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# Analysing the Role of Information and Communication Technology on Asia's Economic Development: Comparing Lower-Middle, Upper-Middle, and High-Income Asian Countries

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Nowadays, it cannot be denied that the world economy development is inseparable from the influence of information and communication technology (ICT), Asia is no exception. ICT can improve lives in many other ways, such as through education, skills development, new service creation, innovation, and automation, which in turn can improve economic development. This study aims to analyse the relationship between ICT and economic development in Asian countries based on the standard production function, specifically to test whether ICT has a different impact on the type of economies levels, namely: lower-middle, upper-middle, and high-income countries in Asia. This study uses data from 35 Asian countries in 2010-2018. By applying panel data analysis, this study provides commendable evidence that ICT can significantly contribute to economic development. Of the three income groups, the biggest role of ICT is in the lower-middle-income group. The smallest role of ICT is in the high-income group, where ICT only contributes to the economic growth of less than 15 per cent. It is important for the leaders of Asian countries to learn and adapt the knowledge of ICT through transfer technology programme from high-income countries to lower-middle-income countries to boost economic growth.

**Key words:** *Asia, Economic growth, ICT, Panel Data, Production function.*

**Introduction**

Information and Communication Technology (ICT) can be used as umbrella terminology that includes all technical equipment for processing and conveying information. ICT covers two aspects, namely information technology and communication technology. Information technology is everything that relates to process, manipulation, information management, and use as a tool while communication technology is everything related to the use of tools to process and transfer data from one device to another (media).

Technological progress is something that cannot be avoided in life. Technological progress will develop in line with the development of science and the human mind. In the economic field, advances in information and communication technology provide a lot of convenience and speed in conducting trading/business activities (Draca, Martin, & Sanchis-Guarner, 2018). Many innovations were created to bring benefits to the smooth running of trading/business activities. The use of ICTs to create new services in the economy and business includes e-banking and e-commerce. E-banking is in the form of ATM, Phone Banking, Internet Banking, and SMS Banking services. While for E-Commerce is the distribution, purchase, sale, marketing of goods and services through electronic systems such as the internet or television, www, or other computer networks.

Improving the quality of life of a nation, region or local community as well as economic well-being is called as economic development (Todaro & Smith, 2011), whereas economic growth is a rise in GDP which is a market productivity phenomenon. Consequently, as economist Amartya Sen points out, "economic growth is one aspect of the process of economic development" (Sen, 1983). Economic growth is increasing the value of inflation-adjusted market of goods and services, which usually measured in percentage increase of gross domestic product in real value or also known as the real GDP. Therefore, in this study, the term economic development and economic growth will be used interchangeably.

In relation with the ICT, ICT can improve lives in many other ways, such as through education, skills development, new service creation, innovation, and automation, which in turn can improve economic development. Therefore, it cannot be denied that the development of the world economy is inseparable from the influence of information and communication technology (ICT), Asia is no exception.

**Figure 1.** GNI Percapita of The World (2018)

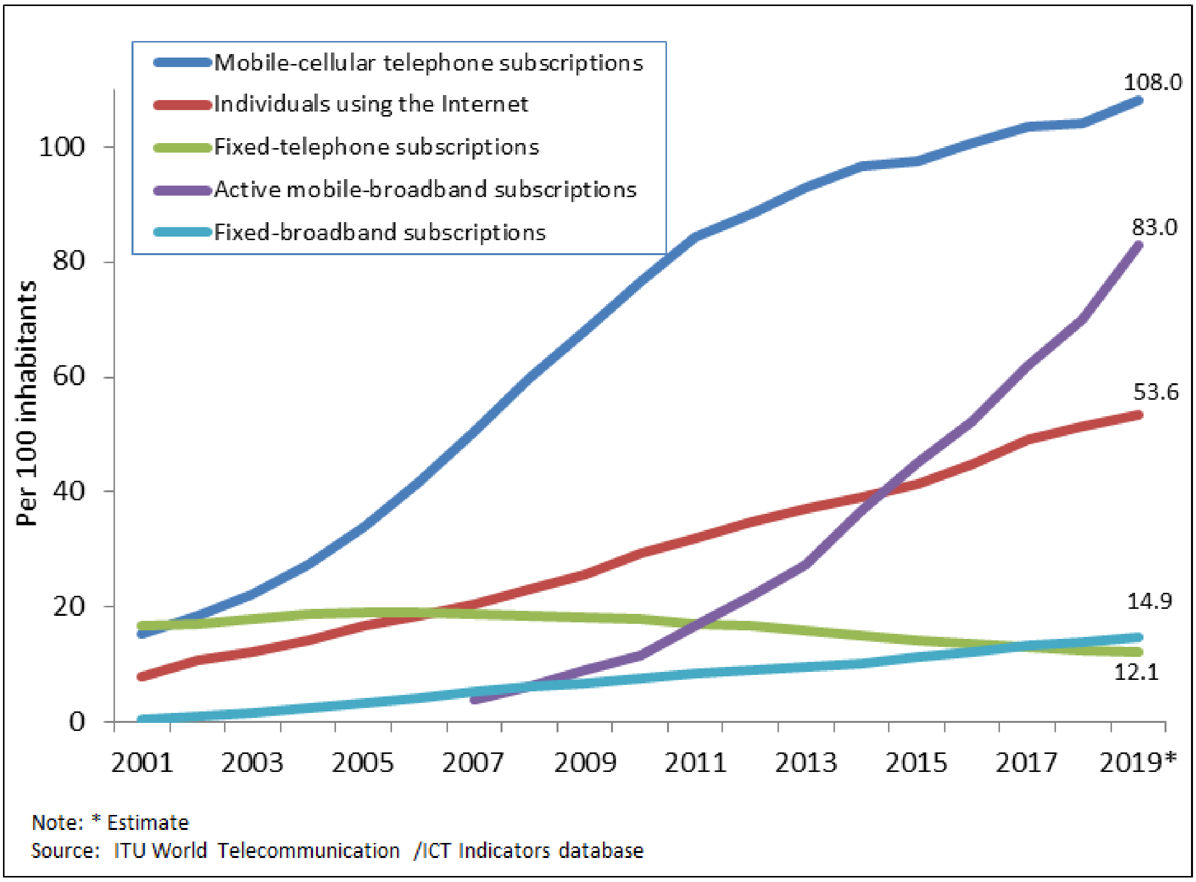

***Source:*** *World Bank*

Based on the data from the United Nations, in Asia, currently, there are 48 countries. In which, Asia is the most populous continent in the world, with about 4.6 billion people or approximately 59.7 % of the total world population lives on this continent, which reflects the huge available market potential. In 2017, Asia has a combined GDP 28.96 trillion USD or about 35.79% of the world GDP, and GDP per capita of Asia is 6,799 USD and expected to reach 8,897 USD by 2021. From these figures, it can be seen that there a lot of potential for the economy in Asia to grow, which in turn brings more prosperity to the people. One of them is through the use of ICT, namely E-banking and E-commerce. In the last few years, e-commerce in Asia has shown a very startling development, both users (sellers and buyers), the traded goods and services, as well as the trade values. Based on Figure 1, most of the countries in Asia are classified as medium-income countries, namely having GNI per capita about 1,035 USD to 12,615 USD, and only a few that classified as high-income countries, namely having GNI per capita more than 12,615 USD (WorldBank, 2018).

On the other hand, the development of ICT worldwide shows an increasing trend (Figure 2). Figure 2 presents the number of subscriptions of ICT's indicators per 100 inhabitants. Based on Figure 2, from five indicators of ICT, two indicators show a very striking development, namely mobile-cellular telephone subscriptions and active mobile-broadband subscriptions. These facts indicate that internet penetration has shown rapid development. While the other two indicators show a stable development, only the last shows a lower development, these two indicators are individuals using the internet and fixed-broadband subscriptions. Out of five ICT's indicator, only fixed-telephone subscription shows a declining trend.

The development of ICT is not only happening on the global scale but also regional, including in Asia. Nowadays, Internet penetration in Asia is 48%, in which in 2021 is expected to reach 59% by 2021. Meanwhile, the penetration of smartphone is 35% and should be grown to 44% by 2021. These numbers might seem daunting, but Asia is a large region and has a lot of opportunity for e-commerce to grow, which lies in densely populated markets, in which often, the penetration of smartphone surpass the world's penetration. In addition, 48% of online shoppers in Asia prefer to shop online via desktop, which is lower than the global average, 19% of online shoppers use mobile, and 25% claim to have no preference (Statista, 2017). Thus, it is evident that ICT plays a significant and massive role in the growth of e-commerce towards economic development in Asia.

**Figure 2.** Global ICT developments, 2001-2019




However, it should be aware that the role of ICT for the development of economy may differ according to the country's economy itself, namely lower-middle, upper-middle, and high income. Thus, although there are plenty of pieces of literature on ICT and economic development or economic growth, most of the studies is based on the experience of the developed economies. There have not been many researchers conducted on countries in Asia, especially by taking into account the country level of income. This study aims to analyse the impact of ICT on the economic growth of Asian countries based on their level of income.

The organization of the paper is as follows: the first section, "Introduction" gives the background of the study as well as the research problem. Next, the "Literature Review" section is filling with a literature review of the studies. The data and their sources are presented in the "Methodology" section. This section also introduced empirical method used for this study. The results and analysis will be discussed in the "Results and Findings" section. And finally, the "Conclusion" section will be providing the conclusion of this study as well as the recommendation based on the findings.

