DIGITAL DIVIDE AND A SPATIAL INVESTIGATION OF CONVERGENCE IN ICT DEVELOPMENT ACROSS PROVINCES IN INDONESIA

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Abstract

In the digital era, technology plays a much bigger role all over the world including in Indonesia. In fact, Indonesia's ICT Development Index (IDI) has improved over time. However, it is noticeable that disparities among regions in regards to ICT development are still wide resulting in digital divide. This paper aims to examine the convergence of regions with regard to ICT development and analyze the key factors which drive the convergence process using annual data from 2015 to 2019. Spatial panel regression method is used to test for absolute and conditional beta convergence. The results reveal that there is evidence for the existence of absolute and conditional convergence in regards to ICT development in Indonesia. Regarding conditional convergence, the convergence process takes a shorter time to reach half-time convergence by taking into account several control variables consisting of output in ICT sector, FDI, and government allocation on education. In addition, the significant spatial correlation among provinces shows that the growth of neighboring provinces' ICT development also contributes to the convergence process. This finding implies that the digital divide has declined and the factors mentioned above are important instruments to help bridge the digital divide.

Abstrak

Di era digital, teknologi memiliki peran yang besar di seluruh dunia termasuk di Indonesia. Hal ini dapat dilihat dari perkembangan Indeks Pembangunan Teknologi Informasi dan Komunikasi (IP-TIK) Indonesia yang selalu meningkat selama beberapa tahun terakhir. Akan tetapi, pembangunan TIK antarwilayah di Indonesia masih tidak merata sehingga menimbulkan adanya kesenjangan digital. Penelitian ini bertujuan untuk mengidentifikasi terjadinya proses konvergensi pembangunan TIK dan menganalisis faktor-faktor yang mendorong ketercapaian konvergensi pembangunan TIK di Indonesia tahun 2015 hingga 2019. Metode analisis yang digunakan adalah regresi data panel spasial untuk menguji konvergensi beta absolut dan kondisional. Hasil penelitian menunjukkan bahwa terdapat potensi terwujudnya pemerataan pembangunan TIK di Indonesia yang ditandai dengan konvergensi absolut dan kondisional pembangunan TIK. Lebih lanjut, hasil analisis konvergensi beta kondisional membuktikan bahwa proses konvergensi membutuhkan waktu yang lebih singkat untuk mencapai paruh waktu konvergensi dengan mempertimbangkan variabel-variabel kontrol meliputi PDRB sektor TIK, PMA, dan anggaran untuk pendidikan. Selain itu, nilai koefisien autokorelasi spasial yang signifikan menunjukkan bahwa pertumbuhan pembangunan TIK di wilayah tetangga juga berkontribusi terhadap proses konvergensi. Maka, hasil penelitian ini memberikan sinyal bahwa kesenjangan digital di Indonesia berpotensi untuk semakin menyempit dan faktor-faktor di atas merupakan instrumen penting untuk membantu mempercepat upaya pengentasan kesenjangan digital.

INTRODUCTION

In the digital era, technology plays a much bigger role in every single aspect of life. Not only is it used as a means of communication, but information and communication technology (ICT) has also been used in other spheres including to optimize a country's economic growth. The Ministry of Communication and Information Technology of Indonesia [1] stated that the extent of ICT diffusion indicates the development of a country which makes it become a vital development tool. In line with that, the Indonesian government has carried out various efforts to make use of the technological advances. One of them was implemented through the Palapa Ring project which was launched to meet the target of the National Medium Term Development Plan (RPJMN) of 2015-2019. The plan contained programs which included and emphasized the role of ICT in various development agendas. The efforts kept going on as digital transformation was appointed as one of the mainstreaming components in RPJMN of 2020-2024 where the national digital transformation acceleration agenda becomes one of the pillars of Indonesia's current main policy [2].

In fact, those efforts are in line with Indonesia's ICT development which shows a positive trend. Over the years, the value of the contribution of the information and communication sector (section J) to Indonesia's Gross Domestic Product (GDP) tends to increase which indicates that the role of ICT sector in the Indonesian economy is also growing. Furthermore, the use of ICT in economic activities such as e-money which is used for payment transactions also has an increasing value [3]. Aside from those indicators, another measure that can reflect Indonesia's ICT development is by ICT Development Index (IDI). The index provides a standard measure of the level of ICT development in a region which allows it to measure the growth of ICT development, the potential for ICT development, and the digital divide across regions. IDI consists of three sub-indexes, which are access sub-index (ICT access), use sub-index (ICT use), and skills sub-index (ICT skills). Over the 2015-2019 period, Indonesia's IDI has always increased which is also followed by the increase of its three sub-indexes [4]. This positive result reflects that there is a progress in the development of ICT in Indonesia.

However, it is inevitable that the government's role in elevating ICT development in Indonesia is constantly faced with uneven spread of ICT development. As Indonesia is the largest archipelagic country in the world which also consists of many remote and isolated regions, creating an even distribution of ICT development becomes a big of a challenge. It can be reflected by the advancement of IDI by provinces. In fact, provinces with relatively high IDI are dominated by western Indonesia provinces with the highest IDI scores are in the range of six. These values are far above the provinces with the lowest IDI scores in the range of three which are dominated by eastern Indonesia provinces [4]. In this way, it is clear that even though Indonesia's IDI tends to increase, there is a wide range of IDI values when we compare each province. In line with that, the Survey of ICT Use by the Ministry of Communication and Information Technology of Indonesia [1] proves that islands in western Indonesia have a significantly higher percentage of ICT use compared to eastern Indonesia, in regard to computer, laptop, smartphone, tablet ownership, or internet access. In this matter, Java Island always obtains the highest percentage, while Maluku and Papua Islands obtain the lowest percentage in all categories. Thus, it leads to an indication that there is also an uneven spread of ICT use in Indonesia.

