income countries						
ICTMob	0.44***			0.95***		
ICTNet		0.51***			0.60***	
ICTTel			0.63***			0.54***
Capital	0.05***	0.19***	0.08***	0.19***	0.12***	0.12***
Labour	0.22***	0.25***	0.20***	0.14***	0.12***	0.16***
FD	0.51***	0.58***	0.46***	0.05***	0.04***	0.08***
FDI	0.26***	0.33***	0.28***	0.18***	0.19***	0.17***
Trade	1.13***	1.01***	1.10***	0.02***	0.13***	0.14***

Note(s): ***$p < 0.01$

showed a bidirectional causality between GDP and capital, GDP and labour, GDP and ICT mobile, GDP and ICT Internet, GDP and ICT telephone as well as between GDP and trade. A unidirectional causality existed from FDI to GDP, whereas the latter Granger caused financial development. Table A1 also presents the dynamic causal relationships among the other variables.

4.2 The issue of cross-sectional dependence and robustness test

Table 8 reports the results of the cross-sectional dependence tests in high-income and middle-income Asian countries, respectively. The empirical results revealed the presence of cross-sectional dependence in all the panels. Therefore, the next logical step was to use a common correlated effect mean group (CCEMG) estimation, which addresses cross-sectional dependence issues.

The results of the CCEMG test for high- and middle-income Asian countries are presented in Table 9. According to the results, all ICT indicators followed by control variables illustrated a positive and significant impact on economic growth for all panels. In the high-income countries, the ICT Internet coefficient had the strongest moderating effect on economic growth as compared to the other ICT variables. However, in middle-income countries, the ICT telephone landline coefficient had the highest magnitude, followed by mobile phone and Internet penetration. These findings are similar to the FMOLS estimation results (although the magnitude is slightly different).

4.3 Analysis of results

According to the results from FMOLS and CCEMG estimation as a robustness test, the study emphasises the importance of ICT on productivity growth in the studied countries (Adeleye and Eboagu, 2019; Asongu and Odhiambo, 2020; Maneejuk and Yamaka, 2020). The magnitude of the ICT Internet variable was quite strong relative to the mobile phone and telephone in high-income countries. These could be related to the fact that fixed-line

Variables	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
High-income countries				
GDP	428.78***	31.58***	31.24***	2.46***
ICTMob	1070.07***	87.39***	87.06***	32.64***
ICTNet	1130.06***	92.61***	92.28***	33.59***
ICTTel	378.19***	27.17***	26.84***	8.78***
Capital	227.44***	14.05***	13.72***	2.20***
Labour	997.28***	81.06***	80.72***	26.83***
FD	548.20***	41.97***	41.64***	6.05***
Trade	317.62***	21.90***	21.57***	7.34***
FDI	104.16***	3.32***	2.99***	2.67***
Middle-income countries				
GDP	1438.47***	108.92***	108.56***	37.92***
ICTMob	1332.84***	100.47***	100.11***	36.44***
ICTNet	1255.74***	94.29***	93.93***	35.38***
ICTTel	450.32***	29.81***	29.45***	9.01***
Capital	334.79***	20.56***	20.20***	4.07***
Labour	1271.43***	95.55***	95.19***	35.56***
FD	752.60***	54.01***	53.65***	16.50***
Trade	414.49***	26.94***	26.58***	3.37***
FDI	132.00***	4.32***	3.96***	4.94***