**Literature Review**

There have been some researchers studied about the impact of ICT on economic development (Baily, 1986; Bassanini, Scarpetta, & Visco, 2000; Bosworth & Triplett, 2001; Datta* & Agarwal, 2004; Kraemer & Dedrick, 1999; Lau & Tokutsu, 1992; Lehr & Lichtenberg, 1997; Loveman, 1994; Niinien, 1998; Oliner, Sichel, Triplett, & Gordon, 1994; Roach, 1987; Roller & Waverman, 2001; Solow, 1957; Wong, 2001). This shows the increasing of attention of many economists and researchers to focus on studying the impact of ICT diffusion on economic growth, especially of developed and developing economies (Yousefi, 2011), which also shows the important role of ICT in economic growth.

Theoretically, there is a significant and positive relationship between ICT and economic development, as highlighted by (Schumpeter, 2017), (Pyka & Andersen, 2012), and (Solow, 1957). They argued that ICT has a role as an input in the economic supply, which in turn caused an improvement in the process of production through capital and making a refinement in the quality of technology and labour force. In addition, (Aghaei & Rezagholizadeh, 2017) and (Quah, 2002) emphasized that at the firm level and the sectoral level, the ICT has created added value which leads to the productivity and economic growth improvement at the national level.

Whilst, theoretically, ICT has shown a positive effect on economic development, several empirical studies on this relationship have produced mixed results. Some found that there was a no significant relationship between ICT and economic growth (Baily, 1986; Baily, Gordon, Nordhaus, & Romer, 1988; Loveman, 1994; Strassman, 1997). They found that there was a limitation of the productivity gain from IT in the aggregate economy. (Pohjola, 2002) also did not find any statistically significant correlation between ICT and economic growth in the case of 43 developing countries from 1985 to 1999, this is due to the poor accessibility and availability of communications technology and technology-based products in many developing countries.

On the other hand, numerous studies have confirmed the presence of a significant positive impact of ICT on economic growth. Studies; such as by (S.-Y. T. Lee, Gholami, & Tong, 2005), (Papaioannou & Dimelis, 2007), (Hardy, 1980), (Roller & Waverman, 2001), and (Madden & Savage, 1998); have found that ICT had a positive impact on economic growth. By using a sample of 27 Central and Eastern European countries during the period 1990–1995, among others, (Madden & Savage, 1998), revealed a strong positive relationship between ICT investment and economic growth. Similarly, (S. H. Lee, Levendis, & Gutierrez, 2012) by applying a linear GMM estimator on data from 44 Sub-Saharan countries over the period 1975–2006 confirmed that mobile phone expansion, as a form of telecommunication infrastructure investments, is an important determinant of the rate of economic growth in Sub-Saharan Africa.

Nevertheless, other studies found that ICT harms economic growth, as studied by (Legge, 2000) and (Aghion et al., 1998), among others. They argued that due to the reduction or elimination of positions for unskilled workers, which in turn increasing unemployment, ICT could negatively affect employment and the labour market, especially in developing countries. Also, the use of ICT has attracted for the opening of new markets for developed countries at the expense of developing countries. This will increase the domination of the developed countries which are more competitive over the developing countries which are less competitive in the international markets.

## Methodology

### *Data Sources*

We use GNI per capita, PPP (constant 2011 international $), from the World Bank as a response variable. Meanwhile, ICT indicators, act as a predictor variable, that we use are: fixed-broadband subscriptions per 100 inhabitants, fixed-telephone subscriptions per 100 inhabitants, percentage of individuals using the internet, and mobile-cellular telephone subscriptions per 100 inhabitants. This ICT data was taken from the International Telecommunication Union (ITU). We also use the level of income, namely: lower-middle, upper-middle, and high-income countries to construct a dummy variable as a predictor. All data are collected from 2010 to 2018. This study analyses 35 Asian Countries due to the incompleteness of the country data.

***Data Analysis***

We use balanced panel data analysis to estimate the impact of ICT indicators (fixed-broadband subscriptions per 100 inhabitants, fixed-telephone subscriptions per 100 inhabitants, percentage of individuals using the internet, and mobile-cellular telephone subscriptions per 100 inhabitants) on economic growth (GNI per capita) of Asian countries. We use the standard production function model. We focus on ICT indicators as the determining variables for economic growth (GNI per capita) for Asian countries. In this paper, economic growth is represented by the production function as follow:

$$GNI_{it} = f(FixedBroadband_{it}, FixedTelephone_{it}, Internet_{it}, MobileCellular_{it}) \quad (1)$$

Where at period *t* and country *i*, GNI refer to gross national income, FixedBroadband is fixed-broadband subscriptions per 100 inhabitants, FixedTelephone is fixed-telephone subscriptions per 100 inhabitants, the Internet is a percentage of individuals using the internet, and MobileCellular is mobile-cellular telephone subscriptions per 100 inhabitants. We use the log form of the variables. Log transformation can lessen the violation of heteroscedasticity assumption because it compresses the scale of the measured variables. The new model is as follow:

$$LnGNI_{it} = \alpha_0 + \beta_1 LnFixedBroadband_{it} + \beta_2 LnFixedTelephone_{it} + \beta_3 LnInternet_{it} + \beta_4 LnMobileCellular_{it} + v_{it} + u_{it} \quad (2)$$

where LnGNI is log form of gross national income, LnFixedBroadband is log form of fixed-broadband subscriptions per 100 inhabitants, LnFixedTelephone is log form of fixed-telephone subscriptions per 100 inhabitants, Ln Internet is log form of percentage of individuals using the internet, and LnMobileCellular is log form of mobile-cellular telephone subscriptions per 100 inhabitants. We allowed for the time and country effect as our model utilized the panel estimation technique. The fixed impact assumed constant error for each Asian country. The panel data estimation for v and u assumed that each country has its own behaviour and influenced by different factors represented by the slope and intercepts that is constant across countries and time.

In this paper, we analyse the whole Asian countries and also analyse by income groups separately. For the whole (overall) Asian countries, we added dummy variables, to accommodate the effect of economies level or income group, namely: lower-middle, upper-middle, and high-income countries. The full (overall) model is as follow:

$$LnGNI_{it} = \alpha_0 + \beta_1 LnFixedBroadband_{it} + \beta_2 LnFixedTelephone_{it} + \beta_3 LnInternet_{it} + \beta_4 LnMobileCellular_{it} + \beta_5 D_{1i} + \beta_6 D_{2i} + v_{it} + u_{it} \quad (3)$$

where $D_{1i}$ is dummy positive for upper-middle-income countries, and $D_{2i}$ is dummy positive for high-income countries. Meanwhile, the lower-middle-income class is set to be a reference.
Fixed Effect Model:

$$LnGNI_{it} = (\alpha_i + \beta_1 D_{1i} + \beta_2 D_{2i}) + \beta_3 LnFixedBroadband_{it} + \beta_4 LnFixedTelephone_{it} + \beta_5 LnInternet_{it} + \beta_6 LnMobileCellular_{it} + u_{it} \quad (4)$$

where $u_{it} \sim N(0, \sigma_u^2)$. An individual intercept $\alpha_i$ are included to control for individual-specific and time-invariant characteristics. That intercepts are called fixed effects. Independent variables cannot be time-invariant. All time-invariant variables effect are represented by intercept $(\alpha_i + \beta_1 D_{1i} + \beta_2 D_{2i})$. Fixed effect capture the individual heterogeneity. The estimation methods of the fixed effect model are Least Square Dummy Variable (LSDV) estimator or the fixed effect estimator. It is not feasible to use the least square dummy variable estimator when N is large.

Random Effect Model:

$$LnGNI_{it} = \alpha + \beta_1 LnFixedBroadband_{it} + \beta_2 LnFixedTelephone_{it} + \beta_3 LnInternet_{it} + \beta_4 LnMobileCellular_{it} + \beta_5 D_{1i} + \beta_6 D_{2i} + u_{it} \quad (5)$$

The error component $(u_{it})$ is the sum of the individual-specific random component $(\mu_i)$ and idiosyncratic disturbances $(\varepsilon_{it})$:

$$u_{it} = \mu_i + \varepsilon_{it} \quad (6)$$

where $\mu_{it} \sim N(0, \sigma_\mu^2)$ and $\varepsilon_{it} \sim N(0, \sigma_\varepsilon^2)$. Independent variables can be time-invariant. Individual random effects are independent. The estimation methods of random effect model are generalized least square (GLS). This study uses Swamy-Arora method to estimate the random effect.

## Results and Findings

### *Overview of the Development of Economic Growth and ICT Indicators*

This study used data from 35 countries in Asian from 2010 to 2018. According to the classification of GNI per capita by World Bank, these countries can be classified into three groups, namely Lower-Middle Income, Upper-Middle Income, and High-Income countries. Figure 3, 4, and 5 depict the GNI per capita of these Asian countries based on their classification.