The results above reflect that there's a big gap in ICT development across provinces. This gap clearly couldn't be separated from the fact that there's an uneven distribution of ICT development which results in the existence of the digital divide in Indonesia. According to OECD [5], digital divide is the gap in access to

ICTs and the use of the internet for various activities among individuals, households, businesses, and geographic areas at different socio-economic levels.

The digital divide in Indonesia is one of the issues that should be dealt with. According to Indonesian Internet Service Providers Association [6], an even distribution of ICT development is not only about access to information, but also closely related to socio-economic issues such as eradication of poverty, even distribution of education, and empowerment of disadvantaged societies. Thus, ICT development is one of the few approaches to elevate social welfare. Hence, the illustration of digital divide in Indonesia could reflect the extent of its social welfare. Moreover, it could also potentially enlarge the economic development's gap across regions in Indonesia considering that ICT plays an important role in accelerating one region's economic rate in this digital era.

Consequently, there needs to be an effort to eliminate disparities with regard to ICT development across provinces so each of them would be able to make use of the advances in ICT as much as possible. In this case, the even distribution of ICT development can be shown by the shrinking digital divide. Therefore, observing the process of closing the gap is closely related to identifying the convergence process, because convergence—with regard to ICT development—implies that the levels of ICT development across regions are tending to converge which also means that its disparities are getting reduced [7].

Aside from that, the convergence process of ICT Development might involve the spatial interactions among regions. This thing can be linked to Tobler's first law of Geography [8] which stated: "everything is related to everything else, but near things are more related than distant things". Several studies proved that ICT development of a region will affect and be affected by its surrounding regions [9,10,11]. Moreover, the fact that Indonesian provinces are polarized in two groups where technologically developed provinces are situated in the West, while the ones in the East are lagging behind supports the notion which proposes that ICT development of a region is related to the geographical position of the region.

In line with the vast technology advances, studies concerning digital divide are getting massive, whether by quantifying digital divide or by looking into its determinants. Kathuria & Oh [7] conducted a research related to digital divide across countries by analyzing the convergence of ICT development and showed that digital divide has declined in relative terms, but not in absolute terms. Park et al. [12] conducted a similar study by analyzing digital divide across countries using convergence analysis of ICT development and found that the level of digitalization convergence can be categorized into three different groupings, where the first group contains the highest level of convergence, while the results for the third group showed the lowest convergence level. This study also identified its determinants which consisted of per capita GDP, tertiary education entrance rate, the ratio of urban population, and the share of service trade in GDP. Meanwhile, Rath [13] examined the convergence of ICT development across countries and revealed that the convergence didn't exist where the growth of per capita income and the ratio of urban to rural population were the factors driving a country's digitalization divergence level.

Further, literature on the digital divide that focused on Indonesia was conducted by Hadiyat [14] who analyzed the determinants of the digital divide. Using a qualitative approach, the results of the study concluded that the factors influencing the digital divide were ICT infrastructure, the socio-economic conditions of the community, and the role of the government. Similar studies using a quantitative approach had also been carried out. Using multiple linear regression, Pick & Azari [15] proved that FDI, the output in ICT sector, and government spending on education have a significant effect on ICT development in developing countries. Meanwhile, Sarkar et al. [10] developed a similar study by adding a spatial dimension approach and found that there is a spatial autocorrelation on the level of ICT use in Africa where per capita income is the variable that gives the most dominant influence.

This study attempts to examine the convergence of provinces with regard to ICT development and analyze the key factors which drive the convergence using annual data from 2015 to 2019. It contributes to the literature in a couple of ways. First, it focuses on measuring the digital divide across provinces in Indonesia which has been much less explored. Second, it uses a more comprehensive metric to analyze digital divide, namely ICT Development Index (IDI) which has a broader scope regarding ICT diffusion which consists of several indicators. Finally, the analysis explicitly includes a spatial econometric approach which takes into account the possible presence of spatial autocorrelation in the model.

METHODOLOGY

1. Concept of Digital Divide

Several theories examining digital divide have been posited over the years. The very first theory regarding digital divide originated from the Adoption-Diffusion Theory (ADT) developed by Rogers [16]. The core of the theory posits the process of adopting a specific innovation for use and diffusing its use in a population of potential users over time. ADT is implemented widely across different spheres including the process of the diffusion of ICT over time which makes it applicable to the concept of digital divide.

van Dijk [17] develops a concept regarding digital divide namely van Dijk's Model of Digital Technology Access. The difference between this theory and ADT is that it serves a more complex theoretical framework and emphasizes the existence of gaps in regards to acces and use of ICT between individuals. Moreover, the determinants of the gaps existing in digital divide can be traced through this concept. This theory states that the gap in the personal position and individual background causes the gap in individual resources which results in the gap in access to ICT and finally leads in turn to the gap in the participation of individuals in society. Thus, inequalities in individual characteristics and their position in society contribute to the access and use of ICT obtained. In addition to individual characteristics, individual resources are also considered as influencing factors.