Note(s): ***p < 0.01

Table 8.
Results of cross-sectional dependence tests

	ICT mobile		ICT Internet		ICT telephone	
	Coef	*T*-statistic	Coef	*T*-statistic	Coef	*T*-statistic
High-income countries						
ICTMob	0.21*	1.78				
ICTNet			1.22***	2.77		
ICTTel				0.19**	2.08	
Capital	0.78***	3.01	0.61**	2.08	0.68***	2.62
Labour	0.82***	6.31	0.50***	3.16	0.85***	4.56
FD	1.20**	2.29	1.20**	2.28	0.98*	1.84
Trade	0.10**	2.22	0.11**	2.07	0.08*	1.70
FDI	0.11*	1.81	0.14**	2.20	0.12**	2.19
Middle-income countries						
ICTMob	0.11***	4.40				
ICTNet			0.09*	1.73		
ICTTel					0.28***	5.15
Capital	0.45**	2.08	0.63**	2.07	0.40*	1.76
Labour	2.94**	2.16	2.38***	1.60	2.65**	2.02
FD	0.35**	1.28	0.47**	1.32	0.54**	1.96
Trade	0.07**	2.36	0.08***	2.59	0.05*	1.90
FDI	0.56**	2.08	0.57**	2.03	0.62***	2.51

Note(s): ***p < 0.01; **p < 0.05; *p < 0.1

Table 9.
Results of CCEMG estimation

telephones had already been installed decades ago in high-income countries, so their growth effect would be less substantial than that caused by massive Internet infrastructure penetration. Therefore, ICT Internet tends to have more impact on promoting economic growth in high-income countries (Kurniawati, 2020).

In middle-income countries, the ICT Internet variable had a lower impact on promoting economic growth. The magnitude of Internet penetration was lower than mobile and telephone users, meaning that middle-income countries have started to benefit from ICT Internet and support previous findings showing that the opportunities from ICT investments may not be fully grasped in the rural areas of middle-income countries (Chavula, 2013). There are several reasons why new technologies, such as the Internet, may not have a significant impact on middle-income countries. The Internet is more expensive than telephone access and requires a higher education level and skill to operate than a telephone. The dominant languages of the Internet are generally not those used by poor people in rural areas. Also, the Internet requires a critical mass of users to be sustainable. These are notably lacking in the rural areas of middle-income countries, which are less aware of the Internet and smartphone.

The analysis of the capital variable indicated a profoundly positive impact on high- and middle-income countries, meaning that gross fixed capital formation is an engine for economic growth in this region (Adeleye and Eboagu, 2019). Capital input appears to be a major driver of economic growth in high- and middle-income Asia countries. Therefore, Asia's productivity will rise as a result of an increase in capital investment.

Moreover, the results obtained on labour participation correspond with the theory that labour is essential for growth. The coefficient of labour was positive and significant at the 1% level in high-income countries and had a higher value in middle-income countries, meaning that a proportional increase in economic growth occurs when total labour participation changes by 1%, on average, ceteris paribus. The greater value of the labour coefficient in middle-income countries may be because a large percentage of skilled labour results in an increased productiveness of the labour force, thereby raising economic growth.

The analysis of the trade coefficient showed positive and statistically significant results at the 1% level in high- and middle-income countries. The magnitude of the trade coefficient illustrated a higher value in high-income countries than in middle-income countries. The results postulated that high-income Asian countries, accelerating trade liberalisation policies and drastically easing restrictions on capital ownership of foreign companies fostered a significant increase in global capital (Ahmed, 2017).

Regarding the effects of FDI on economic growth, the middle-income countries showed a greater FDI impact than the high-income countries, meaning that foreign capital contributes more to boost the economy in middle-income countries than high-income countries. Therefore, FDI is a driving engine for economic growth and has a positive effect on per capita output (Asongu and Odhiambo, 2020; Kurniawati, 2017).

5. Conclusion

This study examined the linkage between ICT development and economic growth in high- and middle-income Asian countries by using three ICT indicators (Internet usage, mobile phone usage and fixed telephone usage).

Several significant findings arose from this exercise. First, this study substantiated that ICT has a statistically significant influence on Asia's economic growth. The association between economic growth and ICT, which is measured as the penetration of Internet users, was highly significant in high-income Asian countries. In contrast, the ICT measurements of telephone line and mobile phone penetration were highly significant in middle-income Asian countries. Second, this study found that the gross fixed capital formation is an essential ingredient for growth in the high- and middle-income regions. The impact was positive on both, but higher for high-income countries. Third, labour force participation has a positive effect on growth in both high- and middle-income countries. This is likely because a large percentage of skilled labour resulted in the labour force's productiveness, thereby increasing economic growth. Fourth, as with other explanatory variables, financial development, trade openness and FDI had a significantly positive impact on economic growth in both regions.