**Figure 3**. GNI Percapita of Lower-Middle Income Asian Countries

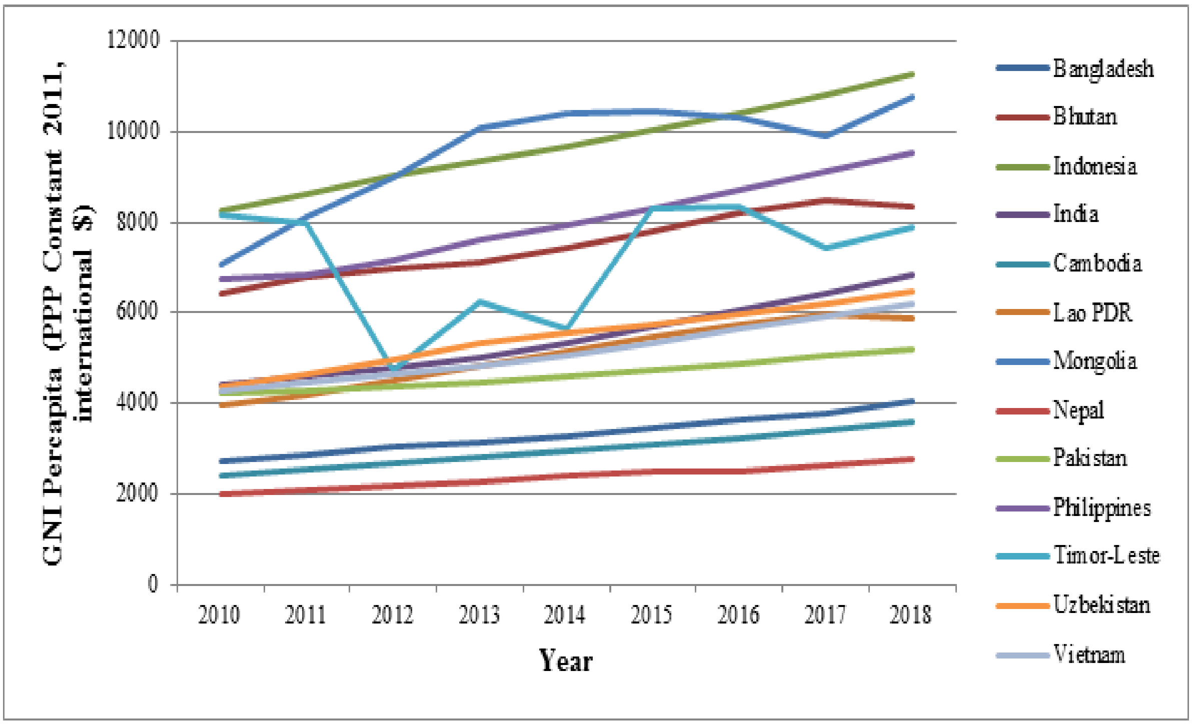



Figure 3 presents the lower-middle-income group, in which there are 13 countries in this group. Most of the countries demonstrate a significant increasing trend in GNI per capita from 2010 to 2018, only Mongolia and Timor Leste that show fluctuations in their GNI per capita, the latter country even, showed a high drop of its GNI per capita in 2012. In 2018, the GNI per capita of Lower-Middle Income countries in Asian was ranging from 2,748 USD (Nepal) to 11,255 USD (Indonesia).

**Figure 4**. GNI Percapita of Upper-Middle Income Asian Countries

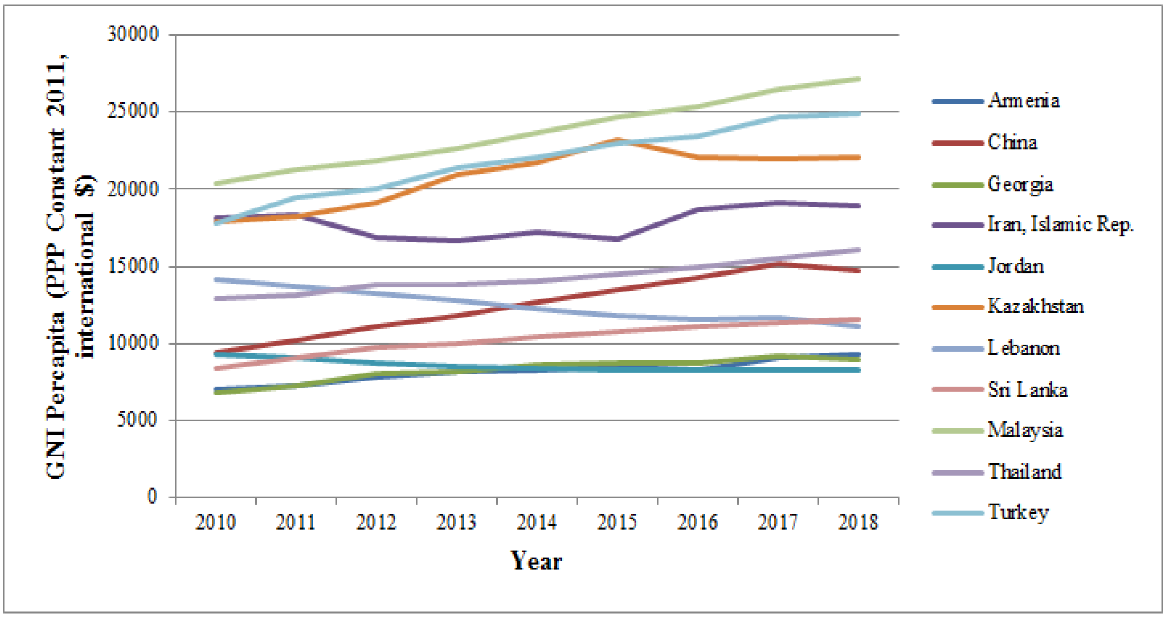
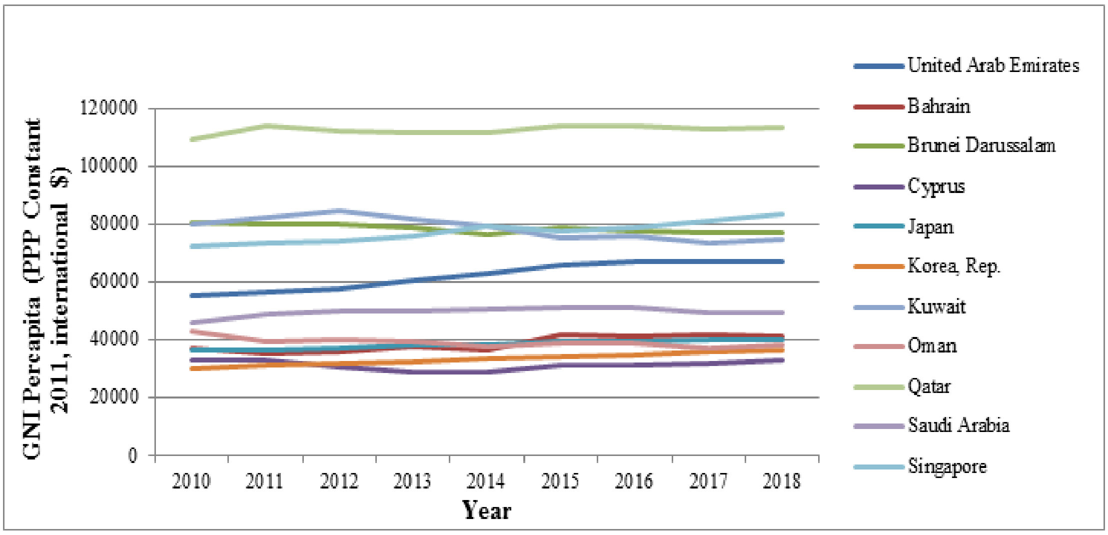



Figure 4 presents the GNI per-capita for the upper-middle-income of Asian countries. There 11 of Asian countries that belong to this group. Although there is some fluctuation, from 2010 to 2018, most of the countries demonstrate an increasing trend, except for Lebanon which shows a decreasing trend. In 2018, the GNI of per capita for upper-middle-income countries ranging from the lowest, 8,267 USD (Jordan) to the highest, 27,226 USD (Malaysia).

**Figure 5**. GNI Percapita of High-Income Asian Countries



Then, the last 11 Asian countries are categorized as high-income countries. Figure 5 depicts these countries based on their GNI per capita form 2010 to 2018, in which most of these countries demonstrate the absence of significant fluctuations, in other words, they have 'a stable' economic growth. In 2018, the country that has the lowest GNI per capita is Cyprus with a value of 33,100 USD, while the country that has the highest GNI per capita is Qatar with a value of 113,549 USD.

All of these figures have shown that during the period of this research, the Asian countries have demonstrated different 'behaviour' on their economic development. Especially when we look at them by income group as discussed earlier. This evidence shows that there are various characteristics among countries in Asia based on their economic development. In which, their economic development have a relationship with the development of ICT indicators, as explained in the following parts.

The ICT indicators use in this study are is explained in the data source. The development of ICT indicators by the income group for the Asian countries are presented in Figure 6 to 17 in the appendix. For fixed broadband subscription (Figure 6-9), shows an increasing trend for most all lower-middle and upper-middle-income countries, whilst for high-income group, some of the countries experiencing slight increasing, while others are experiencing a decline trend such as Cyprus, Singapore, and Bahrain.

