Do Infrastructures Influence the Efficiency Convergence of the Indonesian Economy?

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In the last 10 years, Indonesia has set its infrastructure development to support the economy. Infrastructure, as the vital part of development, contributes to economic performance proxied by technical efficiency. This research aims to examine the role of infrastructure (water, electricity, and roads) toward the convergence of technical efficiency. Data from 33 provinces of Indonesia for the period of 2008–2015 were analyzed using stochastic frontier analysis (SFA) and generalized method of moments (GMM). Results show that technical efficiency converged during the period of interest. Further investigation suggests that water, electricity, and roads exert an important influence on the emergence of efficiency growth and its convergence.

Keywords: Efficiency, Infrastructure, Stochastic Frontier Analysis, Convergence

JEL Classification: O1, O2, O4

I. Introduction

Indonesia has arranged various programs for establishing infrastructure in the last 10 years. The recent government is focused on the

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role of infrastructure in boosting economic activities. According to the data of Badan Pusat Statistik (Statistic Central Bureau), the number of roads, electricity consumption, and water supply has grown significantly during the last decade. This condition has enhanced the economic performance of the 34 provinces of Indonesia.

The economic performance of Indonesia in recent years requires evaluation to identify the various effects of economic dynamics in the country. The evaluation is divided into micro and macro points of view. From the micro perspective, evaluation is executed partially for every economic activity of a company, whereas from the macro perspective, further evaluation is aggregately and simultaneously carried out with various other economic activities in Indonesia.

One of the main concerns regarding Indonesia's economic performance is the availability of infrastructure. Calderon and Serven (2004) identified the existence of a significant effect of the availability of physical infrastructure, such as electricity and roads, on the rise of income per capita. This result indicates that infrastructure may affect various vital elements of the Indonesian economy. Therefore, the current infrastructure development has been enhanced in a bid to support the sustainability of economic activities.

Aside from the level of infrastructure availability, the economy is also facing an inequality in distribution for each region in Indonesia, namely, West Indonesia (Sumatera Island, Kalimantan Island, and Java Island), Central Indonesia (Bali Island, Sulawesi Island, and Nusa Tenggara Archipelago), and East Indonesia (Maluku Archipelago and Papua Island). The infrastructure data show that from 2008 to 2015, West Indonesia received 92.5% of the country's supply of clean water on average while Central and Eastern Indonesia received 6.601% and 0.890%, respectively. Furthermore, West Indonesia received more than 86% of the electricity energy supply, with the remaining supply allocated to Central and Eastern Indonesia. The empirical data show that the proportional inequality of infrastructure distribution for each region, particularly water distribution and road development, reduced from year to year. The government, through its policy, has clearly made an effort to eradicate inequality among the regions of Indonesia. Hence, this policy can remarkably improve economic performance.

The development of infrastructure is still challenged by various problems, especially the constrained budget for infrastructure. Moreover, the budget state (Anggaran Pendapatan dan Belanja Negara) of infrastructure is greater than the current government assets. In fact, Indonesia's Ministry of Finance stated a deficit Rp 1751 trillion in 2014. As a solution for these issues, the government has implemented the scheme of public–private partnership (PPP).

The implementation of PPP, as one of the infrastructure financing posts, has been legally internalized by the Presidential Regulation No. 38 of 2015 on Government Cooperation with Business Entities in the Provision of Infrastructure (Kementerian Keuangan Republik Indonesia, 2017). The scheme has been executed on various priority infrastructure projects, such as Palapa Ring, Steam Power Plant (PLTU) Batang 2x1000 MW, Umbulan Water Supply System (SPAM), Bandar Lampung SPAM, Manado-Bitung toll road project, Balikpapan-Samarinda, Semarang-Trunk, and Pandaan-Malang (Ministry of Finance of Republic Indonesia 2017). These projects are expected to improve economic performance in every area where infrastructure is built.

Economic performance is manifested by various indicators. These indicators can be analyzed quantitatively to generate appropriate insights regarding economic activity. One of the most widely used indicators is technical efficiency that measures how proportional inputs can produce a particular output (Coelli *et al.* 2005, p. 3). The level of efficiency is influenced by various macro and micro factors. Thus, the influence of determinants on economic efficiency in Indonesia requires investigation.