The implication of these findings is that well-maintained ICT infrastructure has the capacity to accelerate economic growth in Asia. Based on the key findings, increasing the number of Internet users and mobile phone subscriptions are crucial to achieving sustainable economic development in high-income Asian countries. Therefore, an effective and efficient digital program must be created within high-income Asian countries to maintain high-speed ICT services and high-quality ICT infrastructure. Countries with an appropriate ICT infrastructure policy can support feasible ICT penetration. This may drive the processes of economic development and innovation that contribute to economic growth.

Moreover, in middle-income Asian countries, the establishment of better-quality ICT service and infrastructure is fundamental to promoting economic growth. Policymakers should accommodate sufficient support to establish ICT infrastructure and enlarge ICT penetration. They should also encourage investors to back the expansion of the Internet. Improving the quality of digital platforms in middle-income Asian countries would assist rural and remote society in reducing the geographical limitations and technology gap, which prevent them from obtaining information and opportunities from other regions.

Information and communication technologies have contributed positively to economic growth in Asia countries. Three ICT indicators showed significant contribution to Asia's economy. When examining each technology factor separately, Internet penetration had the largest positive impact in high-income Asian countries, while telephone landline infrastructure was the most significant in middle-income Asian countries. Based on these empirical results, straightforward policy recommendations can be formed for high-income Asian countries. For example, policymakers should consider a development plan to promote ICT penetration by expanding the ICT infrastructure, increasing the availability of information on markets and technology, reducing the costs of ICT use and elevating the future effects of ICT penetration on growth. The comprehensive ICT policy framework can be expanded in several dimensions: connectivity and access, usage, legal and regulatory framework, production and trade, skills and human resources, cybersecurity and new applications.

The results for middle-income countries also inform essential policy recommendations. First, the development of physical infrastructures, such as broadband, landline and mobile phones are critical. Second, the expansion of Internet access to rural areas, including easy access to information and secure communication services, is required. Third, improvement is needed in the ability of education systems to prepare ICT promotional skills. Fourth, Internet functioning must be enhanced to widen services, including business, marketing, advertisement, e-government, e-commerce and others.

This study has succeeded in unfolding the relationship between ICT and economic growth in high- and middle-income Asian countries. However, future studies should refocus the problem statement on other regions and apply the newest data. The selection of different countries may provide different results and, therefore, updated policy suggestions.

References

Adedoyin, F.F., Bekun, F.V., Driha, O.M. and Balsalobre-Lorente, D. (2020), "The effects of air transportation, energy, ICT and FDI on economic growth in the industry 4.0 era: evidence from the USA", *Technological Forecasting and Social Change*, Vol. 160, 120297.

Adeleye, N. and Eboagu, C. (2019), "Evaluation of ICT development and economic growth in Africa", *Netnomics: Economic Research and Electronic Networking*, Vol. 20 No. 1, pp. 31-53.

Agarwal, S., Sharma, G., Jhingran, V., Sharma, V. and Rawat, Y. (2018), "Role of ICT in economic growth of India", *Disruptive Technologies Transforming Businesses*, Kanpur.

Ahmed, E. (2017), "ICT and human capital spillover effects in achieving sustainable East Asian knowledge-based economies", *Journal of the Knowledge Economy*, Vol. 8 No. 3, pp. 1086-1112.

Alshubiri, F., Jamil, S.A. and Elheddad, M. (2019), "The impact of ICT on financial development: empirical evidence from the Gulf Cooperation Council countries", *International Journal of Engineering Business Management*, SAGE Publications STM, Vol. 11, 1847979019870670.

Asongu, S.A. and Odhiambo, N.M. (2019), "How enhancing information and communication technology has affected inequality in Africa for sustainable development: an empirical investigation", *Sustainable Development*, John Wiley & Sons, Vol. 27 No. 4, pp. 647-656.