**Figure 6.** Fixed-broadband subscriptions per 100 inhabitants of Lower-Middle Income Asian Countries

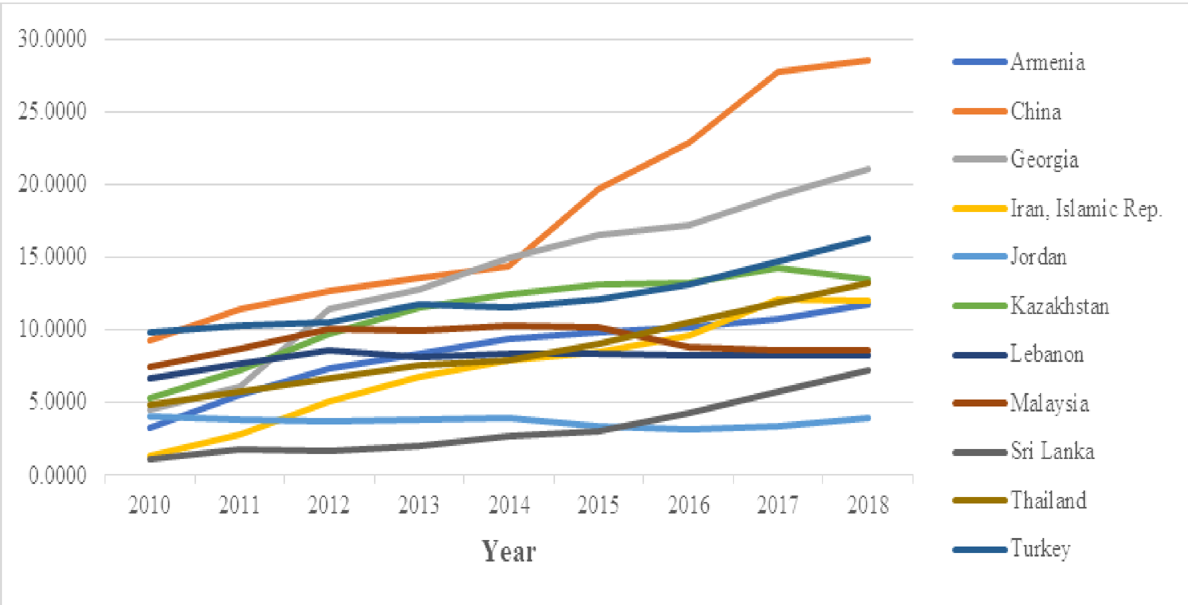


**Figure 7.** Fixed-broadband subscriptions per 100 inhabitants of Upper-Middle Income Asian Countries

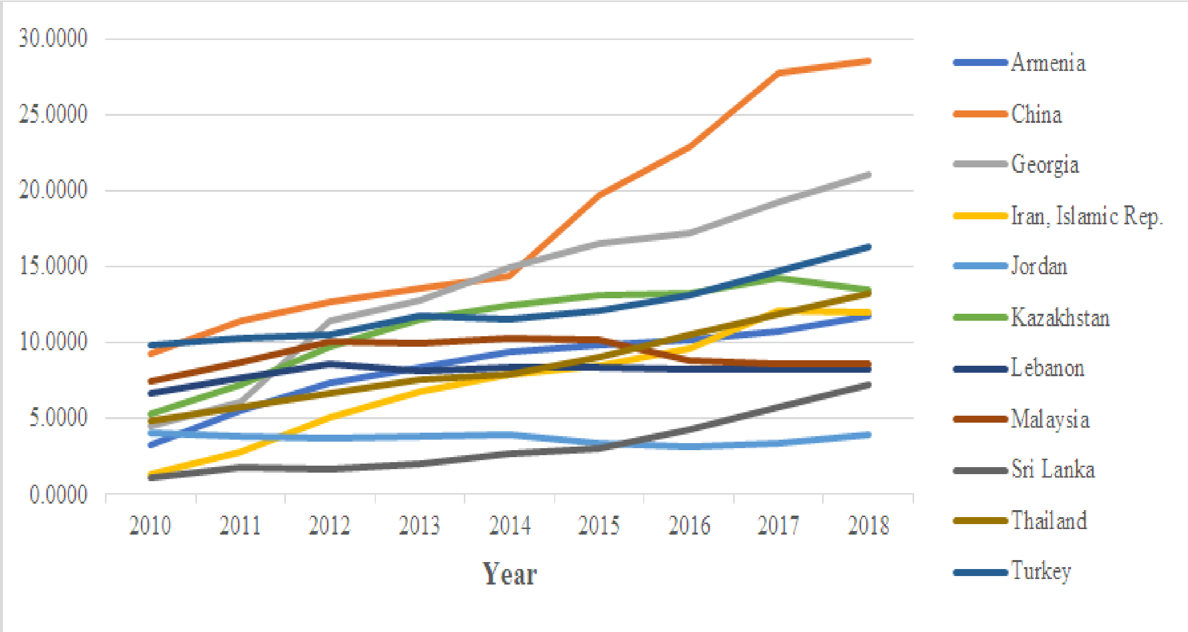



**Figure 8.** Fixed-broadband subscriptions per 100 inhabitants of High Income Asian Countries

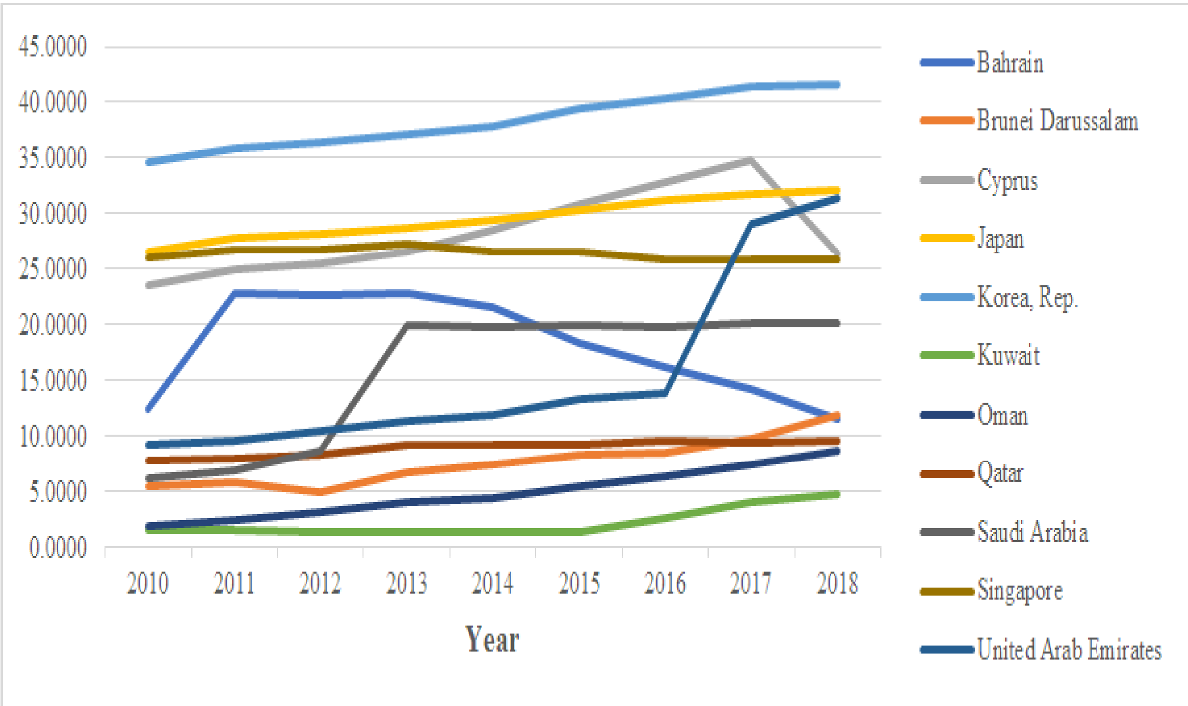
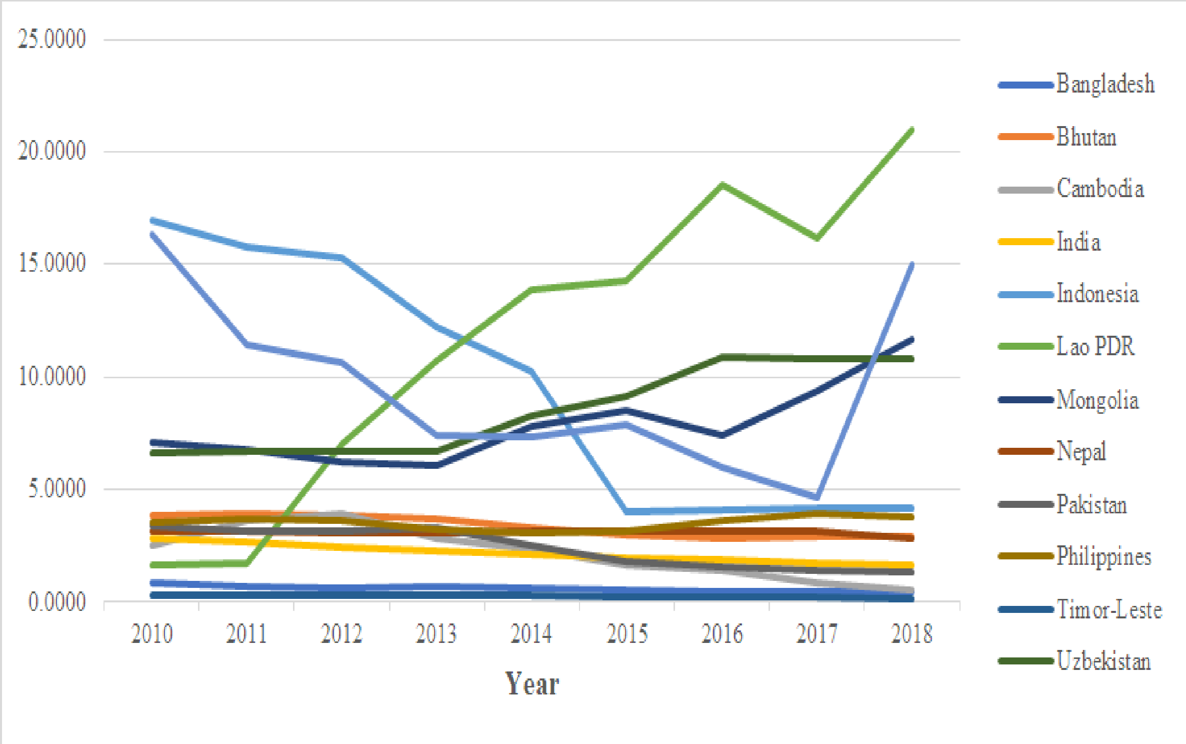


**Figure 9.** Fixed-telephone subscriptions per 100 inhabitants of Lower-Middle Income Asian Countries




Meanwhile, mixed trends have been shown by fixed telephone subscriptions. For lower-middle-income as depicted in Figure 9, some countries experienced very high development such as Lao PDR. On the contrary, some countries are having a declining trend, such as Vietnam and Indonesia. The remaining countries have relatively stable development. The development of fixed telephone subscription in 10 upper-middle countries shows a decreasing trend (Figure 10). Only one country that has a positive trend, that is Iran. For high income, the development of fixed telephone subscription have relatively constant development (Figure 11).