The calculation of efficiency as one reflection of economic performance has expanded and become varied. The results of efficiency calculation are not limited to the calculation of technical efficiency in micro data (firm level) as they also involve macro data with advanced calculation methods, such as the calculation of total factor productivity (Limam and Miller 2004; Kumbhakar and Wang, 2005), determinants of efficiency level (Battese and Coelli 1995; Greene 2004), and efficiency convergence testing (Kneller and Stevens 2003; Cavallo and Kasman 2017). Becerril–Torres *et al.* (2010) popularized the convergence testing of efficiency and determinants by testing the influence of infrastructure on the convergence of economic efficiency in Indonesia.

The current article contributes to the literature by taking infrastructure variables into the research area of efficiency convergence. Becerril-Torres *et al.* (2010) postulated that transportation, communication, and household basic equipment affect the growth of efficiency. On the contrary, the current research attempts to focus on the role of infrastructure in the convergence of efficiency, particularly in the areas of water, electricity, and roads in Indonesia, where the development of infrastructure is still in its early stages. Furthermore, the influence of programs for intensifying the establishment of infrastructure, needs to be evaluated. Opportunities to strengthen the effect of infrastructure on the economy are abundant, especially when infrastructure is in the initial phase.

II. Literature Review

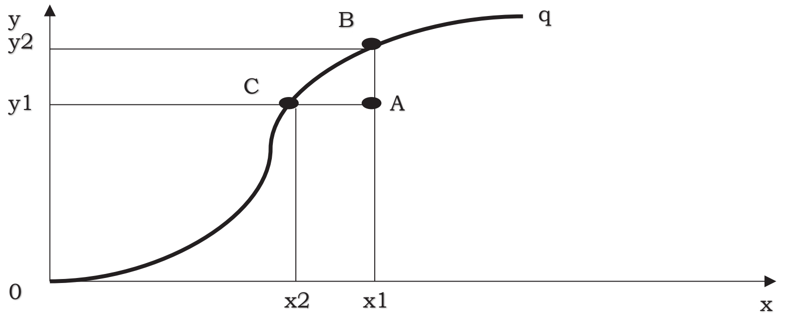
A. Technical Efficiency

The literature discusses the concept of efficiency. Koopman (1951) defined efficiency as a condition that involves an output increase, which affects the decrease of other outputs in the least amount, and an increase of at least one input. With this definition, Coelli *et al.* (2005) concluded that technical efficiency is when producers manufacture similar products with minimal input or use the same input to produce a large volume of products. By contrast, technical inefficiency refers to the failure to obtain maximal possible output with the available input levels (Amsler *et al.* 2009). Given these two terminologies, an efficient circumstance is achieved only if technical efficiency is zero, which indicates the absence of failure. Illustrations of technical efficiency are shown in Figure 1.

In Figure 1, line q is the frontier line. The frontier line is formed from the optimum production standard points, for instance, at points C and B. At point A, production levels are not technically efficient because they are outside the frontier line. To achieve an efficient condition, the firm at point A should reduce the quantity of input x because with the input level of x1 at point A, the firm can produce the same amount of output (y1) which means it is indifferent when they produced at point C with amount of the input at x2. To achieve efficient conditions, the company at point A can also increase its output to the frontier line (point B). With the same level of input usage x1, the company can still increase its output from y1 to y2 (frontier line). Therefore, the company can obtain efficient conditions.

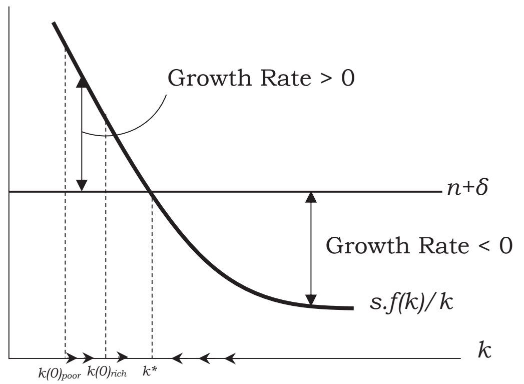
B. Convergence and Efficiency Convergence

The theory of convergence is derived from neoclassical theory, which



Source: Coelli *et al.* (2005)

FIGURE 1
TECHNICAL EFFICIENCY ILLUSTRATION



Source: Barro and Sala-i-martin (2004, p. 38)

FIGURE 2
CONVERGENCE OF GROWTH

assumes that the per capita economic growth rate tends to be inversely related to the level of initial output or income level of a person (Ramsey 1928; Solow 1956); In other words, if the level of income increases, the level of economic growth decreases as it approaches a steady state.