Asongu, S.A. and Odhiambo, N.M. (2020), "Foreign direct investment, information technology and economic growth dynamics in Sub-Saharan Africa", *Telecommunications Policy*, Vol. 44 No. 1, p. 101838.

Bahrini, R. and Qaffas, A.A. (2019), "Impact of information and communication technology on economic growth: evidence from developing countries", *Economies*, Vol. 7 No. 21, doi: 10.3390/economies7010021.

Breusch, T.S. and Pagan, A.R. (1980), The lagrange multiplier test and its applications to model specification in econometrics, *The Review of Economic Studies*, Oxford University Press, Review of Economic Studies, Vol. 47 No. 1, pp. 239-253.

Chakpitak, N., Maneejuk, P., Chanaim, S. and Sriboonchitta, S. (2018), "Thailand in the era of digital economy: how does digital technology promote economic growth? BT - predictive econometrics and big data", in Kreinovich, V., Sriboonchitta, S. and Chakpitak, N. (Eds), Springer International Publishing, Cham, pp. 350-362.

Chavula, H.K. (2013), "Telecommunications development and economic growth in Africa", *Information Technology for Development*, Routledge, Vol. 19 No. 1, pp. 5-23.

Czernich, N., Falck, O., Kretschmer, T. and Woessmann, L. (2011), "Broadband infrastructure and economic growth*", *The Economic Journal*, John Wiley & Sons, Vol. 121 No. 552, pp. 505-532.

Dewan, S. and Kraemer, K.L. (2000), "Information technology and productivity: evidence from country-level data", *Management Science*, Vol. 46 No. 4, pp. 548-562.

Donou-Adonsou, F. and Lim, S. (2018), "On the importance of Chinese investment in Africa", *Review of Development Finance*, Vol. 8 No. 1, pp. 63-73.

Dumitrescu, E.I. and Hurlin, C. (2012), "Testing for Granger non-causality in heterogeneous panels", *Economic Modelling*, Vol. 29 No. 4, pp. 1450-1460.

Erumban, A.A. and Das, D.K. (2016)Information and communication technology and economic growth in India, *Telecommunications Policy*, Elsevier, Vol. 40 No. 5, pp. 412-431.

Evangelista, R., Guerrieri, P. and Meliciani, V. (2014), "The economic impact of digital technologies in Europe", *Economics of Innovation and New Technology*, Routledge, Vol. 23 No. 8, pp. 802-824.

Fernández-Portillo, A., Almodóvar-González, M. and Hernández-Mogollón, R. (2020), "Impact of ICT development on economic growth. A study of OECD European Union countries", *Technology in Society*, Vol. 63, p. 101420.

Ghosh, S. (2017), "Broadband penetration and economic growth: do policies matter?", *Telematics and Informatics*, Vol. 34 No. 5, pp. 676-693.

Henry, O. and Stephen, O. (2010), "Information and communication technologies adoption in SMEs: literature review", *Journal of Chinese Entrepreneurship*, Emerald Group Publishing, Vol. 2 No. 1, pp. 93-104.

Hong, J. (2017), "Causal relationship between ICT R&D investment and economic growth in Korea", *Technological Forecasting and Social Change*, Elsevier, Vol. 116, pp. 70-75.

International Telecommunication Union (2018), *Measuring the Information Society Report 2018*, ITU Publications, Geneva, Vol. 1.

Ishida, H. (2015), "The effect of ICT development on economic growth and energy consumption in Japan", *Telematics and Informatics*, Vol. 32 No. 1, pp. 79-88.

Khan, H., Khan, U., Jiang, L.J. and Khan, M.A. (2020), "Impact of infrastructure on economic growth in South Asia: evidence from pooled mean group estimation", *The Electricity Journal*, Vol. 33 No. 5, p. 106735.

Kim, Y.M. and Park, K.S. (2020), "Labour share and economic growth in OECD countries", *Global Economic Review*, Routledge, Vol. 49 No. 1, pp. 1-22.