**Figure 10.** Fixed-telephone subscriptions per 100 inhabitants of Upper-Middle Income Asian Countries

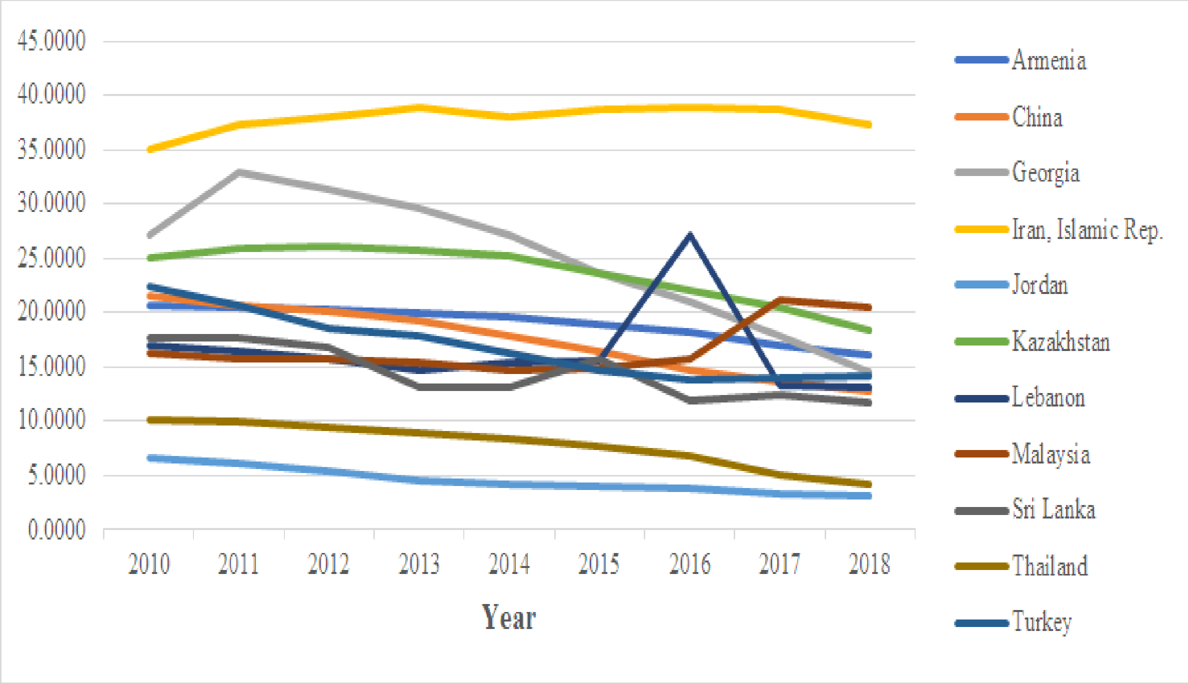
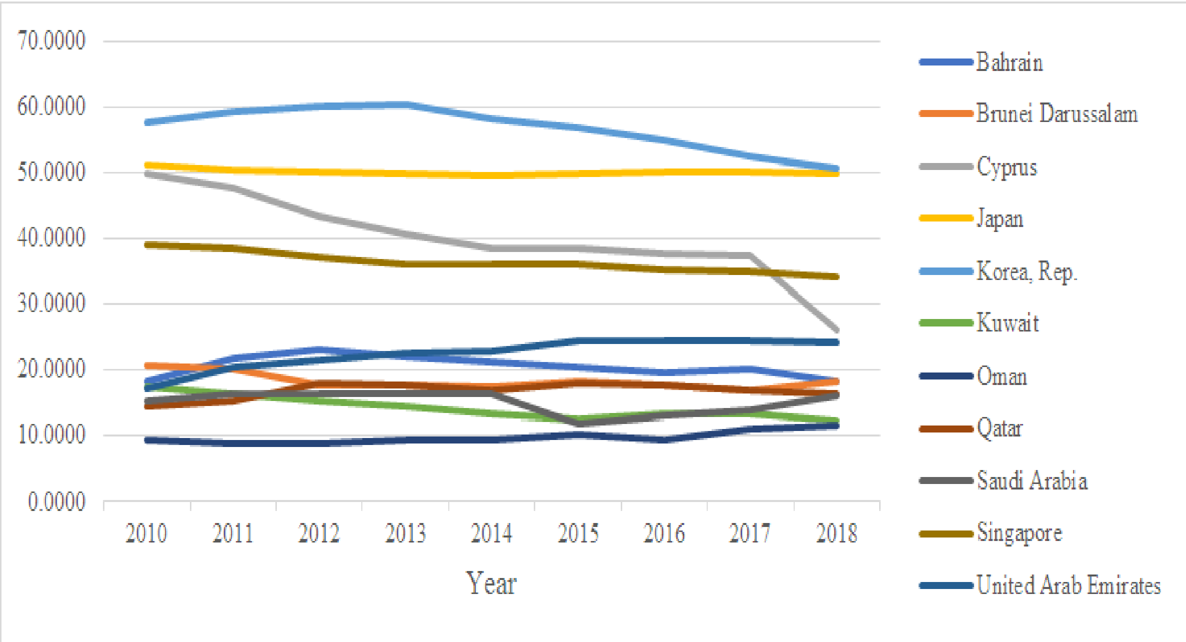



**Figure 11.** Fixed-telephone subscriptions per 100 inhabitants of High Income Asian Countries




Next, as portrayed in Figure 12-14, the percentage of individuals using the internet shows a positive trend in all income group of 35 Asian countries. Although the percentage amount for each income group is different. The highest percentage belongs to high-income countries, followed by upper-middle and lower-middle-income countries. Last ICT indicators used in this study is mobile cellular telephone subscriptions for all income group as can be seen in Figure 15-17. As a percentage of individual using the internet, the development of this indicator shows a positive trend. However, it is increasing as not high as a percentage of individual using the internet.