The theory of convergence is illustrated in Figure 2. The concept of the dynamic model of Swan's Solow illustrates that $s.f(k) / k$ (saving curve) and $n + \delta$ (effective depreciation line) represents the rate of growth of the ratio of capital and labor (k). The ratio of capital and labor of poor countries ($k(0)_{poor}$) at the beginning period is greater than that of wealthy countries ($K(0)_{rich}$). Hence, the lag between the saving curve and the depreciation line effectively represents the growth rate. A low growth rate indicates that the saving is near the effective depreciation line; this case describes potential convergence. Barro and Sala-i-martin (1992) related this theory to the concept of universal poverty, which indicates that poor countries will grow faster than rich countries, leading to a convergence at the end.

Various operational definitions have been put forward to describe efficiency convergence. According to Kamus Besar Bahasa Indonesia, convergence is as *a condition of movement toward a certain point*. Various studies that used such definition of efficiency convergence are prolific (Battese and Coelli 1995; Kumbhakar and Wang 2005; Maudos *et al.* 2000). These studies defined the convergence of efficiency according to their respective objectives.

Battese and Coelli (1995) aimed to determine the level of efficiency of paddy farming in India and to learn the inefficiency effect variables (variables affecting certain levels of inefficiency). One such inefficiency effect variable was time (t), which was found to affect the inefficiency rate of rice productivity in India. If time negatively influences the inefficiency level, efficiency convergence is achieved. In other words, inefficiency level decreases in the following time and eventually converges to the optimum efficiency level.

The convergence of efficiency is defined as the condition of an increasing efficiency level approaching optimum efficiency. This concept was also used in the research of Kneller and Steven (2003) and Kumbhakar and Wang (2005). Both studies used macro data, with gross domestic product (GDP), capital (C), and labor (L) as the variables, to uncover the presence of technical efficiency. However, these studies utilized different variables that affect inefficiency. Whereas Kneller and Stevens (2003) used the same inefficiency effect variables, Kumbhakar and Wang (2005) employed the initial capital-to-labor ratio variable as a justification for the convergence of efficiency.

Other studies related to the convergence of efficiency predominantly followed the classical literature of Barro and Sala-i-martin (1992) who defined general convergence as a condition of movement toward a point resulting in a decrease in the degree of certain inequalities between observations. The studies that used this concept of efficiency convergence include Weill (2009), Becerril–Torres *et al.* (2010), and Shen *et al.* (2015). Those studies attempted to detect the trend of movement of efficiency level regardless of whether the movement is convergent or divergent.

C. Influence of Infrastructure toward Economic and Efficiency Convergence

Hulten and Schwab (1991) considered infrastructure such as roads as a direct input for some sector in the economy, such as transportation and service industries. However, they regarded infrastructure as an indirect environmental input for the manufacturing sector, which can be seen as the path for infrastructure to motivate the convergence of efficiency. Gramlich (1994) stated that infrastructure promotes economic efficiency by reducing transaction cost.

Several studies discussed the effects of infrastructure on economic convergence. Del Bo *et al.* (2010) tested the role of telecommunication and transportation infrastructure in the growth convergence of European Union (EU) regions by using panel ordinary least square and weighted least square. This study found that transport and telecommunication infrastructure has an important role in accelerating the growth convergence process. Furthermore, those variables strongly influence the rate of growth in EU regions.

Becerril–Torres *et al.* (2010) examined macroeconomic convergence in Mexico and the indicators of infrastructure (including road length, airport availability, ports, water supply, certain electric power facilities, waste disposal, and telecommunication) affecting convergence. Using the capital variables (proxied by gross fixed capital formation) and labor (projected by the number of occupations employed), the study tested the beta convergence model in accordance with the neoclassical theory adopted in the work of Barro and Sala-i-Martin (1992). The results suggested that infrastructure (in the form of public investment) significantly affects the convergence of efficiency among states in Mexico. Therefore, those efficiency disparities may decline.