Spatially Aware Technology Utilization Model (SATUM) enhances prior digital divide literature by taking into account the spatial factor of the occurrence of the digital divide. Pick & Sarkar [11] states that although demographic, socio-economic, and economic development factors are implicitly spatial, prior studies regarding digital divide have been pretty much silent about the possibility of spatial autocorrelation existing in the theoretical models. In other words, prior literature is still unable to answer the question whether the extent of ICT diffusion of a region will affect and be affected by its surrounding regions which are geographically close to each other. Thus, based on the finding by Warf [18] which emphasized the geography factor of digital divide, SATUM is employed which explicitly considers the spatial effect.

2. Concepts of Convergence

The concept of convergence directly derived from Solow's Neoclassical Growth Model [19] which is commonly used in modeling economic growth. The aggregate production function in this model states that the level of output is a function of capital and labor. Regarding this model, Mankiw [20] states that in the transition of economic growth to the steady state, if countries started off with different capital stocks but they have the same saving rates, population growth rates, and labor efficiency so that they have the same steady state, then we should expect that poorer countries who have the smaller capital stock will experience catch-up effect so that they will have a quicker growth to reach the steady state compared to rich countries. The process of catch-up is called convergence.

Accordingly, Barro & Sala-I-Martin [21] defines the catch-up process as absolute beta convergence, which is a condition when the economy in poor countries will be able to catch up with the economies of rich countries. Absolute convergence stipulates that all countries have the same steady state level which means that the long-run equilibrium is the same for all economies. This concept implies that the amount of per capita income in a period only depends on the amount of per capita income at the beginning of the period. The equation of the model for absolute beta convergence can be written as [21]:

$$\ln\frac{y_{i,t}}{y_{i,t-1}} = \alpha + \beta \ln y_{i,t-1} + u_{i,t} \qquad (1)$$

Where the left-hand side of the equation shows per capita income growth, t-1 and t are the initial and terminal periods for ith country, $y_{i,t-1}$ is the value of per capita income in the initial period, α is intercept, β is regression parameter, and $u_{i,t}$ is error term.

In the absolute beta convergence equation, the significant and negative value of β implies that there is a negative relationship between the value of per capita income in the initial period and the value of growth in income per capita between periods. Thus, if β is negative, it can be seen that the economy between countries leads to convergence and the greater the value of $|\beta|$, the greater the tendency towards convergence. In this case, the speed of convergence (β^*) and the half-time convergence (τ) can be obtained by the following equations [22]:

$$\widehat{\beta^*} = -\frac{\ln(1-\beta T)}{T} \qquad (2)$$

$$\hat{\tau} = -\frac{\ln(0{,}5)}{\beta^*} \qquad (3)$$

Furthermore, Mankiw [20] stated that in empirical evidences, the economy in the world today has more complex characteristics. This causes the application of the absolute beta convergence hypothesis to empirical observations becomes less representative. Thus, to test the economy against countries with different steady states, a modification of the initial analysis is obtained which is called conditional convergence. The main idea of this hypothesis is that the economies of countries will converge towards their own steady states by taking into account other control variables. Thus, the existence of conditional beta convergence does not only depend on the value of per capita income at the beginning of the period, but is also influenced by other factors. The equation of the model for conditional beta convergence can be written as [23]:

$$\ln\frac{y_{i,t}}{y_{i,t-1}} = \alpha + \beta \ln y_{i,t-1} + \boldsymbol{\gamma}\boldsymbol{X}'_{i,t} + u_{i,t} \qquad (4)$$

Where $\boldsymbol{X}'_{i,t}$ is a vector of determinants of per capita income growth and $\boldsymbol{\gamma}$ is the slope of kth variable where k is the number of variables.

Another approach that is also used to determine convergence is by sigma convergence. According to Barro & Sala-I-Martin [22], sigma convergence focuses on dispersion between economies. In this case, convergence occurs when the dispersion (a measure of the spread) between economies decreases over time. Thus, from an economic perspective, the existence of sigma convergence which is represented by a decrease in the value of the coefficient of variation of per capita income indicates a tendency for equal distribution of per capita income between economies.

3. Concepts of Convergence with Regard to ICT

By using the same concept of convergence, Kathuria & Oh [7] borrowed the concept of beta convergence with respect to ICT and argued that even in this sphere, ICT development of the countries can lead to convergence. Thus, if there are two groups of countries consisting of ICT advanced countries and ICT emerging countries, convergence occurs when ICT emerging countries tend to experience faster ICT development. Thus, when countries are converging with regard to

ICT, it indicates that the digital divide that occurs among these countries is shrinking.

Moreover, Rath [13] proposed a conditional beta convergence with regard to ICT by taking into account several control variables in the model considering that each country has its own steady state. Conditional beta convergence for ICT development has the same concept as the absolute beta equation. One thing that distinguishes those two is the existence of a vector of determinants of ICT development as control variables in the equation.

Another approach mentioned by Rath [13] to test for digital divide across countries is by using the concept of sigma convergence in the sense of ICT. In this case, sigma convergence in ICT development occurs if the dispersion of ICT development between countries tends to decrease over time. Thus, the existence of sigma convergence represented by a decrease in the coefficient of variation of ICT development indicates that there is a tendency for an even distribution of ICT development between countries which can be a signal that the digital divide is shrinking.