**Figure 12.** Percentage of Individuals using the Internet of Lower-Middle Income Asian Countries

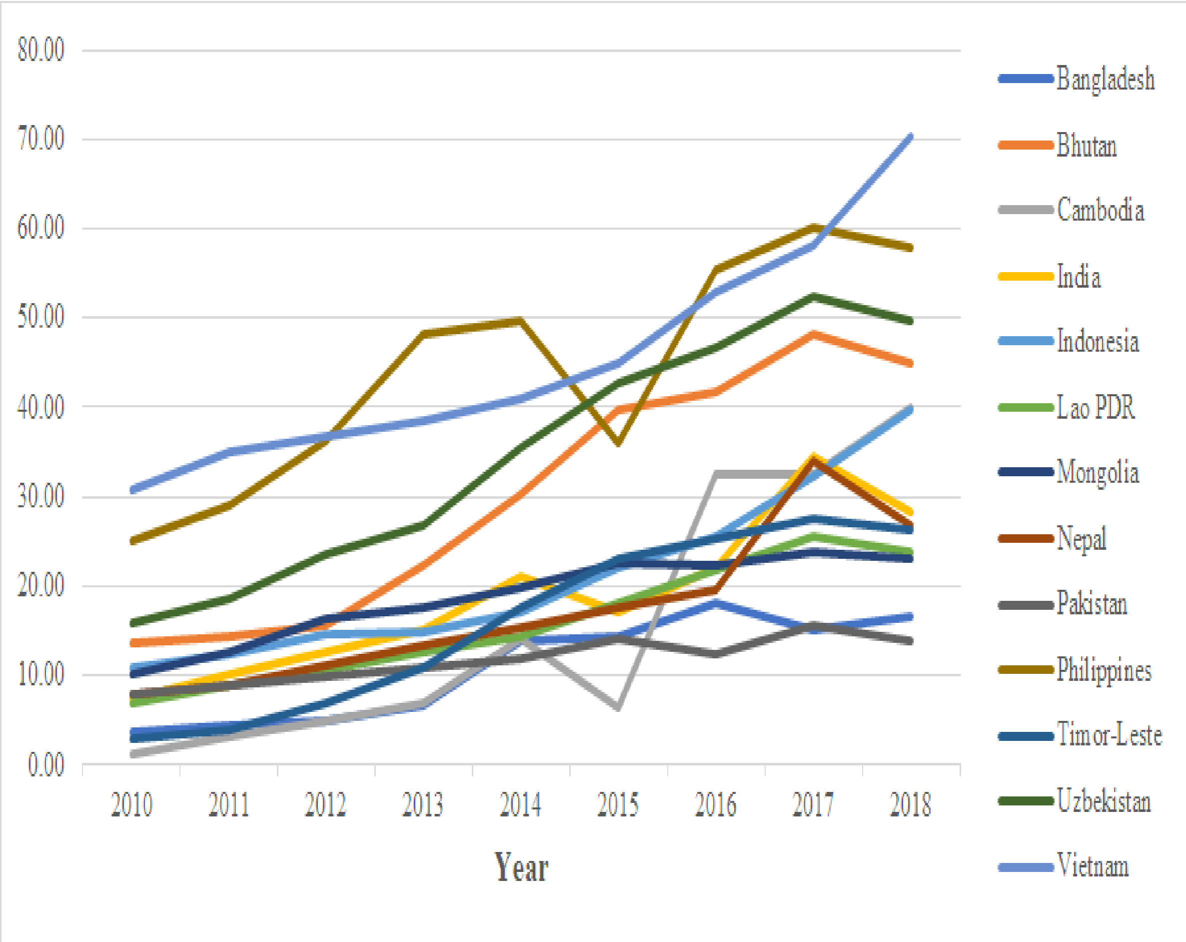


**Figure 13.** Percentage of Individuals using the Internet of Upper-Middle Income Asian Countries

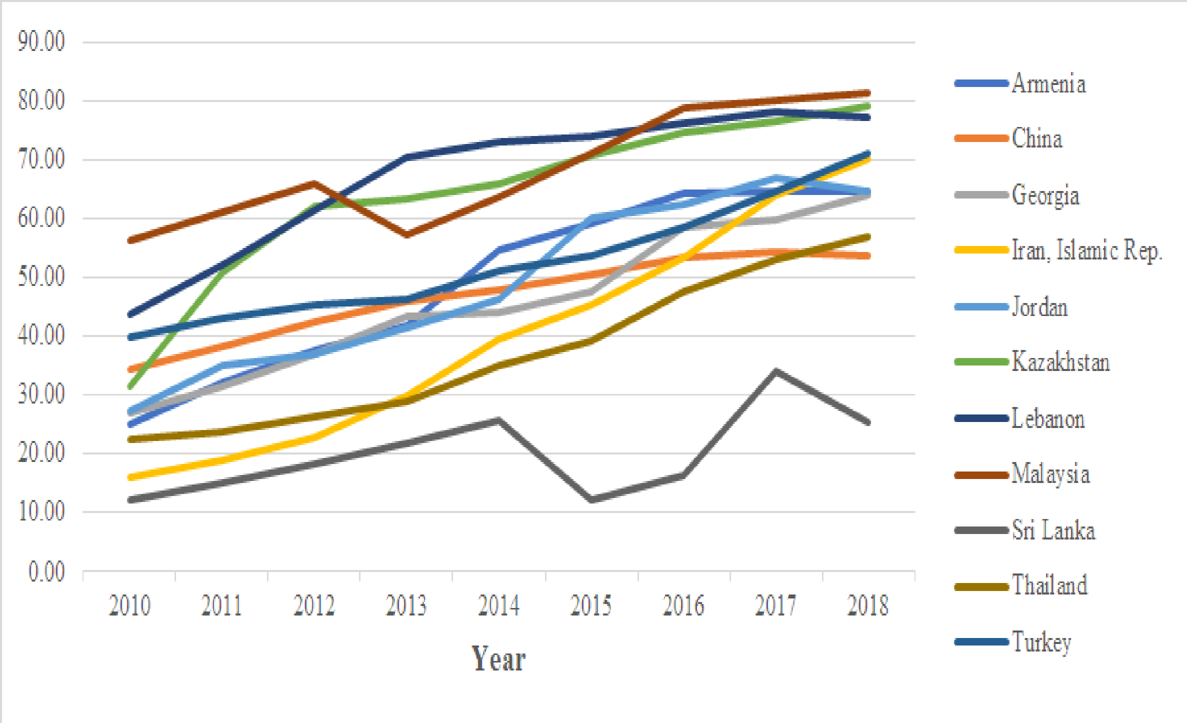



**Figure 14.** Percentage of Individuals using the Internet of High-Income Asian Countries

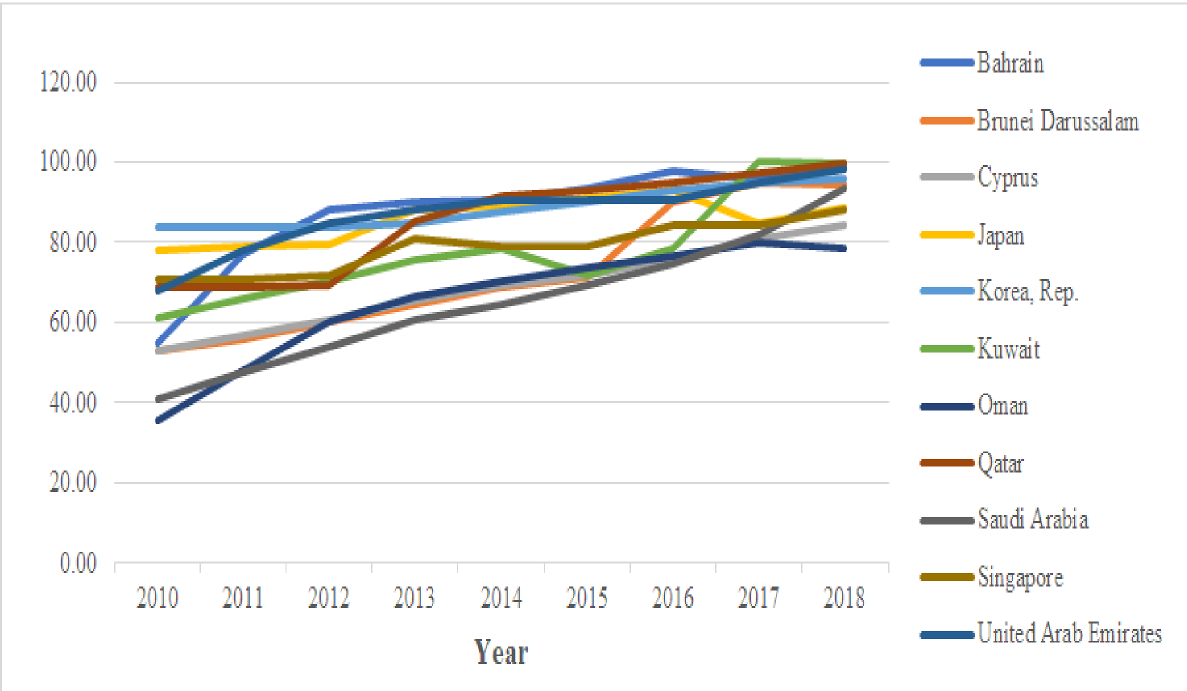


**Figure 15.** Mobile-cellular telephone subscriptions per 100 inhabitants of Lower-Middle Income Asian Countries

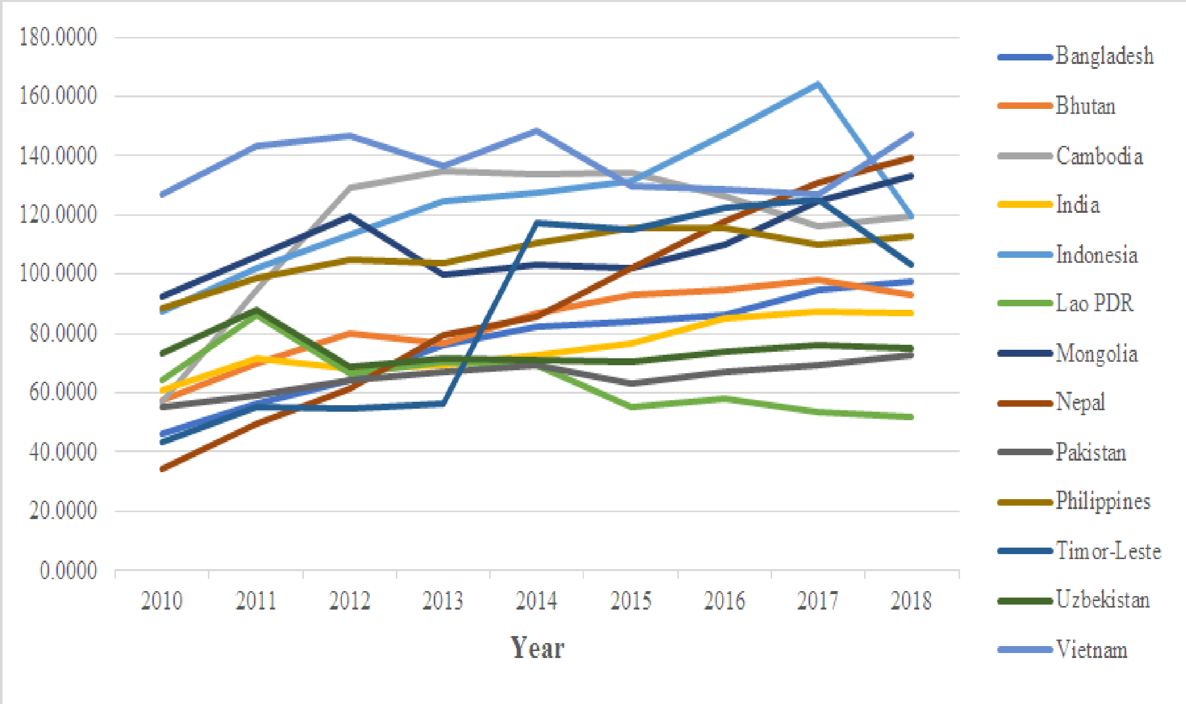



**Figure 16.** Mobile-cellular telephone subscriptions per 100 inhabitants of Upper-Middle Income Asian Countries

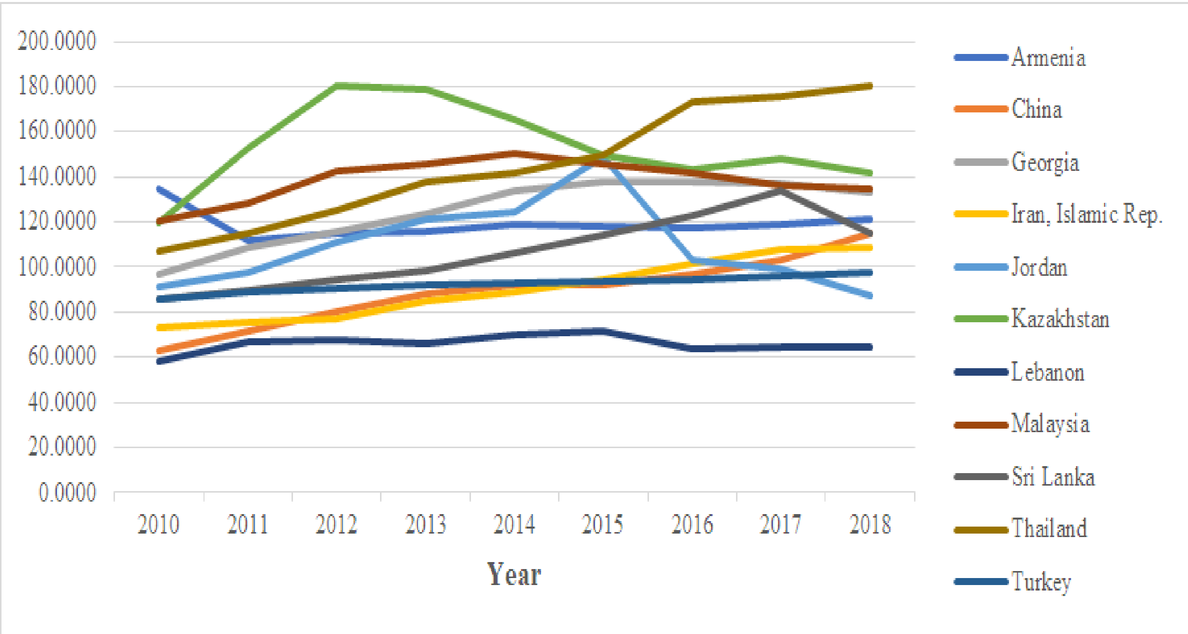
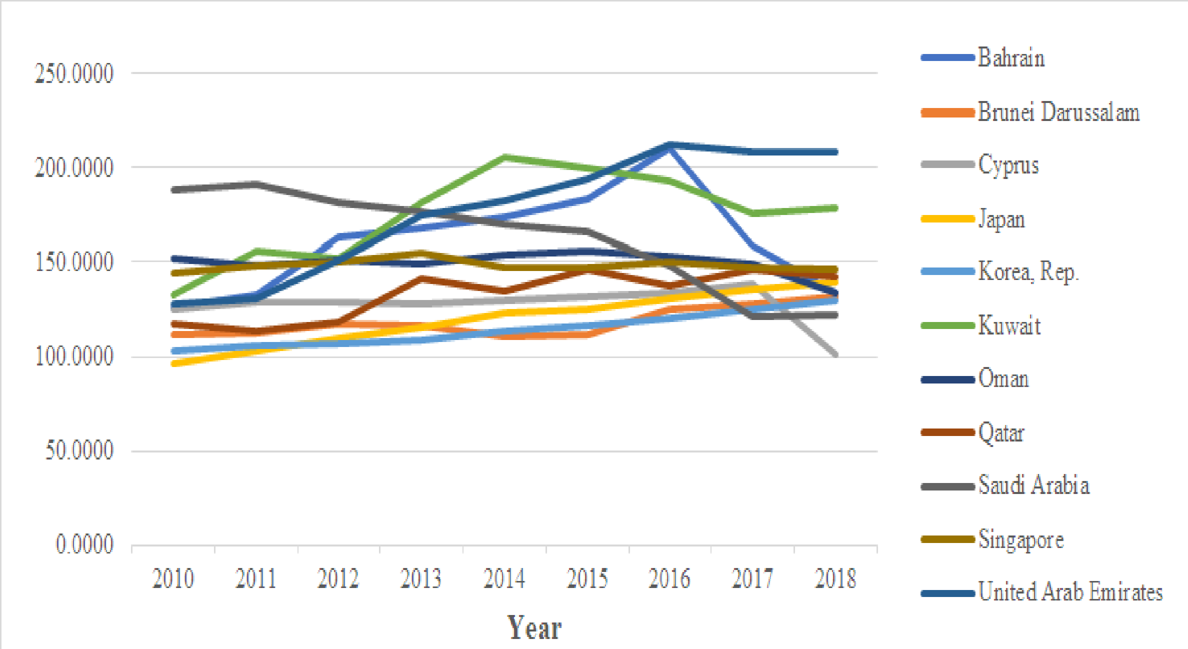


**Figure 17.** Mobile-cellular telephone subscriptions per 100 inhabitants of High Income Asian Countries




Looking at the development of ICT indicators and economic development, there are some different patterns for each of the income group. To analyse this further, we use the statistical method, namely the panel regression for the whole Asian countries. In addition, to insulate the impact of ICT indicators on economic development based on income groups, we run the panel regression separately for these groups.

***Panel Regression for Overall Asian Countries***

Recent studies on panel data analysis have become more popular among researcher. Panel data sets provide multiple advantages over cross-section (individual) and time-series data set. In this paper, we begin several diagnostics. To determine the better model between pooled (OLS) and panel fixed effect model, we use the test of poolability. To determine the better model between pooled (OLS) and panel random effect model, we use Lagrange Multiplier Test - (Breusch-Pagan) for random effect. Furthermore, in order to determine the type of our model, we use the Hausman test. The Hausman test is a test of the significance of the difference between the fixed effects estimates and the random effects estimates. We also run F test for individual and time effects of testing whether there is no individual effect across countries and no time effect, respectively. Once we get the preferred form of the model, we made a brief analysis based on the result that we derive from the GLS estimation. Table 1 gives a summary of diagnostics.

**Table 1:** Diagnostics of Panel Regression for Overall Asian Countries

| **Diagnostics** | **Null Hypothesis** | **Results** | **Conclusion** |
|---|---|---|---|
| Tests of poolability | Pooled model (OLS) better than fixed effect (within) model | p-value = 3.736e-05 | Fixed effect perform better than OLS |
| Lagrange Multiplier Test - (Breusch-Pagan) for random effect | No panel effect; Pooled model (OLS) better than random effect model | p-value < 2.2e-16 | Random effect perform better than OLS |
| Hausman Test | Preferred model is random effects vs. the alternative the fixed effects | p-value = 0.4521 | Random Effect perform better than fixed effect |
| F test for individual effects | No individual effect (One way time effects error component) | p-value < 2.2e-16 | One way (individual) effect model |