Kumar, R.R., Stauvermann, P.J. and Samitas, A. (2016), "The effects of ICT on output per worker: a study of the Chinese economy", *Telecommunications Policy*, Vol. 40 No. 2, pp. 102-115.

Kurniawati, M.A. (2017), "Causal interaction between FDI , capital formation, trade and economic growth : evidence from dynamic panel analysis Kurniawati", *Journal of Business and Policy Research*, Vol. 12 No. 1, pp. 72-87.

Kurniawati, M.A. (2020), "The role of ICT infrastructure, innovation and globalization on economic growth in OECD countries, 1996–2017", *Journal of Science and Technology Policy Management*, Vol. 11 No. 2, doi: 10.1108/JSTPM-06-2019-0065.

Lee, S.-O., Hong, A. and Hwang, J. (2017), "ICT diffusion as a determinant of human progress", *Information Technology for Development*, Routledge, Vol. 23 No. 4, pp. 687-705.

Levin, A., Lin, C.F. and Chu, C.S.J. (2002), "Unit root tests in panel data: asymptotic and finite-sample properties", *Journal of Econometrics*, Vol. 108 No. 1, pp. 1-24.

Maddala, G.S. and Wu, S. (1999), "A comparative study of unit root tests with panel data and a new simple test", *Oxford Bulletin of Economics and Statistics*, Vol. 61 No. s1, pp. 631-652.

Maneejuk, P. and Yamaka, W. (2020), "An analysis of the impacts of telecommunications technology and innovation on economic growth", *Telecommunications Policy*, Vol. 44 No. 10, 102038.

Muhammad, B. and Khan, S. (2019), "Effect of bilateral FDI, energy consumption, CO2 emission and capital on economic growth of Asia countries", *Energy Reports*, Vol. 5, pp. 1305-1315.

Myovella, G., Karacuka, M. and Haucap, J. (2020), "Digitalization and economic growth: a comparative analysis of Sub-Saharan Africa and OECD economies", *Telecommunications Policy*, Vol. 44 No. 2, 101856.

Nair, M., Pradhan, R.P. and Arvin, M.B. (2020), "Endogenous dynamics between R&D, ICT and economic growth: empirical evidence from the OECD countries", *Technology in Society*, Vol. 62, 101315.

Pedroni, P. (1999), "Critical values for cointegration tests in heterogeneous panels with multiple regressors", *Oxford Bulletin of Economics and Statistics*, John Wiley & Sons, Vol. 61 No. S1, pp. 653-670.

Pedroni, P. (2000), "Fully modified OLS for heterogeneous cointegrated panels", available at: https://econpapers.repec.org/RePEc:wil:wileco:2000-03.

Pedroni, P. (2001), "Purchasing power parity tests in cointegrated panels", *Review of Economics and Statistics*, Vol. 83 No. 4, pp. 727-731.

Pesaran, M.H. (2004), *General Diagnostic Tests for Cross Section Dependence in Panels, Cambridge Working Papers in Economics*, Faculty of Economics, University of Cambridge, Faculty of Economics, University of Cambridge, available at: https://ideas.repec.org/p/cam/camdae/0435.html.

Pesaran, M.H. (2006), "Estimation and inference in large heterogeneous panels with a multifactor error structure", *Econometrica*, John Wiley & Sons, Vol. 74 No. 4, pp. 967-1012.

Pesaran, M. (2007), "A simple panel unit root test in the presence of cross-section dependence", *Journal of Applied Econometrics*, Vol. 22 No. 2, pp. 265-312.

Pradhan, R.P., Arvin, M.B., Hall, J.H. and Nair, M. (2016), "Innovation, financial development and economic growth in Eurozone countries", *Applied Economics Letters*, Routledge, Vol. 23 No. 16, pp. 1141-1144.

