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ICT Adoption Drives Productivity in Developed and Developing Countries

(Penggunaan ICT Memacu Produktiviti di Negara Maju dan Membangun)

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ABSTRACT

This study examined the impact of ICT adoption on productivity in developed and developing countries. Data was gathered among 44 developed and 45 developing countries between 2009 and 2015. As identified in previous literature, the key factors that determine productivity are capital, labour, ICT, human capital, prices, research and development (R&D). The data was analysed using the generalized method of moments (GMM). Findings show that ICT adoption drives labour productivity in developed countries, despite the high mobile broadband prices. There is also an indication that people enjoy being connected regardless of the the increase in the price of broadband, in order to enhance their productivity. However, it was observed that ICT adoption has insignificant impact on productivity in the developing countries. Lastly, developing countries were found to have larger inputs of labour and capital which increased their producitivity.

Keywords: ICT adoption; developed countries; developing countries; productivity; generalized method of moments (GMM)

ABSTRAK

Kajian ini mengkaji kesan penggunaan ICT ke atas produktiviti di negara maju dan membangun. Data dikumpulkan di kalangan 44 negara maju dan 45 negara sedang membangun antara tahun 2009 dan 2015. Seperti yang telah dikenalpasti dalam kajian terdahulu, faktor utama yang menentukan produktiviti adalah modal, buruh, ICT, modal insan, harga, penyelidikan dan pembangunan (R & D). Data dianalisis dengan menggunakan Kaedah Dinamik Panel Momen Teritlak (GMM). Penemuan menunjukkan bahawa penggunaan ICT mendorong produktiviti buruh di negara maju, walaupun dikenakan harga jalur lebar mudah alih yang tinggi. Terdapat juga petunjuk bahawa masyarakat sentiasa berhubunga tanpa mengira kenaikan harga jalur lebar, untuk meningkatkan produktiviti mereka. Walau bagaimanapun, kajian mendapati bahawa penggunaan ICT tidak memberi kesan penting terhadap produktiviti di negara-negara membangun. Akhir sekali, negara-negara membangun menggunakan input buruh dan modal yang lebih tinggi yang meningkatkan produktiviti mereka.

Keywords: Penggunaan ICT; negara maju; negara membangun; produktiviti, kaedah momen teritlak (GMM)

INTRODUCTION

Countries that aim to attain the developed nation status with high quality of life, sustained and inclusive growth, healthy institutions and innovative economy tend to innovate and adopt new technologies (e.g. ICT) in order to increase productivity and remain competitive globally. Nonetheless, those worse-off in adopting existing technologies are gradually lagging behind. The more countries adopt ICT, the more their technological readiness, and this subsequently enhances their productivity (WEF 2016). Hence, ICT adoption is crucial to human lives, communication, improving education, health services and creating job creation (ITU 2015). In fact, ICT adoption has impact on the economy, institutions, and investment. However, there is a broad gap between the better-off and the worse-off countries in terms of adopting new technology.

According to neoclassical model of Solow (1957), per capita output and productivity growth are totally influenced by by technological progress and other structural parameters such as capital, labour and savings rate in the long run. However, the complementary of physical capital and human capital are not guaranteed in sustaining the productivity level in certain countries. Technology has been empirically proven to be the most fundamental factor that increases productivity. Without technology, the benefits of improved human capital, or a higher rate of physical capital would only push the economy to a higher standard of living rather than propelling such countries to innovation driven, with GDP per capita above US$17,000 (McArthur & Sachs 2001).

In recent decades, innovative technologies has had a huge impact on industries and business globally. Moreover, the emergence of the Fourth Industrial Revolution (IR 4.0) encourages industries to improve their production with a combination of virtual, physically and biologically (WEF 2016). Apart from the advancement in robotics and automation, IR 4.0 also brought about communication infrastructure, particularly Internet of Things (IoT) and big data which are essential for information dissemination and production process towards enhancing productivity and competitiveness, specifically in developing countries (MIGHT 2017). Hence, ICT adoption through broadband Internet is the appropriate way to disseminate knowledge in the economy (Mack & Faggian 2013).

According to ITU (2015), users connected to Internet through mobile-broadband have increased within a short time. The subscription number has rapidly increased from 4.0 per 100 population to 45.1 per 100 population in 2007 and 2015 respectively. Meanwhile, there is a tremendous growth in subscriptions from about 750 million worldwide in 2000 to 7.1 billion in 2014. Thus, the number of people to be connected is expected to increase to 9 billion by 2021, accounting for nearly 90% of the world population (Ericsson 2016).

Productivity growth has been diverged over time and uneven growth are reported between developed and developing countries. According to Conference Board (2016), the outcome of the economic crisis is reflected in the global economic matters. On the contrary, WEF (2016) predicted that technology has yet to show its full impact on productivity, and this which results in a wider gap of economic performance across countries. Hence, the imbalance in the productivity and growth levels between developed and developing countries is yet to be debated among researchers. The chart of labour productivity growth presented in Figure 1 shows that the productivity growth of developed countries has tremendously increased between 1990 and 1994, while developing countries grew at slower rate. Later, developed countries were lagging behind and were overtaken by the developing countries in year 1995 onwards. Productivity growth in developed and developing countries has slowed since the global financial crisis in 2007. Based on the trend shown in 2009, there was an extremely slowdown in productivity growth for developed and developing countries at -2.4 percent and 0.3 percent respectively.