4. Materials and Methods

This study covers all 34 provinces in Indonesia which examines the digital divide and identifies the existence of convergence in ICT development among them. The panel data used in this study covers a period from 2015 to 2019. The reason for choosing this period is because there' s a change in the measurement of IDI starting from 2015. In addition, IDI data for Indonesia's youngest province–North Kalimantan–only became available in 2015. This study uses information and communication technology development index (IDI) as the response variable as an approach to measure the extent of ICT diffusion in a province. Meanwhile, the control variables used to test for conditional beta convergence consist of output in ICT sector as X_1, Foreign Direct Investment (FDI) as X_2, Employment as X_3, and government allocation on education as X_4. All data are obtained from annual report published by Statistics Indonesia and the Ministry of Education and Culture. However, due to limitations related to the availability of ICT access data in 2015 and 2016, this study uses adjusment figures regarding the limitation by applying ICT access data in 2017 to fill in the data for both of those years. Hence, an assumption is made by considering that the conditions of ICT access prior 2017 have not changed.

The analysis used in this study includes descriptive analysis and inferential analysis. Descriptive analysis is used to illustrate the development of IDI in Indonesia over the years. In addition, this descriptive analysis also includes sigma convergence analysis. Sigma convergence is measured using the coefficient of variation of IDI which is the division between the standard deviation of 34 provinces in Indonesia and its average. In this case, sigma convergence occurs if the values of the coefficient of variation of IDI tend to decrease throughout the 2015-2019 period.

Meanwhile, the inferential analysis to test for beta convergence uses spatial panel data regression. Before performing the analysis, the very first thing that needs to be determined is the spatial weight matrix. This is because the location from one region to another plays an important role in spatial analysis which can be quantified using spatial weight [24]. In other words, an element of the matrix w_{ij} reflects the amount of spatial influence of region j on region i. Further, there are a couple of criteria determining the value of spatial weight w_{ij}. This study uses distance-based spatial weights to represent the spatial relationships specifically by applying the method of the neighborhood contiguity by distance. This criterion is chosen because Indonesia is an archipelagic country where the majority of its regions do not have physical borders with each other, so the use of criteria involving physical borders will tend to be difficult to be applied.

The next major step in doing spatial analysis is by identifying the presence of spatial autocorrelation in the model. In this study, Moran's Index (I) [25] is performed to test for its existence. A positive value of I means there is a positive autocorrelation. In other words, an ICT advanced region is likely to be surrounded by other regions that are also ICT advanced, and vice versa. Meanwhile, a value of zero I denotes the absence of spatial autocorrelation. After that, the selection of models between spatial autoregressive model (SAR) and spatial error model (SEM) is conducted with the help of Lagrange Multiplier (LM) test and Robust LM test [26]. The following selection process is then conducted by choosing between fixed effect and random effect by applying the Hausman test [27]. The last step of the modelling is performed by testing for several assumption tests consisting of normality assumption using Shapiro-Wilk test [28], homoscedasticity assumption using Glejser test [29], and nonmulticollinearity assumption using the value of variance inflation factor (VIF) [30].

EMPIRICAL RESULTS

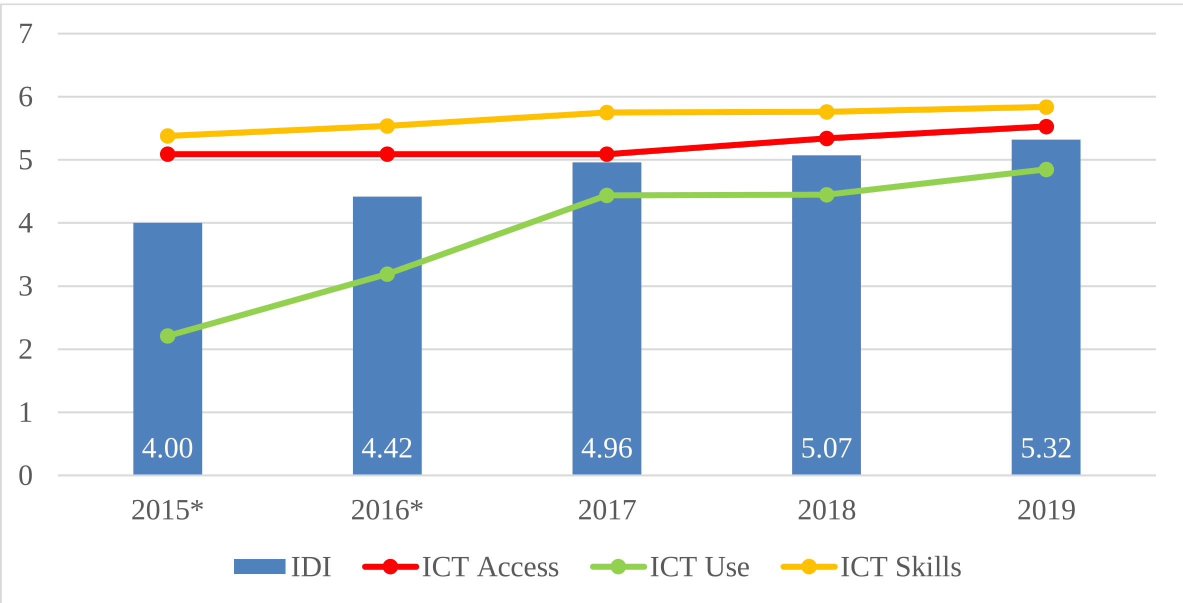
Ever since the government attempts to encourage utilization of technology, ICT development in Indonesia gives a positive signal. It can be shown from the improvement of IDI in Indonesia. In this case, IDI is a composite index on a scale of 1-10 which breaks down into four categories, very low (0.00-2.50), low (2.51-5.00), medium (5.01-7.25) and high (7.26-10.00) [4].