Pradhan, R.P., Arvin, M.B., Nair, M., Mittal, J. and Norman, N.R. (2017), "Telecommunications infrastructure and usage and the FDI–growth nexus: evidence from Asian-21 countries", *Information Technology for Development*, Routledge, Vol. 23 No. 2, pp. 235-260.

Raheem, I.D., Tiwari, A.K. and Balsalobre-Lorente, D. (2020), "The role of ICT and financial development in CO2 emissions and economic growth", *Environmental Science and Pollution Research*, Vol. 27 No. 2, pp. 1912-1922.

Roller, L.H. and Waverman, L. (2001), "Telecommunications infrastructure and economic development: a simultaneous approach", *American Economic Review*, Vol. 91 No. 4, pp. 909-923.

Salahuddin, M. and Alam, K. (2015), "Internet usage, electricity consumption and economic growth in Australia: a time series evidence", *Telematics and Informatics*, Vol. 32 No. 4, pp. 862-878.

Salahuddin, M. and Gow, J. (2016), "The effects of Internet usage, financial development and trade openness on economic growth in South Africa: a time series analysis", *Telematics and Informatics*, Vol. 33 No. 4, pp. 1141-1154.

Sassi, S. and Goaied, M. (2013), "Financial development, ICT diffusion and economic growth: lessons from MENA region", *Telecommunications Policy*, Vol. 37 No. 4, pp. 252-261.

Sinha, M. and Sengupta, P.P. (2019), "FDI inflow, ICT expansion and economic growth: an empirical study on Asia-pacific developing countries", *Global Business Review*, 0972150919873839, SAGE Publications India.

Solarin, S.A. (2020), "The effects of shale oil production, capital and labour on economic growth in the United States: a maximum likelihood analysis of the resource curse hypothesis", *Resources Policy*, Vol. 68, 101799.

Solomon, E.M. and van Klyton, A. (2020), "The impact of digital technology usage on economic growth in Africa", *Utilities Policy*, Vol. 67, 101104.

Stock, T. and Seliger, G. (2016), "Opportunities of sustainable manufacturing in industry 4.0", *Procedia CIRP*, Vol. 40, pp. 536-541.

van Ark, H.H., Gupta, A. and Erumban (2011), *Measuring the Contribution of ICT to Economic Growth*, Fundación Telefónica, Madrid.

World Bank (2020), *World Development Indicators | DataBank*, The World Bank Group.

Yakunina, R.P. and Bychkov, G.A. (2015), "Correlation analysis of the components of the human development index across countries", *Procedia Economics and Finance*, Vol. 24, pp. 766-771.

Zhang, J. and Danish (2019), "The dynamic linkage between information and communication technology, human development index, and economic growth: evidence from Asian economies", *Environmental Science and Pollution Research*, Vol. 26 No. 26, pp. 26982-26990.