Figure 2 reports the uneven distribution of mobile broadband subscriptions in developed and developing countries. The figure indicates that the number of mobile broadband subscriptions is low in developing countries, while developed countries record a rapid increase over the years (2007-2015). On the contrary, the productivity growth recorded differently between these two groups of countries. Developed countries which are considered to be more competitive and innovative show a deteriorating trend on productivity growth as compared to the developing countries in 2015.

Neoclassical growth model of Solow (1957) acknowledge that per capita output and productivity growth in long run are influenced entirely by technological progress. However, the decreasing rate of productivity growth currently indicates that technology does not have effect on productivity. Hence, ICT adoption is believed to be significantly integrated into everyday lives and consequently leads to insights into how it affects production processes, efficiency and entire productivity.

Developed countries which have surpassed the high-income level and achieved high productivity tend to be lagging behind compared to developing countries. Global productivity growth shows the slowdown trend

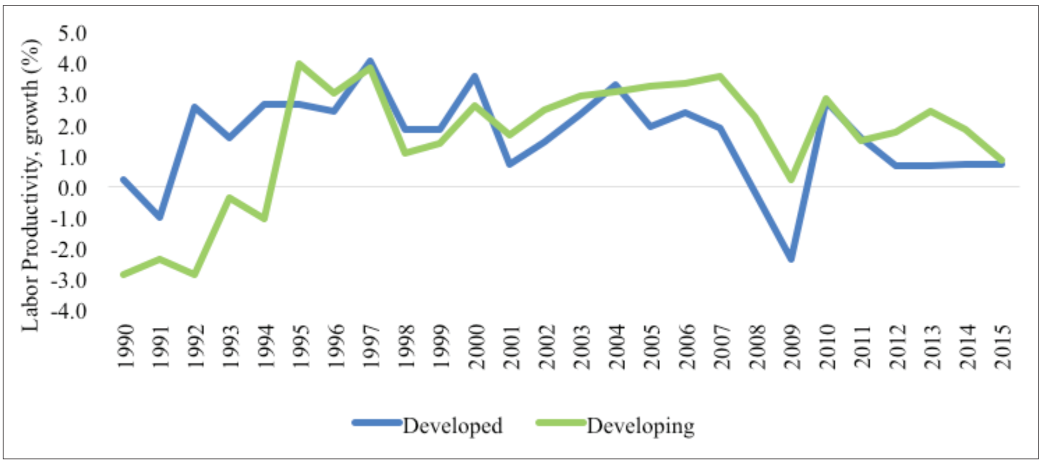

FIGURE 1. Labour Productivity Growth in developed and developing countries, 1990-2015
Source: The Conference Board (2016)

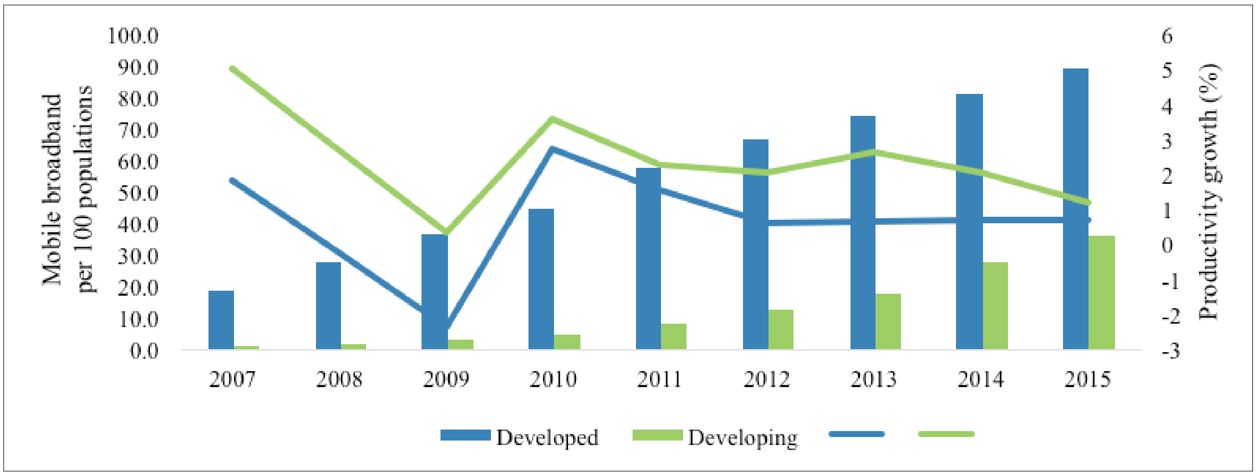

FIGURE 2. The distribution of productivity growth and mobile broadband subscriptions between developed and developing countries
Source: The Conference Board (2016)

for the last 10 years (Figure 1). In this regard, this does not imply that productivity will increase due to mobile broadband adoption (Figure 2). This issue is analysed further to identify if ICT adoption through mobile broadband subscriptions truly affects productivity, or if there are other factors which have impact on productivity in developed and developing countries.