Based on Figure 1, we can see that Indonesia's IDI has always increased. In 2015, Indonesia had an IDI value of 4 that sent Indonesia into the low category. This IDI value is escalating over the years until it reaches medium category with IDI value of 5.07 in 2018 and 5.32 in 2019. This escalation aligns with the development of each subindex, that presents similar result. Thus, we can clearly see that there's a positive outcome in Indonesia's ICT development which also depicts Indonesia's IDI development that keeps progressing and has a potential to keep growing. Although it is believed that ICT development in Indonesia is increasing every year, there is an indication that it has an unequal distribution of development resulted in digital divide.

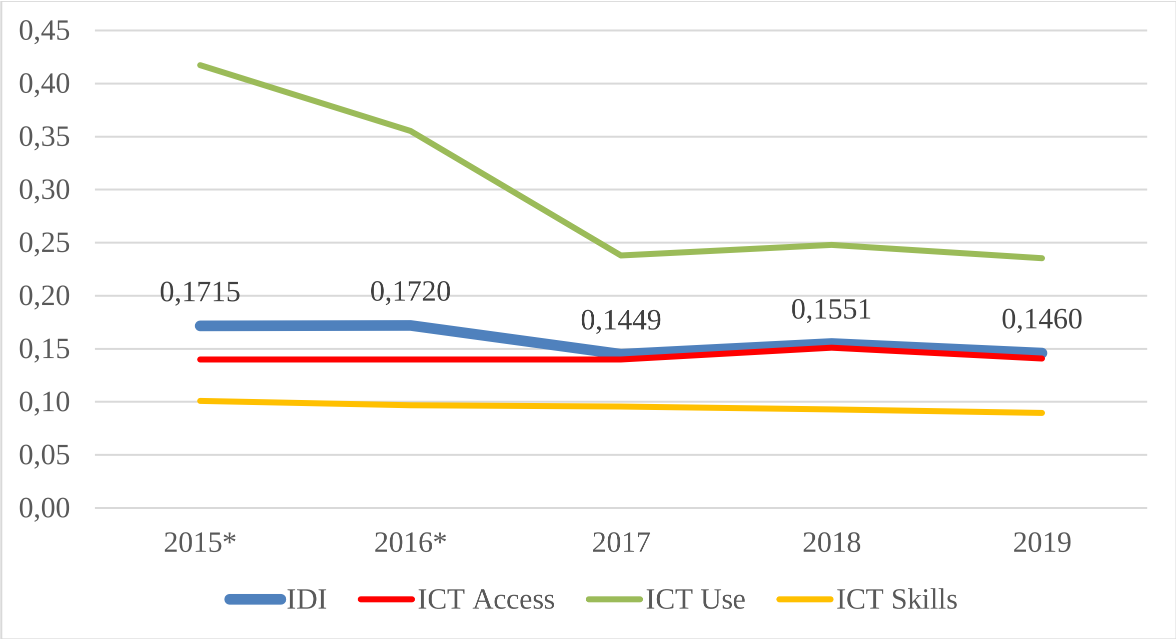
1. Sigma Convergence

The sigma convergence of ICT illustrating the extent of the digital divide across Indonesia is estimated using Figure 2 which shows the coefficient of variation of ICT overall development (IDI), ICT access, ICT use, and ICT skills.

Based on the figure, it is known that the coefficient of variation of IDI across provinces tends to decrease over the 2015-



*) Adjustment figures
Figure 1. Indonesia's ICT Development Index 2015-2019



*) Adjustment figures

Figure 2. Coefficient for the variation in ICT development in sigma convergence

2019 period. Its value in the initial period was 0.1715 and it gradually decreased to 0.1460 in 2019. The decrease indicates a decline in the disparity in the coefficient of variation of ICT development across provinces in Indonesia. Referring to the theory proposed by Rath [13], it can be seen that the digital divide between ICT advanced and ICT emerging provinces narrowed over the years.

More importantly, according to its sub-indexes, the coefficient of variation of ICT use is the highest compared to other sub-indexes. It indicates that this component has the greatest influence on the digital divide that occurs in Indonesia. This can be linked to the value of the use sub-index which has the lowest value compared to other sub-indexes (Figure 1) which reflects that the level of ICT use in Indonesia is still relatively low. In line with these results, Sujarwoto & Tampubolon [31] stated that 80 percent of internet activities in Indonesia only takes place in Java. Meanwhile, there are still many other islands, the majority of which are located in eastern Indonesia, which still do not get consistent electricity facilities, let alone the internet network. However, the coefficient of variation of ICT use shows a positive signal because it significantly reduces and experienced a major decrease in 2017. This means that the gap in the extent of ICT use in Indonesia significantly declined over the years.