III. METHOD

A. Data and Variable

This research uses macro panel data within the period of 2008–2015 and consists of data from 33 provinces in Indonesia. The data were obtained from the Indonesian Central Bureau of Statistics, particularly the publication of the Gross Regional Domestic Product Statistics,

Table 1
Descriptive Statistic of Variables

Variable	Unit		Years							
			2008	2009	2010	2011	2012	2013	2014	2015
GRDP (Y)	Billion Rupiah	Mean	60577.17	63465.40	208004.03	220815.60	234417.74	246476.68	259270.90	272226.58
		Std. Dev	89096.16	93269.27	281962.92	300290.17	319435.61	337242.08	355763.45	374327.09
GFCF (CAPITAL)	Billion Rupiah	Mean	13358	14082	15213	16666	75915	79355	83139	86721
		Std. Dev	23055.89	23820.47	25770.59	28359.00	116102.24	121484.67	125852.29	130046.45
LABOUR (L)	Worker (In Thousand)	Mean	3108	3178	3279	3255	3409	3417	3474	3471
		Std. Dev	4555.364	4662.915	4599.866	4603.083	4861.952	4890.985	4907.283	4858.527
WATER	M^3	Mean	73057.61	78215.88	68769.939	75707.818	82125.242	84579.727	89077.879	110393.12
		Std. Dev	133080.1	132344.3	91369.282	100723.55	108119.5	110895.94	115723.06	150010.92
ELECTRICITY	GwH	Mean	3909.662	4066.459	4499.5745	4808.9364	5277.9882	5701.8688	6025.1124	6184.0445
		Std. Dev	7465.573	7646.962	8379.552	8916.9327	9700.7175	10269.645	10943.521	11077.812
ROAD	KM	Mean	13402.45	14435.55	14505.091	15048.697	15211.182	15393.939	15689.485	15727.182
		Std. Dev	9778.599	9444.363	9495.4919	10004.298	9752.4045	9761.5811	9754.3191	9914.3623
Number of Observation			33	33	33	33	33	33	33	33

where Mean = arithmetic average, Std. Dev = Standard Deviation

Statistics of Clean Water, Electrical Statistics, and Indonesian Statistics. The data descriptions are presented in Table 1.

The variables utilized in this study are based on the research of Becerril–Torres *et al.* (2010), as well as the empirical condition of Indonesia; they are known to have a great influence on efficiency.

a) Output

The output in this study is proxied with the real gross domestic regional product (GDRP) of every province in Indonesia. The real GDRP is used on the basis of a comparison with that in the work of Becerril–Torres *et al.* (2010) using the state's GDP in Mexico.

b) Input

The input variable is used as a benchmark of the level of technical efficiency achieved to produce an output. The variables used are capital (capital) proxied by total investment in each province. This indicator is based on the work of Becerril–Torres *et al.* (2010) that used gross fixed capital formation (GFCF) as a capital variable. The labor variable uses the number of laborers available in each province (Becerril–Torres *et al.* 2010; Piazolo 1996).

c) Infrastructure Variables

Various indicators are used to represent infrastructure. In this study, infrastructure is limited to physical infrastructure. Following Becerril–Torres *et al.* (2010) and Del Bo *et al.* (2010), we used the length of the provincial road (kilometers), the amount of water supplied (m^3), and the amount of electrical energy supplied (GwH) as infrastructure variables. Road length is utilized instead of road quality due to the limited data of each province. Hence, this study attempts to use the near proxy of road infrastructure.

B. Stochastic Frontier Analysis (SFA)

Stochastic frontier analysis (SFA) is a deterministic approach using the frontier production function to define the reference limits of efficiency estimates. SFA is able to discover the lag between actual output and potential output represented in the level of technical inefficiency. Furthermore, SFA can be used to find the optimum real standard that can be obtained by a company in relation to maximizing output or minimizing input use. The points on the determination of the optimum real standard form the frontier line; if the company is on the frontier line, then it is under an optimum efficiency condition (Coelli *et al.* 2005). In general, the SFA model is formulated as follows:

$$\ln q_i = x_i \beta + v_i + u_i \tag{1}$$

q_i is the dependent variable, x_i is the independent variable, v_i is the error of the model, and u_i is the variable that captures the inefficiency level.