It is an undeniable fact that various initiatives were introduced by the government of the developing countries to promote the utilisation of ICT towards enhancing productivity. For example, in 2015, South Korea introduced the "Development and Supply of IT Assistance Devices", "Supply of Green PCs of Love" and "Telecommunication Relay Service" that were designed as part of promoting the ICT adoption across the entire population, particularly to unconnected groups (ITU 2016). In the case of Iceland, with the aim of bridging the final digital divide, the government has approved an expenditure budget of USD 4 million for the development of high-speed networks in 2016. This initiative enables and allows almost all households in the country to have access to Internet with at least a 100 Mbit/s connection by the year 2020 (ITU 2016). In Denmark, the government launched a national broadband strategy, which aims at providing all households and businesses with internetaccess of at least 100 Mbit/s download and 30 Mbit/s upload speeds by 2020.

Although the difussion of mobile broadband subscriptions has proven to have substantial spillover effects on the world economy, these benefits do not appear evenly among countries. Therefore, there is a global fear that poor countries will be left behind, although they are very productive and have the potential to move to a better level of development.Thus, this study attempts to explore other factors besides ICT adoption (such as human capital, physical capital, R&D, good business environment) which influence productivity level in developed and developing countries. Furthermore, some of the literatures focussed on the impact of ICT on economic growth represented by GDP per capita. Besides, a handful of research has been done on the mobile broadband as an indicator of ICT adoption and its impact on productivity between developed and developing countries. For instance, Ghosh (2016) analysed and discovered how fixed and mobile broadband policies impact economic growth, while Mack & Faggian (2013) analysed two dimensions of how human capital alone and a combination of human capital and broadband interact with each other to impact productivity. Both studies gave different results on how broadband affected productivity. Broadband does not have effect on the economy itself, but in conjunction with other factors such as attractive prices, activities on innovation, and highly educated people. Although the above studies analysed the impact of broadband on productivity, the models and scope used were different from the interest of this research. The focus of this research is on the impact of mobile broadband on productivity in developed and developing countries.

The succeeding sections includes Section 2, which briefly describes some prior work and their findings, followed by Section 3 which presents the model and research method used. Section 4 discusses the results and discussion. Finally, the conclusion of the study is presented in Section 5.

LITERATURE REVIEW

Technological progress is an essential factor to sustain long-run growth and labour productivity (Aghion & Howitt 1990; Grossman & Helpman 1991; Romer 1986; Solow 1957). Since the mid-1990s, rapid growth of output and labour productivity across countries has largely been driven by technological advancement (Ceccobelli et al.

2012; Jorgenson 2001; Lam & Shiu 2010; Venturini 2009; Vu 2011).

On top of that, ICT has brought about globalization since a few decades ago. ICT has therefore become a new source for improving labor productivity; and it has been the subject of previous studies. Given the vast technological abundance in the age of IR 4.0, countries are now racing towards championing productivity by capitalizing on their technological advances. These concerns have led various stakeholders (e.g. policymakers, academic hats, and trade conglomerates) to devise various policy instruments in ensuring sustained productivity.

According to Dedrick et al. (2013), ICT investment will possibly benefit upper income countries in termsof increasing their productivity. In addition, other factors such as human capital, trade openness and cost of telecommunications moderately affect productivity too. However, Lovric (2012) employed the Generalized Method of Moments (GMM) through a dynamic panel data approach with a sample of 25 European developed and developing countries between 2001 and 2010, and found a positive and significant impact of ICT investment on output per worker in developed and developing countries.

Meanwhile, in the case of Singapore,Vu (2013) found thatICT contribution to Singapore's economic growth during the 1990-2000 contributed approximately 1-percent to Singapore's GDP during this period and drives the economic growth over time. Historically, the government emphasized on the dynamic efforts in advancement of ICT towards the success of their economic development.

On the contrary, Yousefi (2011) adopted the growth accounting method, by using time-series cross-country data of a total of 62 countries for the period 2000–2006 to investigate the impact of ICT expenditure. The findings revealed that output growth in higher and upper middle income is significantly affected by ICT expenditure, whereas it fails to improve the productivity and economic growth of the lower middle income. Dimelis & Papaionnou (2010) the impact of FDI and ICT on productivity growth in 42 developing and developed countries during the period 1993 to 2001. The results indicated that the growth contribution of ICT was quite high for developed compared to the developing countries.

However, there are studies which observed complementary factors of ICT in promoting productivity. For instance, Najarzadeh et al. (2014) examined the impact of Internet on labor productivity in 108 countries for the period 1995–2010. The study employed GMM regression estimation through dynamic panel data and findingse revealed that Internet has positive and statistically significant effect on labor productivity. Somehow, Samimi & Ledary (2010) investigated the relationship between Digital Opportunity Index (DOI) as ICT index which covers 11 ICT indicators on productivity. They employed Cobb Douglas Function and gathered data from 2001 to 2006, using panel data for 30 developing countries. Results indicated a weak significant relationship between ICT index and productivity growth. The findings also showed that a new development of ICT is required in order to raise productivity and enhance economic growth.

However, there are limited studies relate the impact of new ICT factors such as broadband on productivity and directly compare the impact of ICT between developed and developing countries. Koutroumpis (2009) in his study revealed that the effects of the GDP per capita are associated with greater adoption of broadband. The author adopted Roller and Waverman (2001) model which was based on fixed telephone, while he used broadband penetration in the study. The study employed a panel data in 22 OECD countries from 2002-2007 and found that a percentage point increase in broadband adoption may increase the output by an average of 0.025 percent.On top of that, Czernich et al. (2011) estimated the effect of broadbandon GDP per capita growth in the panel of 25 OECD countries in 1996–2007. They applied production function with constant returns to scale incorporated with capital, labour and human capital and found that a 10 percentage point increase in broadband penetration raised annual per capita growth by 0.9 to 1.5 percentage points. This finding may further enable macroeconomic growth by accelerating the distribution of ideas and information, thereby enhancing the productivity of its industries in the daily activities and production process.