2. Beta Convergence

The results of sigma convergence analysis reveals that there's a decline in the disparities among regions in regards to ICT development which indicates the presence of convergence process. Thus, we next examine the speed of convergence and half-time convergence using absolute beta convergence.

Table 1. Result of Moran test

Moran's I	**P-value**
0.0827	0.0067*

**) significant at α = 5 percent*

First, we present the result of a significant Moran's I test in table 1 which shows the presence of spatial autocorrelation in terms of ICT development across provinces. Moreover, the positive value of I means there is a positive autocorrelation which implies that ICT advanced region is likely to be surrounded by other regions that are also ICT advanced, and vice versa.

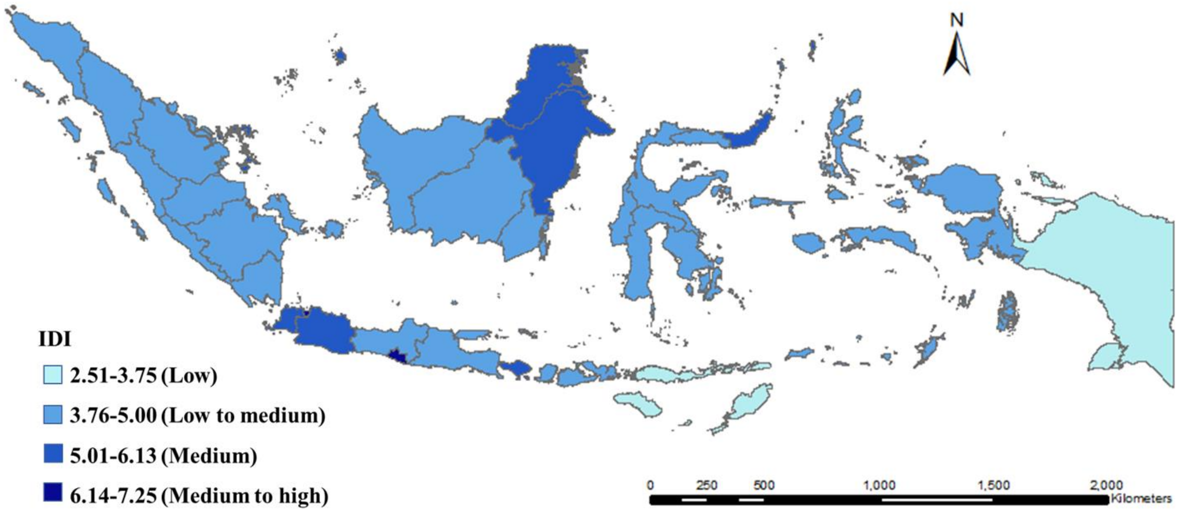


Figure 3. Distribution of IDI across provinces in 2015-2019 (average values)

In this case, this outcome can be linked to the results of Figure 3 which shows the distribution of ICT development across provinces. In general, provinces which are closer geographically tend to have similar IDI scores. For instance, DKI Jakarta, which is the province with the highest IDI in Indonesia, is neighboring West Java and Banten, which also have a relatively higher IDI. Similarly, East Kalimantan and North Kalimantan are physically adjacent to each other and have similar IDI values. However, there are some specific provinces which show different results and need to be explored more detailed. D.I. Yogyakarta, the province with the second highest IDI in Indonesia, is geographically surrounded by Central Java which is the province with relatively lower IDI. This anomaly also occurs in the region next to it, East Java. Despite being surrounded by other provinces with relatively high IDI and having IDI values higher than the national average, these two provinces have lower IDI values compared to their neighboring provinces. By taking a look into their subindexes, we can explain the reason why it could occur. Even though Central Java and East Java have relatively high values in ICT use and ICT access, these two provinces have low values of ICT skills. Jawa Tengah and Jawa Timur have ICT skills values of 5.29 and 5.52, respectively, which are lower than the national average, 5.83. This result implies that there needs to be qualified values of each sub-index considering that all of them play an important role in order to improve the quality of ICT development of a region.

Meanwhile, the positive spatial autocorrelation in terms of ICT development also applies to the opposite, where provinces with lower IDI tend to be surrounded by provinces with low IDI. In fact, the four provinces with the lowest IDI are all in Eastern Indonesia, namely Papua, East Nusa Tenggara, West Sulawesi, and North Maluku. According to Ariyanti [32], this condition is closely related to the geographical location of the provinces in eastern Indonesia which tend to be difficult to reach. Therefore, various ICT installations are likely difficult to carry out. Hence, we can clearly figure that Indonesian provinces are polarized in two groups where ICT advanced provinces are situated in the West, while the ones in the

Table 2. Results of model selection for absolute beta convergence

Tests	P-value
LM Lag	0.0000*
LM Error	0.0000*
Robust LM Lag	0.0000*
Robust LM Error	0.6795
Hausman	0.0010*

**) significant at α = 5 percent*

East are likely lagging behind which causes digital divide.

The next step of the analysis is selecting the best model shown in Table 2. The results of LM Tests reveal that both models are significant. Thus, it is followed by Robust LM tests to determine the most suitable model. The results of Robust LM Test show a significant result in Robust LM lag which means that SAR model is more suitable for modelling absolute beta convergence in ICT across provinces. Further, the Hausman test gives a significant result which means that fixed effect is more appropriate for the data used in this study. Several assumption tests consisting of normality and homoscedasticity are performed and it also reveals that there's no violation on all of those assumptions.