Appendix

Null hypothesis A does not homogeneously cause B	High-income countries W-stat	High-income countries Inferences	Middle-income countries W-stat	Middle-income countries Inferences
CAP−GDP	2.06*	CAP → GDP	2.13*	CAP ↔ GDP
GDP−CAP	1.26		2.15*	
LAB−GDP	4.32***	LAB ↔ GDP	6.07***	LAB ↔ GDP
GDP−LAB	5.65***		2.06*	
ICTMob−GDP	3.13***	ICTmob → GDP	6.17***	ICTmob ↔ GDP
GDP−ICTMob	0.85		4.53***	
ICTNET-GDP	2.54***	ICTNet ↔ GDP	3.94***	ICTNet ↔ GDP
GDP−ICTNET	2.22**		4.14***	
ICTTel−GDP	5.40***	ICTtel → GDP	4.65***	ICTtel ↔ GDP
GDP−ICTTel	1.85		14.86***	
FD−GDP	1.71	GDP → FD	1.01	GDP → FD
GDP−FD	2.41**		2.46***	
TRD−GDP	2.07**	TRD ↔ GDP	3.49***	TRD ↔ GDP
GDP−TRD	2.44**		3.49***	
FDI−GDP	1.44	GDP → FDI	3.14***	FDI → GDP
GDP−FDI	4.25***		1.61	
LAB−CAP	1.16	CAP → LAB	1.62	CAP → LAB
CAP−LAB	3.43***		2.09*	
ICTMob−CAP	1.00	No Causality	3.87***	ICTmob ↔ CAP
CAP−ICTMob	1.55		2.65***	
ICTNET−CAP	0.72	No Causality	2.69***	ICTNet ↔ CAP
CAP−ICTNET	1.13		3.35***	
ICTTel−CAP	2.21**	ICTtel ↔ CAP	2.73***	ICTtel ↔ CAP
CAP−ICTTel	3.46***		4.83***	
FD−CAP	1.12	No Causality	1.59	CAP → FD
CAP−FD	1.53		3.75***	
TRD−CAP	1.84	CAP → TRD	2.23*	TRD ↔ CAP
CAP−TRD	3.25***		2.29**	
FDI−CAP	1.34	CAP → FDI	1.75	CAP → FDI
CAP−FDI	4.02***		2.09*	
ICTMOB−LAB	9.23***	ICTmob ↔ LAB	2.79***	ICTmob → LAB
LAB−ICTMob	2.55***		1.72	
ICTNET−LAB	6.45***	ICTNet ↔ LAB	1.48	LAB → ICTNet
LAB−ICTNET	3.80***		3.63***	
ICTTel−LAB	4.76***	ICTtel ↔ LAB	2.15**	ICTtel ↔ LAB
LAB−ICTTel	2.62***		13.20***	
FD−LAB	4.98***	FD ↔ LAB	3.26***	FD ↔ LAB
LAB−FD	4.30***		3.20***	
TRD−LAB	5.49***	TRD ↔ LAB	2.13**	TRD ↔ LAB
LAB−TRD	3.02***		3.26***	
FDI−LAB	3.25***	FDI ↔ LAB	1.78	No causality
LAB−FDI	5.91***		1.60**	
FD−ICTMob	2.36**	FD ↔ ICTmob	2.77***	FD ↔ ICTmob
ICTMob−FD	2.70***		5.74***	
FD−ICTNET	1.64	ICTNet → FD	3.78***	FD ↔ ICTNet
ICTNET−FD	4.29***		4.91***	

(*continued*)

Table A1. DH causality test results

Null hypothesis A does not homogeneously cause B	High-income countries W-stat	Inferences	Middle-income countries W-stat	Inferences
FD–ICTTel	1.79	ICTtel → FD	7.41***	FD → ICTtel
ICTTel–FD	3.72***		1.27	
TRD–ICTMob	3.32***	TRD ↔ ICTmob	3.37***	TRD ↔ ICTMob
ICTMob–TRD	2.31**		3.29***	
TRD–ICTNET	1.37	ICTNet → TRD	1.80	ICTNet → TRD
ICTNET–TRD	4.44***		2.35**	
TRD–ICTTel	2.30**	TRD ↔ ICTtel	3.99***	TRD ↔ ICTtel
ICTTel–TRD	3.66***		4.07***	
FDI–ICTMob	1.09	ICTmob → FDI	1.85	ICTmob → FDI
ICTMob–FDI	4.44***		2.20**	
FDI–ICTNET	5.40***	FDI ↔ ICTNET	2.43**	FDI → ICTNet
ICTNET–FDI	3.49***		1.92	
FDI–ICTTel	1.44	ICTtel → FDI	2.44***	FDI → ICTtel
ICTTel–FDI	2.42**		1.02	
TRD–FD	3.44***	TRD ↔ FD	1.91	FD → TRD
FD–TRD	2.75***		2.01*	
FDI–FD	1.53	FD → FDI	2.15*	FD ↔ IFD
FD–FDI	3.19***		2.12*	
FDI–TRD	1.76	No causality	1.90	TRD → FDI
TRD–FDI	1.88		2.63***	

Table A1.

Note(s): ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Corresponding author
Meta Ayu Kurniawati can be contacted at: kurniawati.meta473@gmail.com