Thompson and Garbacz (2011)especially in low income and rural areas. This study focuses on the direct effect (broadband penetration as an input explored and analysed productive efficiency effect of mobile broadband and fixed broadband between high income and low income countries applying panel data for the period 2005–2009. Similarly, the model was applied by Thompson and Garbacz (2007), the estimation results indicate that in the full sample of countries, mobile broadband has an important direct effect on the economy, economic impact, however, this contradicts the results for fixed broadband. The difference between the high and low income countries is that the low income countries reportedly derived more significant advantage from mobile broadband. They also suggested that beside the growing usage of broadband, a blend with the attractive price given for broadband will encourage people to adopt broadband to ensure a long term improvement in productivity.

While most literature focused on the impact of ICT on economic growth represented by GDP per capita, very limited studies compared the impact of broadband on productivity between developed and developing countries. For instance, Ghosh (2016) explored how broadband policies impact economic growth. He found that policies are important in the high broadband penetration countries, whereas 3G/4G services has the same effect in high and low broadband penetration countries. The study suggested that a combination of broadband and educated workers enable produces positive impact.

Based on the review of previous literatures which suggest that ICT has a crucial influence on productivity with the combination of physical capital and labour. Hence, this study aims to investigate whether ICT adoption drives productivity including human capital, prices, research and development in developed and developing countries.

METHODOLOGY AND DATA

METHODOLOGY

In order to achieve the objectives of the study, this study employed the generalized method of moments (GMMs) panel estimator which was initially developed by Holtz-Eakin et al. (1988). Later, it was expanded by Arellano and Bond (1991), Arellano and Bover (1995) and Blundell and Bond (1998).

Most literature adopt developed models to examine the impact of ICTs on economic growth by using the real GDP per capita as the independent variable , but less studies used productivity level. This study attempts to apply labour productivity per employees, replacing ordinary growth model as in Lovric (2012). To estimate productivity impact, we adapt an intercountry production function of the form:

$$Q_{it} = f(k_{it}^{\alpha} L_{it}^{\beta}) \quad (1)$$

Where Q represents the labour productivity per employee, K is the level of capital stock and L is the total labour force in the countries i at time t. Equation 1 is estimated as a Cobb–Douglas production function using a panel data set that covers 44 developed countries and 45 developing countries over 9 years (2007–2015). The Cobb–Douglas production function is the most common function for studying the impact of productivity and was adopted in other major studies (Dedrick et al. 2013; Lovric 2012; Mack & Faggien 2013). However, a multitude of modeling approaches have been utilized to evaluate the link between technology advancement and productivity, such as panel data approaches (Dedrick et al. 2013; Koutroumpis 2009; Lovric 2012; Mack & Faggien 2013). The usual variables used by other researchers such as physical capital, labour and ICT by previous studies of Dedrick et al. (2013), Lovric (2012) Mack and Faggien (2013) and Papaioannou and Dimelis (2007) were also used in this study. Dedrick et al. (2013) and Najarzadeh et al. (2014) used GDP per capita as a function of physical capital, labor, Internet penetration, mobile penetration, although the selection of independent variables was different.

Hence, our interest is to determine if ICT adoption has an impact on productivity in developed and developing countries. And we consider the following model for productivity: Using the production function, this study have for country $i(i= 1, 2, ..., N)$ in year t $(t = 1, 2, ..., T)$:

$$Ln\ Q_{it} = \beta_0 + \beta_1 Ln\ K_{it} + \beta_2 Ln\ L_{it} + \beta_3 Ln\ ICT_{it} + \beta_4 Ln\ Z_{it} + v_i + \mathcal{E}_{it} \quad (2)$$

$$Ln\ Q_{it} = \beta_0 + \beta_1 Ln\ Q_{it-1} + \beta_2 Ln\ K_{it} + \beta_3 Ln\ L_{it} + \beta_4 Ln\ ICT_{it} + \beta_5 Ln\ HC_{it} + \beta_6 Ln\ PR_{it} + \beta_7 Ln\ RD_{it} + v_i + \mathcal{E}_{it} \quad (3)$$

where i is country index, t is time index, Q is the logarithm of labour productivity per employee where data were obtained from The Conference Board dataset. K is the logarithm of capital stock, L is the logarithm of labor force participation, ICT is the logarithm of the mobile broadband subscriptions. Z is control variables comprises of HC represents the human capital, PR denotes the mobile broadband prices and RD is the company spending on R&D.

The widespread mobile broadband diffusion encourages innovation and positively contributes to productivity and growth, and attracts foreign investment (ITU 2012). However, studies on the impact of mobile broadband on productivity are minimal. Ghosh (2016), Lee et al. (2011), Prieger (2013), Thompson and Garbacz (2011)especially in low income and rural areas. This study focuses on the direct effect (broadband penetration as an input used mobile broadband as a determinant of productivity in their studies.