Table 3. Estimation of parameter model for absolute beta convergence

Variable	Coefficient	P-value
Intercept	0.3344	0.0000*
$\ln y_{t-1}$	-0.1953	0.0000*
ρ	0.4085	0.0015*
Adjusted R-Squared : 0.7547		Speed of convergence ($\widehat{\beta^*}$) :17.84%
		Half-time convergence ($\hat{\tau}$) :3.89 years

*) significant at α = 5 percent

The parameter estimates from SAR model are then determined by applying maximum likelihood estimation. The estimated parameter are shown in Table 3 and the final model of absolute beta convergence can be written as:

$$ln \frac{\widehat{y_{\iota,t}}}{y_{\iota,t-1}} = (0.3344 + \hat{\mu}_i) + 0.4085 \sum_{j=1}^{34} w_{ij} \ln \frac{y_{i,t}}{y_{i,t-1}} - 0.1953 \ln y_{i,t-1} \quad (5)$$

From above equation, it can be seen that the lagged IDI (y_{t-1}) is statistically significant and has a negative value of -0.1953. Thus, referring to the concept of absolute beta convergence in regards to ICT developed by Kathuria & Oh [7], this value indicates that there is an absolute beta convergence of ICT development in Indonesia. In other words, ICT emerging provinces generally have an absolute tendency to grow faster than ICT advanced provinces. The speed of convergence that occurs across provinces in Indonesia is 17.84 percent while the time needed to reach the half-time convergence is 3.89 years. The occurrence of this convergence has also been indicated from the results of the sigma convergence analysis where the coefficient of variation of IDI tends to decline. Thus, the ICT development across provinces in Indonesia in absolute terms leads to convergence and the digital divide in Indonesia is shrinking.

Table 4. Results of model selection for conditional beta convergence

Tests	P-value
LM Lag	0.0000*
LM Error	0.0000*
Robust LM Lag	0.0000*
Robust LM Error	0.4877
Hausman	0.0010*

*) significant at α = 5 percent

Next, we test for conditional beta convergence by taking into account several control variables in order to get the key factors which influence and drive the convergence process. By conducting the same steps in prior model selection shown in Table 4, the model chosen for modeling conditional beta convergence in ICT across provinces gives a similar result to the absolute one, namely SAR model with the fixed effect aprroach. After performing the assumption tests consisting of normality, homoscedasticity, and nonmulticollinearity assumptions and proving no sign of violation, the parameter estimates from the second SAR model are then determined.

Table 5. Estimation of parameter model for conditional beta convergence

Variable	Coefficient	P-value
Intercept	-1.5479	0.0004*
ln y_{t-1}	-0.4432	0.0000*
ρ	0.3573	0.0018*
ln x_1	0.1537	0.0061*
ln x_2	0.0073	0.02411*
x_3	0.0018	0.3863
ln x_4	0.0828	0.0002*
Adjusted R-Squared : 0.7965		Speed of convergence ($\widehat{\beta^*}$) :36.69%
		Half-time convergence ($\hat{\tau}$) :1.89 years

*) *significant at* α *= 5 percent*

The estimated parameters are shown in Table 4 and the final model of conditional beta convergence can be written as:

$$\begin{aligned} ln\frac{\widehat{y_{i,t}}}{y_{i,t-1}} &= (-1.5479 + \hat{\mu}_i) \\ &+0.3573\sum_{j=1}^{34} w_{ij}\ln\frac{y_{i,t}}{y_{i,t-1}} \\ &-0.4432\ln y_{i,t-1} \\ &+0.1537\ln x_{1i,t} \\ &+0.0073\ln x_{2i,t} \\ &+0.0018x_{3i,t} \\ &+0.0828\ln x_{4i,t} \end{aligned} \quad (6)$$

From above equation, we can see that the the lagged IDI (y_{t-1}) is statistically significant and has a negative value. This outcome shows that there is a conditional beta convergence of ICT development in Indonesia which means that ICT emerging provinces also have a conditional tendency to grow faster than ICT advanced provinces. Thus, the development of ICT between provinces in Indonesia leads to convergence and the digital divide in Indonesia is shrinking. The speed of convergence that occurs between provinces in Indonesia is 36.69 percent while the time required to reach the half-time convergence is 1.89 years.

In this case, if we compare the speed of absolute beta convergence with the conditional beta one shown in Table 6, we

Table 6. Comparison of absolute beta and conditional beta convergence results

Beta convergence	Speed of convergence	Half-time convergence
Absolute	17.84%	3.89 years
Conditional	36.69%	1.89 years

*) *significant at* α *= 5 percent*

can see that there is an increase in the speed of convergence from 17.84 percent to 36.69 percent. This implies that by taking into account other variables that affect ICT development, the ICT development of provinces in Indonesia has a tendency to grow at a faster rate in order to achieve convergence. The same result is also applied for the half-time convergence. The half-time convergence in conditional beta convergence is twice as short, 1.89 years, compared to the half-time of the absolute beta one, which takes 3.89 years. These results also indicate that the existence of control variables that affect ICT development can accelerate the effort to reduce the digital divide in Indonesia.