In accordance with research of Becerril–Torres *et al.* (2010), the SFA model is used in panel data with the translogarithmic production function. The specifications of the model in general are as follows.

$$\begin{aligned}\ln Y_{it} = {} & \beta_0 + \beta_1 Ln(K_{it}) + \beta_2\ Ln(L_{it}) + \beta_3\ Ln(K_{it})\, Ln(L_{it}) \\ & + \beta_4\ (Ln(K_{it}))^2 + \beta_5 (Ln(L_{it}))^2 + \beta_6\ t_{it} + V_{it} + U_{it}\end{aligned} \tag{2}$$

where i = 1, 2, ... 34 provinces, t = 2000 ... 2016, Y_{it} is an output proxied by gross regional domestic product, and X_{it} is an input consisting of capital (K) and labor (L). V_{it} is a random error, and U_{it} is the level of inefficiency. The inefficiency consists of the following equation:

$$U_{it} = \delta_0 + \delta_1 T + \delta_2 T^2 + \delta_3(Ln(K_{it}) - Ln(\mathrm{L}_{it})) + W_{it} \tag{3}$$

The inefficiency equation consists of temporary variables (T) and random error (W_{it}). With this equation, we used the Farrel (1957) theorem with the following specifications:

$$ET_{it} = \exp(-U_{it}) = \exp[-(\delta_0 + \delta_1 T + \delta_2 T^2 + \textstyle\sum_{i=1}^{31} \lambda_i D_i) - W_{it}] \tag{4}$$

Technical efficiency is calculated on the basis of the level of production achieved relative to the maximum reach rate. The value of technical efficiency ranges from 0 (very inefficient) to 1 (very efficient).

The following likelihood ratio test is utilized to select the appropriate production function between translogarithmic and Cobb Douglas.

$$\lambda = -2[\lambda(H_0) - \lambda(H_1)] \tag{5}$$

where $\lambda(H_0)$ and $\lambda(H_1)$ are the values of the log likelihood of the *null* hypotheses (Cobb Douglas) and alternative hypotheses (translog), respectively. The likelihood ratio test attempts to choose the best production function used to measure technical efficiency. This methods considers λ as a parameter by seeing Log Likelihood value in each production function. If λ is greater than *x*2 table, the *null* hypotheses are rejected, thus translog should be used.

C. Generalized Method of Moments (GMM)

Initiated by Hansen (1982), the generalized method of moments (GMM) applies dynamic regression consisting of lag time among independent variables (Anderson and Hsiao 1982). The fundamental function of GMM is the advancement of the method of moments for describing the features of a population (Woolridge 2001). Method of moments estimates μ, the expected value or mean of a certain random variable such as y (denoted as $E(y)$), to measure central tendency and recognize it as the first moment. Other parameters, specifically population variance, denote σ^2 or Var (y) as the second moment decomposed from $E[(y - \mu)^2]$. This two sets of moment are used in a manner that minimizes the asymptotic variance among the method of moment estimators of μ. Moreover, GMM estimates panel data within the limited serial correlation in the error term of the equation (Bond 2002).

GMM uses panel data to be estimated in dynamic regression with lag time. The presence of lag time certainly leads to endogeneity; hence, improving the fixed effect or random effect is inappropriate (Verbeek 2008; Nickhell 1981). Baltagi *et al.* (2013) postulated the model of dynamic panel in the following equation:

$$y_{it} = \delta y_{i,t-1} + x'_{it}\beta + u_{it} \tag{6}$$

where δ is the scalar, x'_{it} is the $1 \times K$ matrix, β is $K \times 1$, and u_{it} is assumed to follow the one-way error component model.

$$u_{it} = \mu_1 + v_{it} \tag{7}$$

where μ_{it} ~$IID(0, \sigma^2_\mu)$ depicts the individual influence and v_{it} ~$IID(0, \sigma^2_v)$ is the parameter of transient error. In terms of dynamic model, this situation is substantially different due to y_{it} being a function of μ_{it} similarly with $y_{i,t-1}$ is a function of μ_{it}. As μ_{it} is a function of

u_{it}, a correlation between $y_{i,t-1}$ and u_{it} exists. As a result, the least square estimator, as empowered by the static panel model, becomes inconsistent and biased, even with v_{it} showing no correlation at all.