The interpretation of human capital differs among researchers. Jajri and Ismail (2010) found human capital as the accumulation of efforts devoted to quality labour by schooling and training. Similarly, Grossman and Helpman (1991) and Romer (1986) treated human capital as those who gained skill from schooling. Hence, Lovric (2012) applied tertiary enrolment in the model and is expected to have a positive impact on productivity. In terms of cost, mobile broadband prices play a major role in determining access to the Internet or other networks, providing businesses and people with the high-speed broadband at affordable prices, ensuring access to world-class broadband services to all businesses in the country. This will make businesse globally competitive and increase productivity (Ghosh 2016). Furthermore, innovation is believed to increase employment, sustainable growth, social welfare and quality of life (Savrul & Incekara 2015). Innovation in telecommunication infrastructure significantly contributes to the growth of productivity and economic development (OECD 2008). However, the interpretation of innovation differs among researchers. Some used number of patents, R&D expenditure or any related innovation activities which contributes positively to economic growth. Carlaw and Lipsey (2003) suggested that the combination of advanced technology with broadband enables the R&D as a potential to foster innovation. Such effects can be strengthened by broadband as it enables more intensive use of ICTs thereby enhancing the possibilities of their innovative use among firms. In turn, it creates larger spillovers and productivity gains (Ghosh 2016).

Specifically, for panel data structure, the model specification comprises the unobserved factors affecting the depending variable. Where, is an unobserved time invariant country effect and is the error term assumed to be independently distributed. This estimator is the most suitable and only applicable to panel data with large cross-sectional observations and small time series observation, which is similar to this study. The GMM estimator has several advantages when it is used to estimate growth model as compared to cross-section technique and traditional panel estimators. The estimator can be prepared by controlling the country specific effects that cannot be achieved through employing the country-specific dummies. This is due to the dynamic structure of the regression equation and controlling the simultaneity bias caused by the possibility of the endogenous being from the explanatory variables (Azman-Saini et al. 2010). Taking the argument proposed by Lin and Wu (2013) into account, technology development matured to a more stage, hence, more panel data and advanced statistic methods such as GMM are required.

GMM is applicable to two types of estimators namely, one-step and two-step estimators (Arellano & Bond 1991). The difference between these two variants is the type of weighting matrices used in the estimation. The one-step estimator uses weighting matrices that are independent of estimated parameters. This step recommends the use of two-year lagged levels and earlier as instrument for the first difference equation. On the other hand, the two-step estimator uses the optimal weighting matrices where the moment conditions are weighted by a consistent estimate of their covariance matrix. This makes the two-step estimator more efficient than the one-step estimator. However, the use of the two-step estimator in small samples has several problems. These problems are caused by the proliferation of instrumental variables which resultin different standard errors and estimated parameters (Windmeijer 2005) and deteriorated over identification test (Bowsher 2002). Thus, Roodman (2009) suggests reducing the dimensionality of the instrumental variable matrix in order to overcome the problems caused by the proliferation of instruments.

Windmeijer (2005) explained that the two-step estimation with numerous instruments enables to deal with biased standard errors and parameter estimates. Hence, Windmeijer (2005) derived an estimate of this finit sample bias and used it to correct the robust estimator of VCE of two-step GMM estimator. Specifying vce (robust) produces an estimated variance covariance matrix (VCE) that was robust to heteroskedasticity. Hence, the two-step vce(robust) system GMM estimator was applied to estimate a system of equations in both first-difference and levels, where the instruments used in the levels equations were lagged first difference of the series. The GMM system estimator used in this study was computed using Stata software.

Furthermore, the consistency of GMM estimators according to two specification tests was checked. First, for each model, the Sargan test of overidentifying restrictions was reported. The hypothesised relationship is that the instrumental variable is interrelated to some set of residuals, and therefore, they are acceptable. If the null hypothesis is confirmed statistically or not rejected, the instrument passes the test. The higher the p-value the better the estimation, which means that result of the statistical test is not misleading of the model. Second, Arellano-Bond for zero-autocorrelation refers to first order and second order serial correlation in the residuals is reported. The first and second order serial correlation tests were reported by the AR (1) and AR (2) respectively. At 5 % significance level, the first order serial correlation test AR (1) rejected the null hypothesis, while at 5% significance level, the second order serial correlation test AR (2) accepted the null hypothesis. The second order serial correlation AR (2) over identification test is sufficient to indicate that the model is adequately specified and has been applied by Dedrick et al. (2013), Lovric (2012) and Mack and Faggien (2013) and Papaioannou and Dimelis (2007). The GMM estimators are consistent if there is no second order serial correlation in the residuals. We examine the results group by group (developed and developing countries) which allows the true variables to influence the dependent variables in each group.

DATA

Since technology is diffused differently in various parts of the world, this study classified the countries into two groups based on the World Bank categorization[1]: developed and developing countries. Developed countries are those which obtained the GNI per capita above USD 12,235, while developing countries are those with GNI per capita less than USD 12,235. This study employed the annual data from 2009-2015 (7 years) for 44 developed countries and 45 developing countries[2]. The countries and the study period were selected based on the availability of data. The dependent variable is labour productivity per employed (constant 1999 US$), while the independent variables are gross capital formation, labour force participation, tertiary education enrolment, mobile broadband subscriptions, mobile broadband prices and company spending on R&D, (for details of data descriptions and sources and list of countries, see Table A1 and A2 respectively in the Appendix).

