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INTERTEMPORAL EFFICIENCY AND PRODUCTIVITY CHANGE OF TELECOMMUNICATION INDUSTRY (TI) IN ASEAN-5

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ABSTRACT

The study aims to measure the technical and intertemporal efficiency and find the primary source of productivity change on top three telecommunication firms in each country of ASEAN-5 (Indonesia, Malaysia, Thailand, Philippines, and Singapore) from 2010 to 2016. Data Envelopment Analysis (DEA) bootstrapping with 2000 iterations, DEA window, and Malmquist index are applied to calculate technical efficiency, intertemporal efficiency, and productivity change. The estimation results elucidate that, on average, the technical efficiency of firms is relatively low. On the opposite, the intertemporal efficiency results indicate that the mean efficiency score of each window is high. However, the LDW and LDP tend to be high, showing that the efficiency scores fluctuate. The Malmquist index calculation yields that technological progress possesses a significant contribution to productivity change.

Keywords: *Technical Efficiency, Intertemporal Efficiency, Productivity Change, Telecommunication Industry, ASEAN-5*

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Introduction

Telecommunication has experienced a fundamental change, which affects other sectors and the economy. The advancement of telecommunication has eliminated distance and reduced the allocated time to disseminate information on urban and rural communities and to convey news between cities, countries, and continents (Gunawardena, 1990; Rizvi, 2011; Harmah & Payne, 2015; Jijiang, Jianqiang, & Rodrigues, 2015).

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Dynamic world activities require high-speed access to information, and the telecommunication industry has been experiencing huge development, providing advancement of the services. The development of telecommunication has brought an implication into the digital economy, which influences and transforms various sectors such as health, tourism, industry, education, agriculture, trade, transportation, and banking (Novelli, Schmitz, & Spencer, 2006; Osabutey & Okoro, 2015; Kiberu, Mars, & Scott, 2017; Romero et al., 2020). The digital economy facilitates economic activity and contributes to economic growth. Furthermore, the more significant economic activities induce financial investment related to the improvement of telecommunication (Dutta, 2001). As a result, the investment in telecommunication possesses the potential to improve economic productivity (Datta & Agarwal, 2004). The economic productivity is sourced from the telecommunication providing network for transferring information, which supports trade and generates economic growth (Madden & Savage, 2000).

The data published by the ASEAN Secretariat (2017) shows that the number of subscription fixed telephone in each country in ASEAN was tended to decrease while the opposite occurred in the number subscription of the cellular telephone. The shift of preference is due to the advancement of telecommunication facilities in a cellular telephone, which do not exist in the fixed telephone, such as multimedia messages. The increasing number of people using cellular telephone implies that the telecommunication industry earns from providing the services. The revenue contributes to the economy as a source of income to the country. The telecommunication penetration rates are among the highest in developing countries, and the ASEAN telecommunication service revenue estimation was $64 billion in 2013 (The ASEAN Secretariat, 2015). The Gross Domestic Product (GDP) of Indonesia, Thailand, Malaysia, Singapore, and the Philippines grew more than the average of ASEAN's GDP (1.68 percent) from 2010 to 2016 (World Bank, 2017). These five countries (ASEAN-5) were also having substantial value-added telecommunication sector to GDP. The data sourced from the ASEAN Secretariat (2015) revealed that Indonesia possessed the highest percentage of telecommunication value added to GDP, which was 6.8 percent in 2013. The telecommunication industry contributed to the Philippines, Singapore, Malaysia, and Thailand economies were 4.7, 4.2, 4.1, and 3.6 percent respectively. The data was supported by the evidence that an increasing number of firms operating in the telecommunication industry in ASEAN.

The growing number of firms in the ASEAN telecommunication industry raises a question of how the productivity and efficiency of the firms are. There are two main approaches to measure efficiency, which are parametric and non-parametric. The former is Stochastic Frontier Analysis (SFA), while the latter is Data Envelopment Analysis (DEA). DEA is an effective method to evaluate the relative efficiency of the decision-making unit (DMU). DEA does not need to choose the functional form between outputs and inputs (T. Coelli, 1996). Although DEA overcomes some disadvantages of the parametric method, DEA does not consider the statistical noise resulting from measurement error. However, Simar & Wilson (1998) proposed DEA bootstrap, which addressed the limitation of DEA and allowed to validate the results by adjusted efficiency score. The productivity or Total Factor Productivity (TFP) of firms will be measured by the Malmquist index, which could measure the amount of growth in actual outputs that is not explained by the growth in inputs.