D. Specification of Efficiency Convergence

The concept of convergence relates to the degree of regional disparity in a country. Hence, in the case of the convergence of efficiency, it implies how unequal the efficiency level of each province is and the tendency of imbalance increasing (divergent) or decreasing (convergent). In accordance with the work of Barro and Sala-i-martin (1992), convergence in the current work is divided into *beta* (β) convergence and *sigma* convergence (σ). Koo and Lee (2000) defined *beta* convergence as the negative relations between the rate of efficiency growth and the efficiency in the initial period. Moreover, *beta* convergence is employed to determine the catching-up effect of lower-efficiency provinces to match the provinces with higher efficiency levels, whereas sigma convergence is when a disparity exists in the differentiated efficiency levels between provinces (Wild 2016). The current research uses beta convergence to capture the effect of infrastructure on the convergence phenomenon. The equation is as follows.

$$\frac{Ln(e_{it} / e_{it-T})}{T} = a - b\ Ln(e_{it-T}) + u_{i,t,t-T} \tag{8}$$

where the value of b is > 0 and depicts the speed of convergence (Zhang and Matthews 2012).

Weil (2009), Carvallo and Kasman (2017), and Wild (2016) also used a similar formulation to test the convergence of efficiency in panel data. The formulation is as follows.

$$Ln(EFF_{qt}) - Ln(EFF_{q,t-1}) = \alpha + \beta Ln(EFF_{q,t-1}) + \varepsilon_{qt} \tag{9}$$

where $0< \beta <1$, EFF is the rate of technical efficiency, α and β are parameters estimated, and ε_{qt} is an error term. Beta convergence occurs when the value of β is negative. The abovementioned equations ((8) and (9)) empower GMM to discover relevant parameters.

E. Specification of the Influence of Infrastructure toward Efficiency Convergence

Del Bo *et al.* (2010) and Calderon and Serven (2004) explained that infrastructure significantly affects economic activities in a region. In other words, infrastructure realized from public and private funds affects economic activities. In the current study, infrastructure is indicated to affect the convergence of efficiency as a parameter of the economy. The influence of infrastructure variables on the convergence of efficiency is illustrated in the equation below.

$$\frac{Ln(e_{it} / e_{it-T})}{T} = a - b\ Ln(e_{it-T}) + cI_{it-T} + u_{i,t,t-T} \tag{10}$$

The existence of infrastructure influence is seen in variable I as an indicator of each type of infrastructure. Becerril–Torres *et al.* (2010) used four models consisting of 1) the overall effect of infrastructure, 2) the influence of transport infrastructure, 3) the influence of communication infrastructure, and 4) the effect of basic and household equipment. When convergence occurs, the parameter "b" becomes negative. However, the effect of variable I is seen from its parameter value, "c". If "c" is negative, then the increase in infrastructure actually decreases the growth of the efficiency level. Hence, such increase does not contribute to the growth of the technical efficiency of a province. By utilizing GMM, this study examines the influence of water, electricity, and road infrastructure, partially and simultaneously, on the growth of the efficiency of the Indonesian GDRP in 2008–2015.

IV. Results

A. Test of Efficiency Specification

A test of specification is necessary in the use of stochastic frontier to derive the appropriate method. In this work, we used the maximum likelihood of Frontier 4.1 for the translog and Cobb Douglas production function. The results are presented in Table 2.

As shown in Table 2, all parameters of the translog are significant at the 10% level, but β_1 of Cobb Douglas is irrelevant. Delta 1 (δ_1), which is a time trend variable, can be interpreted given an increase in year; then, the level of inefficiency declines (which means increased efficiency). In

Table 2
Maximum Likelihood Calculation of Translog and Cobb Douglas Production Function