TABLE 1. Descriptive statistics of developed countries

Variable	Obs	Mean	Std. Deviation	Min	Max
LP	396	40900.59	12785.45	8186.79	70147.15
K	396	2.23	5.03	1.62	3.67
L	396	11791.89	24087.2	156.95	151036
HC	396	60.75	20.548	9.953	116.62
ICT	396	51.35	39.84	0.51	216.90
PR	396	21.86	13.290	10	71.8
RD	396	4.04	0.96	2.37	6.12

Source: Authors' calculation

RESULTS AND DISCUSSION

This section presents the results of the descriptivevariables used in analyzing the impact of ICT adoption on productivity in developed and developing countries. The information presented in Table 1 and 2 represent the descriptive statistics for developed and developing countries respectively.

The total number of observations for developed countries is 396 (Table 1). The mean value for labour productivity per employee (dependent variable) is 40900.59, with a standard deviation of 12785.45. The minimum value is 8186.79 while the maximum value is 70147.15. The capital stock (K) and labour (L) are important independent variables in the production function model respectively. The maximum and minimum values of the capital (K) are 2.23 and 5.03, and the scores are 11791.89 and 24087.2 for labour force (L). Another important independent variable is ICT adoption (ICT), which demonstrate a mean value of 51.35 (standard deviation 39.84). The minimum and maximum values are 0.51 and 216.90 respectively.

Meanwhile, Table 2 represents the descriptive analysis for developing countries. The total number of observations for developing countries is 405. Based on the descriptive analysis, findings show that the average value for labour productivity (LP) per employee (dependent variable) is 15372.9 (standard deviation of 8146.98), while the minimum and maximum values are 2837.97 and 47536.79 respectively. For capital stock (K) and labour (L), their mean values are 1.49 (SD= 5.45) and 47426.13 (SD = 13011.1) respectively. Meanwhile, ICT adoption (ICT) shows a mean value of 19.53 (SD= 22.38). The minimum and maximum values are 1.92 and 141.19 respectively.

Tables 3 and 4 show the pairwise correlation matrix for the key variables involved in the analysis for the developed and developing countries respectively. For developed countries, there is a positive linear association between capital (K) and labour (L) on productivity. Furthermore, ICT adoption has a positive correlation with labour productivity (LP). However, in the case of other variables, human capital (HC), price (PR) and R&D (RD) in developed countries indicate positive correlations with labour productivity (LP).

The correlation matrix for developing countries is presented in Table 4. Capital (K) indicates a positive linear association with labour productivity (LP). However, labour (L) has a negative correlation with labour productivity (LP) for the developing countries. For ICT adoption (ICT), there is a positive correlation between labour productivity (LP). While for the case of other variables, human capital (HC), price (PR) and R&D (RD) in developed countries denotes a positive correlation between labour productivity (LP).

Table 5 shows the impact and significance observed based on the two-step and the robust (VCE) estimations for developed and developing countries. Both estimation results have passed the Sargan test of overidentifying restrictions and Arellano-Bond test of autocorrelation.

TABLE 2. Descriptive statistics of Developing Countries

	Obs	Mean	Std. Deviation	Min	Max
LP	405	15372.9	8146.98	2837.97	47536.79
K	405	1.49	5.45	1.01	5.02
L	405	4.7426.13	130110.1	632.9	774510
HC	405	32.92	10.06	2.74	82.30
ICT	405	19.53	22.38	1.92	141.91
PR	405	19.23	19.16	10	292.1
RD	405	3.07	0.55	1.83	5.2

Source: Authors' calculation

TABLE 3. Correlation matrix for Developed Countries

	LP	K	L	HC	ICT	PR	RD
LP	1.000						
K	0.381	1.000					
L	0.264	0.952	1.000				
HC	0.227	0.359	0.731	1.000			
ICT	0.319	0.276	0.201	0.323	1.000		
PR	0.067	0.151	0.133	0.074	0.511	1.000	
RD	0.587	0.609	0.434	0.206	0.360	0.042	1.000

Source: Authors' calculation

TABLE 4. Correlation matrix for developing countries

	LP	K	L	HC	ICT	PR	RD
LP	1.000						
K	0.136	1.000					
L	-2.77	0.881	1.000				
HC	0.642	0.097	-0.209	1.000			
ICT	0.302	0.122	-0.072	0.404	1.000		
PR	0.095	0.176	0.089	0.105	0.463	1.000	
RD	0.041	0.503	0.473	-0.172	0.081	0.048	1.000

Source: Authors' calculation

For developed countries, the findings reveal that lagged labour productivity (, stock capital (L), labour force (L), broadband subscriptions (ICT) and broadband prices (PR) are significant variables, while human capital (HC) and company spending on R&D (RD) have insignificant impact on labour productivity. For the developing countries, all variables are significant except for company spending on R&D (RD). Thus, it can be concluded that each group of countries reveals different impacts on productivity. We examined the group by group which allows the truthful variables determine each group. Then we proceed with the robust VCE of the estimation.

The results suggested that lagged dependent (, variable shows significant level for both groups of countries. The developed countries contribute the largest coefficient at 0.92 percentage point, while the developing countries have 0.7581 percentage point. The impact of capital (K) on labour productivity (LP) is positive and statistically significant at 1 percent significance level in developing countries. However, labour force (L) statistically significant but reveals a negative coefficient. Hence, an increase in a percentage point in labour is associated to a decline of 0.0788 of labour productivity (LP) for the developing countries. Meanwhile, capital (K) and labour force (L) have insignificant impact on labour productivity (LP) for the developed countries.