The use of DEA measuring efficiency of telecommunication industry performance is limited, and there is a lack of studies applying DEA bootstrap to evaluate telecommunication firms. Hu & Chu (2008) investigated the efficiency, productivity, and factors affecting the inefficiency of 24 telecommunication firms in APEC during 1999-2004. In order to answer the objectives of the study, Hu & Chu (2008) employed DEA, Malmquist index, and Tobit. Yang

& Chang (2009) used DEA and DEA window analysis to measure three leading telecommunication firms in Taiwan during 2001-2005. Diskaya, Emir, & Orhan (2011) there has been a fierce competition in the telecommunication sector. Technologic competition has made the competition in the sector a kind of strategic war. The sector of which role increased in terms of economic developments has entered a reconstruction process at an equal rate in all countries. In fact, countries which apprehend the future of the sector will also determine the future of economy. In this respect the aim of this study is to make performance benchmarking by using Data Envelopment Analysis and Malmquist Total Factor Productivity Index on telecommunication sector which is thought as one of the most important signs of national economies in the global economic crisis environment. This benchmarking, which includes the period of global crisis between the years of 2007-2010, targets to measure to what extent countries have been affected from the global crisis environment by means of performance evaluation among the strongest telecom managements of countries such as Turkey and Group of Eight (G8 researched G8 countries, and Turkey measured the efficiency and productivity by employing the DEA and Malmquist index. The productivity of the telecommunication industry in Uganda was investigated by Hisali & Yawe (2011) using the Malmquist index.

This study aims to analyze the technical and intertemporal efficiency and productivity change of the telecommunication industry in ASEAN-5 during 2010-2016. This study contributes to the literature in several ways. First, this study employs the DEA bootstrap, which obtains the bias-corrected DEA estimates. Using DEA bootstrap, technical efficiency is calculated and considering the noise. Second, this firm level-study provides the measurement of intertemporal efficiency, which considers the change or trend of efficiency from time to time over the periods observed. The application of intertemporal efficiency is relatively rare in the literature.

Literature Review

Production is defined as a process to combine, transform, and convert inputs into outputs. The production function model is formed to construct production output with various combinations of input used (Nicholson & Snyder, 2008). The production function model is *q=f(X)*, in which X denotes a combination of inputs such as labor, machinery, energy, and raw material to produce several q outputs. The technology used by the company is also reflected in the production function. Chambers (1989) argued that there are four characteristics of the production function: (a) non-negativity reveals that the value of the production function can be determined (finite), non-negative, and accurate; (b) weak essentiality describes that the production process uses at least one input to produce a non-negative output; (c) non decreasing in x or monotonic explains that the addition of input will not reduce output produced and the assumption is $x^0 \geq x^1$. Thus, $f(x^0) \geq f(x^1)$; and concave in x or law of diminishing occurs because the various linear vectors combination x^0 and x^1 produce output more than or equal to $f(x^0)$ and $f(x^1)$.

Productivity can be measured by the ratio of the output to the input unit used. Productivity is divided into partial or semi and total productivity (Hannula, 2002). First, it is described as the level of production output associated with only one type of input. The latter is the level of output produced associated with the combination of several types of inputs. Therefore, to analyze the productivity of the industry, the total productivity is suitable to be applied. The total productivity or Total Factor Productivity Change (TFPC) considers all outputs and inputs in the entire period. TFPC is decomposed into Technical Efficiency Change (TEC), Scale Efficiency Change (SEC), and Technological Change (TC) (Flokou, Aletras, & Niakas, 2017). In this study, the TFPC is measured by the Malmquist index introduced by Caves, Christensen, & Diewert (1982).

Farrell (1957) proposed the concept of efficiency and classified it into technical efficiency and allocation efficiency. Technical efficiency reflects the ability of a firm to obtain maximal output from a given set of inputs (T. Coelli, 1996).

The technically efficient firm would produce maximum output using a certain number of inputs or produce a certain number of outputs with a minimum unit of input (Greene, 1997). The efficiency score is ranging from zero to one. If the score gets closer to number one, the more efficient the company is. Otherwise, the closer the score is to zero, the more inefficient the company is. The second is allocative efficiency, which reflects the ability of a firm to use the inputs in optimal proportions, given their respective prices.

DEA Window Analysis has been applied in this study mining at overcoming the weakness of DEA, which measures the efficiency relative between DMU and other DMUs. The DEA Window Analysis proposed by Charnes, Cooper, & Rhodes (1978) measures intertemporal efficiency, which evaluates the change of efficiency from time to time. In DEA Window Analysis, each DMU in every period is considered as a different DMU. The DMU is not compared to the actual data, but the DMU is compared with a subset of panel data. Therefore, the DEA Window Analysis could denote the stability of efficiency of each DMU (Flokou et al., 2017). The stability score of efficiency consists of Long-Distance per Window (LDW), Long Distance per Year (LDY), and Long Distance per all Period (LDP) (Coelli, 1996; Brockett, Golany, & Li, 1999; Alayya & Nugraha Rani, 2019). LDW measures the biggest difference in efficiency scores in one window. LDP measures the biggest difference in efficiency scores in the entire observation period, while the LDY score measures the biggest difference in efficiency scores in one year. The smaller value of LDW, LDY, and LDP illustrates the DMU has achieved stable efficiency (Sufian, 2007).