Parameter	Translog		Cobb Douglas	
	Coefficient	SE	Coefficient	SE
β_0	37.005***	6.2483	19.474***	1.0953
β_1	-1.543***	0.3794	0.0241	0.0347
β_2	1.814***	0.6624	0.935***	0.0206
β_3	-0.139***	0.0408	0.055***	0.0095
β_4	0.059***	0.0131	-	-
β_5	0.114***	0.0341	-	-
β_6	0.208***	0.0249	-	-
δ_0	11.622***	1.0153	11.296***	0.3722
δ_1	-0.512***	0.0446	-0.668***	0.0492
δ_2	0.058***	0.0048	0.057***	0.0039
δ_3	-0.517***	0.0405	-0.525***	0.0232
σ_2	0.124***	0.0109	0.136***	0.0077
Γ	0.731***	0.0970	0.999***	0.0001
Likelihood Ratio	-202.94236		-111.50905	

where *** : significant at 1%, ** : significant at 5%, * : significant at 10%

this condition, the convergence of efficiency occurs in accordance with the theory of Battese and Coelli (1995), Kneller and Stevens (2003), and Kumbhakar and Wang (2005) that interpreted a change in efficiency level that is influenced by time changes. The Delta 3 (δ_3) parameter is interpreted as the influence of capital and labor ratios at the beginning of a period on the convergence of efficiency levels. These results show that the ratio significantly affects the efficiency level. In particular, the level of efficiency increases by 73.1% in terms of speed. The *gamma* parameters show coefficients of 0.731 for translog and 0.999 for Cobb Douglas. The *sigma-square* parameters show coefficients of 0.124 for translog and 0.136 for Cobb Douglas. These coefficients are defined as the variance distribution of V_{it} and U_{it}. The *gamma* values of 73.1% and 99.9% indicate the proportion of error rate on U_{it}. These results show that all the parameters can be used to measure efficiency. The result of the log likelihood ratio reveals that the value of λ is 24.47, which is greater than that in the x^2-table. Therefore, translog production

TABLE 3
EFFICIENCY CONVERGENCE TEST

Variable	Parameter	2008-2015	
		Coeff	SE
Constant	β_0	-3.375	0.001
lnTECHNICAL-EFFICIENCY	β_1	-1.135***	0.002
Sargan Test		γ^2 (14) = 32.58372	

where ***: significant at 1%, **: significant at 5%, *: significant at 10%.

functions are used for the following steps.

B. Test on Convergence of Efficiency

The convergence test is conducted to determine the trend of change in efficiency level in each province. The results of the convergence efficiency testing by using GMM in accordance with the work of Becerril–Torres *et al.* (2010) are explained below.

As shown in Table 3, *beta* convergence occurred among the provinces in Indonesia in the period of 2008–2015, with the speed of the convergence being 113% (see equation (8)). The significance of the *beta* convergence indicates the existence of the catching-up effect from provinces that have low efficiency levels toward provinces with high technical efficiency. It implies the improvement of the Indonesian economy in relation to the spatial inequality issues. It also means that all variables included in this study (investments are proxied by GFCF and the number of laborers in each province) proportionally contributes in obtaining a certain output proxied to GDRP. It is also related to the recent policy of the government for the PPP scheme, which leads to an increasing amount of investments in each province. Therefore, the recent GDRP in several periods is increasingly proportional toward the investments and number of laborers, as well as the distribution to each province.

C. Influence of Infrastructure on Convergence of Efficiency

The development of infrastructure for eight years (2008–2015) is suspected to affect various economic performance factors in Indonesia. One such factor is the technical efficiency movement. Infrastructure consists of road length, number of customers of clean water, and

Table 4
Test of Infrastructure Influence toward Convergence of Efficiency

Variable	Model with Infrastructure		
	Water	Electricity	Road
Constant	-4.620*** (0.073)	-3.673*** (0.068)	-1.856*** (0.422)
lnTE ($t-1$)	-1.018*** (0.028)	-0.846*** (0.024)	-0.572*** (0.067)
Water	0.151*** (0.006)		
Electricity		0.157*** (0.007)	
Road			0.041*** (0.004)
Sargan Test	γ^2 (14) = 27.52	γ^2 (14) = 29.94	γ^2 (14) = 32.20

where *** : significant at 1%, ** : significant at 5%, * : significant at 10%. Standard error (SE) inside the bracket.

electricity distribution. The results of the convergence test are as follows.