The impact of human capital (HC) on labour productivity (LP) is discussed by most of the empirical studies (Czernich et al. 2011; Lovric 2012; Thompson & Garbacz 2011)especially in low income and rural areas. This study focuses on the direct effect (broadband penetration as an input. However, this study reveals that human capital (HC) is crucial and influences labour productivity (LP) for developing countries. This finding is consistent with the results in other studies (Czernich et al. 2011; Ghosh 2016; Thompson & Garbacz 2011especially in low income and rural areas. This study focuses on the direct effect (broadband penetration as an input) where developing countries focused on expanding talented and high skilled people to enhance labour productivity.

The result suggests that in the developed countries, broadband subscriptions (ICT) elasticity has a positive and statistically significant effect on labour productivity (ICT) at 10 percent level. A 1 percent increase in broadband subscription (ICT) leads to an increase of 0.0046 in labour productivity (LP). The findings theoretically support the New Growth Theory by Aghion and Howitt (1990), Grossman and Helpman (1991) and Romer (1986) where they emphasized the importance of technology revolution could influence productivity. Besides, researchers (Ghosh 2016; Koutroumpis 2009; Qiang 2010) discovered that broadband adoption has a positive influence on labour productivity. However, for developing countries, ICT adoption was observed to have an insignificant impact on labour productivity, which is against the theory. It means that ICT adoption requires the bearing of substantial cost for most of the industries in these countries, especially in the short run.

The study expected that with reducing mobile broadband prices, productivity will improve. With the affordable prices, ensuring access to information through

TABLE 5. Specification of System GMM

	Twostep System GMM		With VCE(Robust) System GMM	
Variables	Developed	Developing	Developed	Developing
	0.9214***	0.7699***	0.9200***	0.7581***
	(0.0090)	(0.0142)	(0.0367)	(0.0715)
	0.0089***	0.0750***	0.0076	0.0745***
	(0.0027)	(0.0028)	(0.0181)	(0.0165)
	–0.0164***	–0.0798***	–0.0167	–0.0788***
	(0.0018)	(0.0082)	(0.0414)	(0.0308)
	-0.0054	0.0329***	–0.0056	0.0337**
	(0.0036	(0.0041)	(0.0260)	(0.0174)
	0.0047***	0.0029***	0.0046*	0.0029
	(0.0010)	(0.0010)	(0.0029)	(0.0035)
	0.0083***	–0.0041***	0.0089**	–0.0039
	(0.0008)	(0.0009)	(0.0038)	(0.0033)
	0.0131	-0.0084	0.0219	–0.0068
	(0.0103)	(0.0090)	(0.0295)	(0.0231)
Constant	0.7109***	1.0488***	0.7466	1.1576
	(0.1074)	0.1726)	(0.4394)	(0.8687)
Sargan Test	40.0254	40.1394	-	-
	[0.2203]	[0.2166]		
AR (1)	–4.3625	–3.4819	–4.1786	–3.21
	[0.0000]	[0.0005	[0.0000]	[0.0013]
AR (2)	–1.2568	–0.2060	–1.2556	–0.1986
	[0.2088]	[0.8368]	[0.2092]	[0.8425]
Observations	352	360	352	360
Number of countries	44	45	44	45
Number f instruments	42	42	42	42

Source: Authors' calculations.

Notes: The variables are labour productivity per employee (LP) as a dependent variable, and for explanatory variables, we have lagged adependent variable), Gross Fixed Formation (K), labour force (L), a human capital (HC), mobile broadband (ICT), mobile broadband prices (PR), company spending on R&D (RD). Values in ( ) and [ ] denote standard errors and p-value respectively. While, ***, ** and * denotes significant at 1%, 5% and 10% level respectively.

more widespread internet especially to all businesses will encourge competitionglobally and increase productivity (Ghosh 2016). However, broadband price (PR) denotes a positive and significant impact on labour productivity (LP) at 5 percent level for the developed countries. This indicates that an increase in a percentage in mobile broadband price (PR) will increase labour productivity by 0.0089 units in developed countries. In fact, people in developed countries are enjoying the control of broadband, no matter how much the price has increased (Lee et al. 2011). On the contrary, the empirical results reveal that mobile broadband prices do not seem to be important in developing countries.

CONCLUSION

This research investigated the impact of ICT adoption on labour productivity for the period 2009 to 2015 by employing 44 developed countries and 45 developing countries.This study further applied the Arellano–Bond GMM dynamic panel estimation separately for developed and developing countriesand the Cobb-Douglas production function was used.The estimation results indicated that the determinants vary for each group of country.

Productivity growth for developed countries has been on the increase for the last two decades, although, at one point these countries were lagging behind and were overtaken by the developing countries. This shows that ICT adoption drives labour productivity in developed countries, instead of high mobile broadband prices. The findings imply that people are productive and enjoy being connected, regardless of the increase broadband price. This study contributes to previous findings (Lee et al. 2011) which indicate that the more diversified the ICT adoption, the more their readiness and this enables to improve productivity level throughout the economy.