Data and Research Methods

The data are drawn from the annual ASEAN-5 telecommunication firm report and International Monetary Fund (IMF) between 2010 and 2016. The variables are used in this study categorized by inputs and outputs. The inputs are the number of labor and total fixed asset as input variables, while the outputs are total revenue, and the number of customers or (subscribers) becomes output variables. The data are analyzed through quantitative approaches aimed to measure efficiency and productivity. The efficiency analysis is divided into technical efficiency and intertemporal efficiency. The former is measured through DEA bootstrap, which takes into account the error term. DEA Window measures the latter. In order to fulfill the third objective, productivity is calculated through the Malmquist index. Table 1 provides the top three DMU lists in the telecommunication firms industry in Indonesia, Malaysia, the Philippines, Singapore, and Thailand. The exception in the Philippines, there are only two DMU observed.

Table 1: DMU of ASEAN-5 Telecommunication Company

No	Country	Company	No	Country	Company
1	Indonesia	(A) Telkom	8	Philippines	(H) PLDT
2	Indonesia	(B) Indosat	9	Singapore	(I) M1
3	Indonesia	(C) XL-Axiata	10	Singapore	(J) SingTel
4	Malaysia	(D) Celcom	11	Singapore	(K) StarHub

No	Country	Company	No	Country	Company
5	Malaysia	(E) Maxis	12	Thailand	(L) DTAC
6	Malaysia	(F) DiGi	13	Thailand	(M) AIS
7	Philippines	(G) Globe	14	Thailand	(N) True

Source: Data Processed

DEA Bootstrap

In this study, the DEA bootstrap uses 2000 times of iteration level. The iteration objective is to minimize the error level that may not be shown in the deterministic model. This study follows Sadjadi & Omrani (2010) suggestion to do the iteration 2000 times, and thus the sample represents the whole population.

The following is the model to measure the efficiency with output oriented and variable return to scale (VRS) assumption:

$$\begin{aligned} &Maximize \quad \hat{\phi} = \phi - \varepsilon_B(\phi) \\ &Subject\ to \ : -\hat{\phi}_i + Q\lambda \geq 0, \\ &\qquad x_i + X\lambda \geq 0, \\ &\qquad I1'\lambda = 1, \\ &\qquad \lambda \geq 0 \end{aligned} \tag{1}$$

Where $\hat{\phi}$ indicates a corrected bias estimator efficiency score, ϕ is the uncorrected estimator. The bootstrap bias-corrected is expressed as $\varepsilon_B(\phi)$. The proportional increase in output assuming the number of inputs used remained constant is indicated by $\hat{\phi} - 1$. Output vector i, the whole matrix output i, vector input i, the whole matrix input i are denoted by $q_i, Q, x_i,$ and *X* respectively. Technical efficiency values depend on the value of $1/\hat{\phi}$. The efficiency score is ranging from 0 to 1. The VRS model has a convexity constraint I1'λ = 1 where I x 1 is a vector (Coelli et al., 2005).

The DEA Window intends to analyze the stability of intertemporal efficiency (Flokou et al, 2017). Each DMU in each year is assessed as a different DMU. Therefore, the intertemporal efficiency will increase the number of observations. The DMU is not compared to all data, but the DMU is compared to the subset data. The measurement of intertemporal efficiency is reflected in the following formula:

$$W = K - P + 1 \tag{2}$$

N is the number of DMUs observed (14 DMU), K denotes the number of observation periods (7 years). The window length is P, which should be less than equal to the number of observations ($P \leq K$) . The number of the window is W. Following the calculation from equation (2), each DMU is analyzed four times ($W = K - P + 1 = 7 - 4 + 1 = 4$) in this study. On the other hand, $N \times P \times W$ shows the number of different companies using the intertemporal concept, and there are 224 DMUs.