3. The Key Factors Driving the Convergence Process in ICT Development

The spatial autoregressive coefficient of both models–equation (5) and equation (6)–reveal positive and significant results which imply the presence of interactions of the growth of ICT development between regions. In other words, apart from being determined by other independent variables in the region, the growth of ICT development in a region is also influenced by the growth of ICT development in its surrounding regions. The positive values of the spatial autoregressive coefficient in both models indicate that there is a regional grouping based on the growth rate of ICT development where areas with high ICT development growth tend to be surrounded by areas with high ICT development growth as well. This also applies to the opposite where areas with low ICT development are surrounded by areas with low ICT development growth. This result corroborates the concept of Spatially Aware

Technology Utilization Model (SATUM) which explicitly states the existence of spatial autocorrelation in measuring digital divide [11]. This is because the growth of ICT development in a region is not only influenced by the variables mentioned above, but is also influenced by the growth of ICT development in its surrounding regions. Further, regarding the convergence process, we can see that the presence of spatial effects can stimulate the growth of ICT development in a region. Thus, the spatial effect plays in important role to the convergence process and help bridge the digital divide in Indonesia.

Output in ICT sector (X_1) has a significant and positive effect on the growth of ICT development. An increase in the output in ICT sector by 1 percent can significantly increase the growth of ICT development by 0.1537 percent with the assumption of ceteris paribus. These results are in line with prior studies [9,33,15] which proved that the ICT sector has a positive effect on the level of ICT development. ICT sector is a sector that naturally involves the use of ICT in the production process so that increasing output in this sector can increase the demand for ICT. Further, Varoudakis & Rossotto [34] stated that in addition to expanding the ICT sector itself, output growth in the ICT sector can also produce a multiplier effect in other sectors so that it can stimulate investments in ICT. Thus, when the output of the ICT sector helps increase the growth of ICT development in a region, it can be concluded that Output in ICT sector is one of the key instruments to accelerate the convergence process in bridging the digital divide.

FDI (X_2) has a significant and positive effect on the growth of ICT development in Indonesia. An increase in FDI by 1 percent can significantly increase the growth of ICT development by 0.0073 percent with the assumption of ceteris paribus. These results are supported by prior studies [35,15,36] which stated that FDI has a positive effect on the extent of ICT development. This is because FDI contains investments that affect the widespread use of certain technologies, spending on ICTs, and improving the quality of technology infrastructures. Furthermore, multinational companies from countries that invest will tend to standardize their operations and the capabilities of their workers, including in the host countries [36]. Therefore, FDI allows host countries to gain access to more advanced technology and technical knowledge which in turn would contribute to the ICT development growth and drive the convergence process.

Employment (X_3) has a coefficient of 0.0018. However, despite having a positive relationship, the employment variable has no significant effect on the growth of ICT development in Indonesia. This can be explained through the skill-biased technological change [37], where the technological advancement only benefits certain workers. In fact, technological advances do not automatically benefit the entire society and it can even create a more unequal employment opportunities. Fuady (2018) finds that ICT advancements in Indonesia can only be utilized by workers who work in technology-intensive jobs and require high skills. This means that only a small number of workers in Indonesia who can make use the role of ICT. This can cause the demand for ICT and the level of use of ICT among workers tend to be low in general. Therefore, the increase in employment in Indonesia has not been able to have a significant effect on the growth of ICT development.

Government allocation on education (X_4) has a significant and positive effect on the growth of ICT development in Indonesia. An increase in the government allocation on education by 1 percent can significantly increase the growth of ICT development by 0.0828 percent with the assumption of ceteris paribus. This result is in line with prior literature [38,15,39] which proves that government allocation on education has a positive effect on the level of ICT development in developing countries including Indonesia. This is because the extent of education in a region can affect its ICT development, especially in the aspect of ICT use and ICT skills. In terms of ICT use, the higher the education level, the higher the expertise in operating a technological device [40]. Meanwhile, in terms of ICT skills, Subiakto [41] stated that the lack of knowledge would unable people to utilize ICT properly. Thus, a qualified level of education is needed in order to support the society to optimize the use of ICT. In fact, having access to ICT alone is not enough to bridge the digital divide if it is still lack of ICT skills. So, it can be seen that government allocation on education is an investment in human resources, the ICT users. Thus, the government allocation on education has a positive impact on ICT development, especially to improve the quality of the aspects of ICT use and ICT skills in order to drive the convergence process and help shrink the digital divide.

CONCLUSION

Indonesia is still facing an uneven spread of ICT development which causes the digital divide. The positive spatial autocorrelation indicates that Indonesian provinces are polarized in two groups where ICT advanced provinces are likely to be surrounded by other provinces that are also ICT advanced which are situated in the West, while the ones in the East are likely lagging behind. However, over time, there is a potential for an even distribution of ICT development which is reflected by the presence of a convergence process with regard to ICT development across provinces in Indonesia. Within the limitations of this study, the time required to achieve the half-time convergence in the absolute term is 3.89 years. Meanwhile, in the conditional term, by considering the addition of control variables including output in ICT sector, FDI, and government allocation on education, the half-time convergence can be achieved in a shorter time of 1.89 years. In addition, the significant spatial correlation among provinces shows that the growth of neighboring provinces' ICT development also contributes to the convergence process. Thus, these significant control variables can be used as instruments to accelerate the convergence process to create a more even distribution of ICT development and bridge the digital divide in Indonesia.

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