| F test for time effects | No time effect (One way individual effects error component) | p-value = 0.991 | |
| Breusch-Pagan Heteroscedasticity Test of Random Effect | Homoscedastic | p-value = 0.8192 | Homoscedastic |

With regards to the diagnostic results, our analysis finds that the utilization of panel data is well suited for this type of samples data. The model estimation results for this panel regression analysis is shown in Table 2. This analysis uses GLS instead of OLS. Next, we had used the Hausman test on the random effect regression to determine the best model between the random and fixed effect regressions; then, we proceed with the analysis in Table 2. Based on Table 2, the best model is a random effect model given that the p-value of 0.4521 suggests to not reject the null hypothesis. The F test for individual effects and time effects concludes that the best model is one-way individual effect model. So, the preferred model is one way (individual) - random effect model. Then, we run the Breusch-Pagan Heteroscedasticity Test of Random Effect; the null hypothesis is not rejected so we do not need to use robust covariance matrix estimation. It shows that GLS with random effect should explain better relative to the fixed effect model. In other words, economic growth in Asia countries is influenced by only country-specific random effects.

**Table 2:** Panel Regression Results for Overall Asian Countries

| | Fixed Effect | | Random Effect | |
|---|---|---|---|---|
| | **Estimate** | **Standard Error** | **Estimate** | **Standard Error** |
| **Intercept** | - | - | 8.0746218[a] | 0.1814184 |
| **LnFixedBroadband** | 0.0658984[a] | 0.0136196 | 0.0626203[a] | 0.0135180 |
| **LnFixedTelephone** | -0.0096708 | 0.0169424 | -0.0084095 | 0.0166866 |
| **LnInternet** | 0.0814781[a] | 0.0194587 | 0.0852641[a] | 0.0193839 |
| **LnMobileCellular** | 0.0574498[b] | 0.0329506 | 0.0592224[b] | 0.0328577 |
| **$D_1$** | - | - | 0.7193372[a] | 0.1701872 |
| **$D_2$** | - | - | 2.0153700[a] | 0.1724371 |
| **$R^2$** | 0.44833 | - | 0.57411 | - |
| **Adjusted $R^2$** | 0.37238 | - | 0.56582 | - |
| **F or Chisq. Statistics** | 56.0757 | - | 415.196 | - |

Balanced Panel: n = 35, T = 9, N = 315
[a]Denotes significance level for 1 % level
[b]Denotes significance level for 5 % level

Based on random effect in Table 2, we reveal that fixed broadband subscription has a positive and significant impact at 1 % significant level on economic growth. Over the sample period studied, one per cent unit increase in fixed broadband subscription leads to about 0.06 percentage rises in economic growth. The result also shows that percentage of individuals using the internet and mobile cellular telephone subscription have a positive and significant impact on economic growth at 1% and 5% significant level, respectively. One percent increase in percentage of individuals using internet leads to about 0.08 percentage points rises in economic growth. Meanwhile, one percent increase in mobile cellular telephone subscription leads to about 0.06 percentage rises in economic growth. In the contrary, fixed telephone subscription has a negative and not significant impact on economic growth.