However, ICT adoption was observed to be insignificant in developing countries and does not affect labour productivity. The findings demonstrate that the developing countries have larger inputs of labor and capital which lead to faster labour producitivity. This probably indicates that educated labour are slow at adopting new technology to enhance productivity in developing countries. However, United Nations (UN) through their sustainable development goals (SDGs) highlights the importance of educated labour force in enhancing the productivity performance of the countries by 2020. SDG's aim at expanding skilled people globally comprises enrolment of higher education, including vocational and ICT training as well as scientific and engineering programmes, which enable to enhance productivity in both developed and developing countries.

Nonetheless, there are limitations of the research. This study measured ICT adoption as a proxy for mobile broadband subscriptions for any bandwidth of 256 kbit/s or greater.The available data does not allow us to consider differences in average of maximum bandwidths across countries; hence, this study focused on analysing the extensiveness of number of mobile broadband subscriptions.The measurement may not tell the reality of the diffusion of ICT adoption due to the fact that the new technology may be used more or less by the users. Furthermore, demand for mobile broadband has increased since 2000 while the availability of data started from 2007. Thus, the results of this study represent medium-term effects (for the period 2007 to 2015).

There are some potential areas for future research. Since mobile broadband is telecommunications adoption and keeps revolutionalizing with the new innovations, it is interesting to extend the research detail which applies to other ICTs by observing the readiness diffusion of the countries. Besides, given the diffusion variation among countries, it is interesting to investigate the average speed of the broadband services and how investment and income levels in each country determine the Internet access fees, which at the end assesses the connectivity efficiency.The results have some policy implications for developed and developing countries. It is essential for policy makers to consider higher education in order to achieve positive spillover effect on labour productivity of such countries. In addition, in this digitialisation era, an introduction of re-skilling and up-skilling programmes to fullfill the industries' need are required in bridging the digital divide among countries.

Hence, there is a justification for governments to subsidize bringing utilisation of ICT to some far-off locations within a country, specifically for developing countries so as to boost productivity. Furthermore, the attractive fees enable to increase the adoption of ICT without having to worry about increasing cost. In fact, the higher the adoption, the more readiness people tend to be more productive and this consequently will pay off for the economy. Furthermore, the government should strengthen the fundamental structure inclusive of the educated and high skilled labour which is one of the likely ways of improving labour productivity.

NOTES

[1] According to calculating World Bank Atlas method, economies are divided according to 2017 GNI per capita. The groups are: countries with GNI per capita less than USD1,005 are categorized as low-income countries, lower-middle income countries are those having GNI per capita between USD1,006 and USD3,955, upper-middle income are those having GNI between USD3,956 and USD12,235; while high-income countries are those with GNI per capita above USD12,236. The developing countries comprises the low, lower middle and upper middle income countries in the World Bank categorization (Aubert, 2004). However, low-income countries were excluded to avoid any bias in the analysis. See http://www.worldbank.org/data/countryclass/classgroups.htm

[2] The sample include island countries such as Malta and Trinidad and Tobago which represent developed countries and the GNI per capita are USD23810 and USD18840 respectively, while the developing countries include Dominican Republic, Jamaica and Sri Lanka which have GNI per capita of USD6630, USD4750 and USD3840 respectively.

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APPENDIX

Data Sources and Sample Countries

TABLE A1. Summary of independent variable descriptions for ICT adoption and productivity

Symbol	Variables	Proxy	Description	Data Source
LP	Labour Productivity	Labour productivityper person employed	(constant 1990, US$)	The Conference Board Total Economy Database
K	Capital Stock	Gross Capital Formation	US$	World Development Indicators, World Bank
L	Labour	Labour force participation	Thousand	World Development Indicators, World Bank
HC	Human Capital	Gross tertiary education enrolment	%	World Development Indicators, World Bank
ICT	ICT adoption	Mobile Broadband Subscription	100 per population.	International Telecommunication Union (ITU)
PR	Prices	Mobile Broadband Prices	prices, postpaid computer-based mobile-broadband plans with a data allowance of 1 GB per month (US$)	International Telecommunication Union (ITU)
RD	Innovation	Company spending on R&D	Likert scale (1-7). In your country, to what extent do companies invest in research and development (R&D)?	World Economic Forum Dataset (WEF)

TABLE A2. List of Countries

Developed Countries		Developing Countries	
Australia	Latvia	Albania	Kazakhstan
Austria	Lithuania	Argentina	Kenya
Bahrain	Luxembourg	Armenia	Kyrgyz Republic
Belgium	Malta	Azerbaijan	Macedonia, FYR
Canada	Netherlands	Bangladesh	Malaysia
Chile	New Zealand	Bolivia	Mexico
Croatia	Norway	Bosnia and Herzegovina	Moldova
Cyprus	Oman	Brazil	Morocco
Czech Republic	Poland	Bulgaria	Nigeria
Denmark	Portugal	Cambodia	Pakistan
Estonia	Saudi Arabia	China	Peru
Finland	Singapore	Colombia	Philippines
France	Slovak Republic	Costa Rica	Romania
Germany	Slovenia	Dominican Republic	Russian Federation
Greece	Spain	Ecuador	South Africa
Hong Kong SAR	Sweden	Egypt	Sri Lanka
Hungary	Switzerland	Georgia	Thailand
Iceland	Trinidad and Tobago	Ghana	Tunisia
Ireland	United Arab Emirates	Guatemala	Turkey
Italy	United Kingdom	India	Ukraine
Japan	United States	Indonesia	Venezuela
Korea, Rep.	Uruguay	Jamaica	Vietnam
		Jordan	

Source: Author's compilation