The test of the influence of infrastructure on efficiency convergence shows that all the variables exert a remarkable effect. The results support the idea that infrastructure acts as an indirect input for the economy that effectively reduces transaction costs. However, the results are varied, with road length having the lowest influence among others. Meanwhile, electricity has the largest influence, with its value being close to the value for water supply. The positive sign of these three infrastructure variables indicates the contribution of infrastructure to efficiency growth, *i.e.*, convergence.

Electricity has the strongest influence on efficiency (Prasetyo and Firdaus 2009) due to electricity being the infrastructure that directly supports companies' production. Realizing this important correlation, the Indonesian government has implemented some programs related to the establishment of electricity systems. For example, the government has supplied 35.000 MW of electricity to entire provinces. This program aims to meet the electricity needs of Indonesians from the most western area (Sabang in Sumatera Island) to the most eastern area (Papua). It is expected to exert a significant influence on economic growth, especially outside Java, which previously lacked electricity supply.

Since the implementation of the program on electricity in 2015, significant progress has been observed in the economy. For instance, economic growth surged from 2015 to 2017. The results of the program indicate that electricity has an incredible effect on the growth of efficiency due to companies not necessarily allocating the cost the electric generation, especially in rural areas that lack electricity. The government has realized that economic growth is achievable if the electricity supply is sufficient in entire areas to support various economic activities. The same is indicated by the results of this study.

The water infrastructure also shows considerable influence on the growth of efficiency. As revealed in our study, such influence is reflected in the massive utilization of water among companies. Indonesia has two large sectors, namely, manufacturing and agriculture, which tremendously support economic growth. Both sectors are heavily dependent on water supply. Manufacturing, such as food and beverage, textile, tobacco, and so on, certainly requires a large amount of water for production. Some areas, particularly Eastern Indonesia, lack water supply. Hence, water must be distributed from other regions, consequently affecting the cost of production. In a similar way, agriculture depends greatly on clean water. For instance, the water infrastructure significantly affects irrigation systems. Therefore, water, as the main input of production, could significantly boost the economy in each province if its supply is sufficiently allocated by the government; in such a case, efficiency occurs.

Road infrastructure has lowest contribution to the convergence of efficiency. The rationale is that roads are not used in the process of production, and thus, their influence on productivity could not be easily detected. Additional roads are not necessarily developed in areas of economic activities. Hence, their effect on output growth cannot reach the maximum potential.

As mentioned in the methodology section, the issue in road infrastructure is data proximity. The closest proxy, which is largely available, is road length only, whereas other proxies, such as road quality, might be able to represent road infrastructure. However, the closest proxy is widely considered due to the qualitative approach to justify road quality. Road infrastructure is different from water and electricity infrastructure as they serve as the main input to produce various goods and thus exert great influence. Kumo (2012) recognized the complexity of the mechanisms correlated between road and economic growth. Hence, the results are not supported theoretically. Furthermore, this complexity indicates that the increase in number of roads (in kilometers) could not directly affect the growth of the economy or even the degree of effect. Therefore, long periods are necessary to capture the contribution of road infrastructure to the growth of efficiency.

V. Conclusion and Policy Implication

This research attempts to measure the technical efficiency of 33 provinces of Indonesia during the period of 2008–2015. The evidence shows a convergence of technical efficiency among provinces in Indonesia. This condition indicates that the disparities of efficiency among provinces are diminishing and that provinces with low efficiency are catching up to the provinces with high efficiency. This reduction of disparities is implied due to the improvement of the infrastructure in those areas, particularly the water, electricity, and road infrastructure. Road infrastructure shows the smallest contribution due to the indirect influence of transportation on economic performance. Hence, the period of observation should be extended to capture the true effects of roads on the convergence of efficiency. The finding of technical efficiency convergence being incredibly influenced by infrastructure, especially water and electricity, indicates that governments must be concerned about infrastructure that directly increases the supply of water and electricity distributed to each province.

In the last 20 years, Indonesia has experienced regional expansion, with provinces split into two or more provinces. For instance, six new provinces were established in 2000–2012. As a result of these expansions, this study is unable to cover all provinces in Indonesia. Furthermore, time lag prevents the model specification from extracting some critical information associated with the variable of interest, such as roads. A long period is needed to discover the influence of such time lag on convergence. The aforementioned issues serve as the limitations of this study that should be considered in future research.

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