In the world, according to the 2013 statistics, the total number of subscribers of fixed-telephone was about 1.26 billion. Due to upgrades in digital technology and the conveniences, namely by switching to wireless (cellular) or internet-based alternatives, this number has continuously decreased. This is in accordance with the results of the study by (Aksoy, Aydin-Unal, Akinci, & Verimli, 2015) who revealed that there were the existence of three motivational fixed line usage dimensions: Perceived Convenience, Business Purposes, and Perceived Advantage. Customers in the "Perceived Advantage" group displayed differences across age categories. Thinking of fixed-line services to be a safer solution for human health and sticking to their long-lasting habits, mature customers were significantly discriminated against the 20-29 age group. This results, is quite logical, in which younger people have more skilled in learning and adopting new technologies, on the contrary, older people are reluctant or slower in changing their habits. This is consistent with the descriptive analysis of this study that this decline is occurring majority in upper-middle and high income countries. From Table 2, we can see that grouping Asian countries into 3 classes has a significant role in controlling the different influence of ICT on economic growth.

**Table 3:** Error Components of Random Effect

| **Effect Component** | **Share** | **Variance** | **Std. Dev.** |
|---|---|---|---|
| **Idiosyncratic** $(\sigma_\varepsilon)$ | 0.034 | 0.005875 | 0.076647 |
| **Individual** $(\sigma_\mu)$ | 0.966 | 0.164567 | 0.405668 |
| **Theta** $(\theta)$ | 0.9371 | | |

Table 3 shows the error components of random effect, namely: idiosyncratic and individual components. Those are estimated using Swamy-Arora method. The idiosyncratic component is an effect from random disturbance. An individual component is an effect from individual (cross-sectional) countries. From Table 3, we can make a conclusion that the most contributed in error components of random effect is individual components (variance among countries) with a share of 96,6 % of the total error.

It is important for the leaders of Asia countries to take this opportunity to learn and adapt the knowledge of ICT through knowledge sharing such as transfer technology programme from high-income countries, especially to lower-middle-income countries. The goodness of fit of the specification of the overall model that is $R^2$ and adjusted $R^2$, remains good, which are 0.57411 and 0.56582, respectively.

***Impact of ICT on Economic Growth by Income Group***

This part of analysis discuss about the impact of ICT on GNI per capita in 35 Asian countries based on the respective income group. The analysis employs panel regression using the same procedure as previous analysis. Therefore, we have three panel regression model, namely for lower-middle, upper-middle, and high income. The diagnostics of panel regression for three income groups can be seen at appendix (Table 5-7). We find that all of these panel regression models, the preferred model are one way individual random effect model as follow:

**Table 4:** Impact of ICT on Economic Growth by Income Group

| | **Lower-Middle Income** | | **Upper-Middle Income** | | **High Income** | |
|---|---|---|---|---|---|---|
| | **Estimate** | **Standard Error** | **Estimate** | **Standard Error** | **Estimate** | **Standard Error** |
| **Intercept** | 8.371108 [a] | 0.237428 | 9.130375 [a] | 0.443075 | 9.9794470 [a] | 0.3252497 |
| **LnFixedBroadband** | 0.067605 [a] | 0.018506 | 0.145653 [a] | 0.033396 | -0.0428242 [b] | 0.0235130 |
| **LnFixedTelephone** | 0.002590 | 0.020638 | -0.098000 [b] | 0.047132 | 0.0088068 | 0.0542707 |
| **LnInternet** | 0.120373 [a] | 0.026239 | -0.051168 | 0.042389 | 0.0735160 | 0.0456500 |
| **LnMobileCellular** | -0.032572 | 0.048341 | 0.114202 | 0.081292 | 0.1353319 [a] | 0.0424426 |
| **$R^2$** | 0.57051 | - | 0.46386 | - | 0.14004 | - |
| **Adjusted $R^2$** | 0.55517 | - | 0.44105 | - | 0.10345 | - |
| **Chisq. Statistics** | 148.773 | - | 81.3276 | - | 15.3078 | - |

[a]Denotes significance level for 1 % level
[b]Denotes significance level for 5 % level

**Table 5:** Diagnostics of Panel Regression for Lower-Middle Income Asian Countries

| **Diagnostics** | **Null Hypothesis** | **Results** | **Conclusion** |
|---|---|---|---|
| Tests of poolability | Pooled model (OLS) better than fixed effect (within) model | p-value = 3.202e-07 | Fixed effect perform better than OLS |
| Lagrange Multiplier Test - (Breusch-Pagan) for random effect | No panel effect; Pooled model (OLS) better than random effect model | p-value < 2.2e-16 | Random effect perform better than OLS |
| Hausman Test | Preferred model is random effects vs. the alternative the fixed effects | p-value = 0.996 | Random Effect perform better than fixed effect |
| F test for individual effects | No individual effect (One way time effects error component) | p-value < 2.2e-16 | One way (individual) effect model |
| F test for time effects | No time effect (One way individual effects error component) | p-value = 0.9994 | |
| Breusch-Pagan Heteroscedasticity Test of Random Effect | Homoscedastic | p-value = 0.0425 | Heteroscedastic |

**Table 6:** Diagnostics of Panel Regression for Upper-Middle Income Asian Countries

| **Diagnostics** | **Null Hypothesis** | **Results** | **Conclusion** |
|---|---|---|---|
| Tests of poolability | Pooled model (OLS) better than fixed effect (within) model | p-value = 5.023e-15 | Fixed effect perform better than OLS |
| Lagrange Multiplier Test - (Breusch-Pagan) for random effect | No panel effect; Pooled model (OLS) better than random effect model | p-value < 2.2e-16 | Random effect perform better than OLS |
| Hausman Test | Preferred model is random effects vs. the alternative the fixed effects | p-value = 0.8891 | Random Effect perform better than fixed effect |
| F test for individual effects | No individual effect (One way time effects error component) | p-value < 2.2e-16 | One way (individual) effect model |
| F test for time effects | No time effect (One way individual effects error component) | p-value = 1 | |
| Breusch-Pagan Heteroscedasticity Test of Random Effect | Homoscedastic | p-value = 0.1048 | Homoscedastic |

**Table 7:** Diagnostics of Panel Regression for High Income Asian Countries

| **Diagnostics** | **Null Hypothesis** | **Results** | **Conclusion** |
|---|---|---|---|
| Tests of poolability | Pooled model (OLS) better than fixed effect (within) model | p-value = 3.988e-11 | Fixed effect perform better than OLS |
| Lagrange Multiplier Test - (Breusch-Pagan) for random effect | No panel effect; Pooled model (OLS) better than random effect model | p-value < 2.2e-16 | Random effect perform better than OLS |
| Hausman Test | Preferred model is random effects vs. the alternative the fixed effects | p-value = 0.885 | Random Effect perform better than fixed effect |
| F test for individual effects | No individual effect (One way time effects error component) | p-value < 2.2e-16 | One way (individual) effect model |
| F test for time effects | No time effect (One way individual effects error component) | p-value = 0.9954 | |
| Breusch-Pagan Heteroscedasticity Test of Random Effect | Homoscedastic | p-value = 0.192 | Homoscedastic |

Based on the results in Table 4, it can be seen that there are differences in the significance of ICT indicators in the three income groups. Fixed broadband subscription has a significant impact on economic growth in all groups. The effect of a fixed broadband subscription is positive on economic growth, except for high-income countries. In high-income countries, the decline in fixed broadband subscriptions had a positive impact on economic growth. This is allegedly because the fixed broadband subscription model has begun to be abandoned, especially in developed countries because it is less flexible.

Fixed telephone subscription significantly affect the economic growth only in upper-middle-income countries at 5% level of significance. The direction of the relationship is negative; in other words, over the sample period studied, one per cent unit increase in fixed telephone subscription leads to about 0.09 percentage declines in economic growth. This implies that economic development does not fully benefit from the fixed telephone subscription.

Percentage of individual using the internet has a significant impact on economic growth only on lower-middle-income countries at 1% level of significance. The effect is positive, meaning that one per cent unit increase in individuals using the internet leads to about 0.12 percentage points rises in economic growth.

Mobile cellular telephone subscription has a significant impact on economic growth only in high-income countries at 1% level of significance. The effect is positive so that one percent unit increase in mobile cellular telephone leads to about 0.13 percentage rises in economic growth.

Of the three income groups, the biggest role of ICT is in the lower-middle income group. This is seen in $R^2$ and adjusted $R^2$ which is highest at 0.57051 and 0.55517, respectively. The smallest role of ICT is in the high income countries group, where ICT only contributes to economic growth of less than 15 percent. This can be seen in $R^2$ and adjusted $R^2$, which is only 0.14004 and 0.10345, respectively.

**Conclusions**

ICT can significantly contribute to the economic development in Asian countries, with different impacts for different types of economies levels. The study supports the policy recommendation that the government of each country should increase attention in the diffusion of ICT to fasten and realize the sustainable economic development in Asia. Of the three income groups, the most significant role of ICT is in the lower-middle-income group. This indicates that the increase in economic growth in lower-middle-income countries can be accelerated by an increase in the ICT indicator. The situation is different in high-income countries, where the possibility of economic growth is already high so that the role of ICT is at its saturation point. It is important for the leaders of Asia countries to take this opportunity to learn and adapt the knowledge of ICT through knowledge sharing such as transfer technology programme from high-income countries especially to lower-middle-income countries to boost economic growth.

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