Malmquist Production Index

The third objective is to measure the Total Factor Productivity Change (TFPC) using the Malmquist index. Using the Malmquist index, TFPC is decomposed into Technical Efficiency Change (TEC), Scale Efficiency Change (SEC), and Technological Progress (TC). TFPC is calculated as follow:

$$TFPC^{s,t}(x_s, x_t q_s, q_t) = \frac{d_0^t(x_t, q_t)}{d_0^s(x_s . q_s)} \left[\frac{d_0^s(x_t, q_t)}{d_0^t(x_t, q_t)} \times \frac{d_0^s(x_s, q_s)}{d_0^s(x_s, q_s)} \right]^{1/2} \quad (3)$$

d_0^s denotes the distance function in the first year, d_0^t expresses the distance function in the second year. x_s and x_t indicate input in the first and second year, while q_s and q_t are output in the first and second year. $\frac{d_0^t(x_t, q_t)}{d_0^s(x_s, q_s)}$ is equal to TEC, which compares the relative efficiency in period t+1 and period t. TEC is a catching-up effect that is reflecting the change in efficiency that affects productivity. If the firm experiences an increase in efficiency (improved performance), the TEC score will be more than one. In contrast, when the TEC score is less than one, the company experiences a deteriorating performance. The TEC score is equal to one when the company is stagnant. By using the VRS assumption in both periods (T^t_{VRS} dan T^{t+1}_{VRS}), the TEC can be decomposed into pure efficiency change (PEC) and Scale Efficiency Change (SEC). When the value of the SEC score is more than one, the company experiences an increase in scale efficiency. On the opposite, SEC scores less than one denotes that the company has decreased scale efficiency. The SEC score equal to one shows that the company has a stagnant scale efficiency. $\left[\frac{d_0^s(q_t, x_t)}{d_0^t(q_t, x_t)} \times \frac{d_0^s(q_s, x_s)}{d_0^s(q_s, x_s)} \right]^{\frac{1}{2}}$ equivalent to technological progress (TC). TC allows companies to produce more output with specific combination inputs or produce the same output level using fewer inputs. TC score of more than one indicates an increase in technology used by the DMU. On the other hand, TC scores less than one means that the DMU experiences a technological decline (technological regress).

Finding and Discussion

Table 2: DEA Bootstrapping Estimation Results on ASEAN-5 Telecommunications Industry

Countries	DMU	2010	2011	2012	2013	2014	2015	2016	Average
Indonesia	C	0.86	0.85	0.77	0.77	0.81	0.78	0.78	0.80
Indonesia	A	0.78	0.81	0.84	0.81	0.79	0.81	0.78	0.80
Singapore	J	0.44	0.61	0.86	0.87	0.86	0.82	0.82	0.75
Thailand	L	0.63	0.72	0.76	0.81	0.79	0.76	0.70	0.74
Thailand	N	0.49	0.55	0.72	0.79	0.81	0.79	0.78	0.70
Indonesia	B	0.45	0.63	0.66	0.62	0.70	0.73	0.83	0.66
Singapore	I	0.66	0.59	0.63	0.67	0.68	0.73	0.68	0.66
Malaysia	F	0.73	0.35	0.30	0.32	0.38	0.46	0.47	0.43
Philippines	G	0.20	0.22	0.26	0.27	0.26	0.32	0.32	0.26
Malaysia	E	0.22	0.20	0.20	0.23	0.24	0.34	0.21	0.23
Thailand	M	0.14	0.14	0.15	0.15	0.15	0.12	0.12	0.14
Philippines	H	0.10	0.13	0.15	0.15	0.15	0.15	0.14	0.14
Singapore	K	0.11	0.12	0.10	0.09	0.05	0.11	0.11	0.10
Malaysia	D	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02

Source: Data Processed

Table 2 reports the performance of the ASEAN-5 telecommunications industry from 2010 to 2016. The DEA bootstrap results exhibit that the majority of firms are inefficient. The average technical efficiency score is 0.46 or 46 percent. The firm D has the lowest technical efficiency score (0.2). To achieve efficiency condition, this firm should increase the output by 0.8 or 80 percent.

In contrast, Indonesian telecommunication firms have the best performance. On average, the efficiency scores of these three firms (A, B, and C) are 0.76. Firm A and C have the highest average efficiency scores among 14 telecommunication firms in ASEAN-5. Both firms A and C have the same average efficiency, which is 0.80. On average, firm J, L, N, B, and I are above the average of technical efficiency overall firms. The efficiency scores of these five firms are ranging from 0.66 to 0.75. These companies have the potential to increase production output to be efficient. Companies can achieve efficient production by improving technology and managerial skills in managing the company.

Figure 1 captures the LDP scores and the average score of intertemporal efficiencies of telecommunication firms in ASEAN-5 between 2010 and 2016. The lowest LDP score is achieved by firm 1. The low LDP score indicates that the efficiency scores in the entire observation period are stable. In contrast, the LDP score of firm K exhibits a huge difference between the highest and the lowest efficiency score. The low LDP score and the high intertemporal efficiency scores of firm 1 show that firm 1 has constantly maintained the efficiency score at the level of 0.97 within the observed periods. Firm E has achieved the highest intertemporal efficiency score, but the LDP score is around 0.17. It indicates that the most efficient firm has unstable efficiency scores.

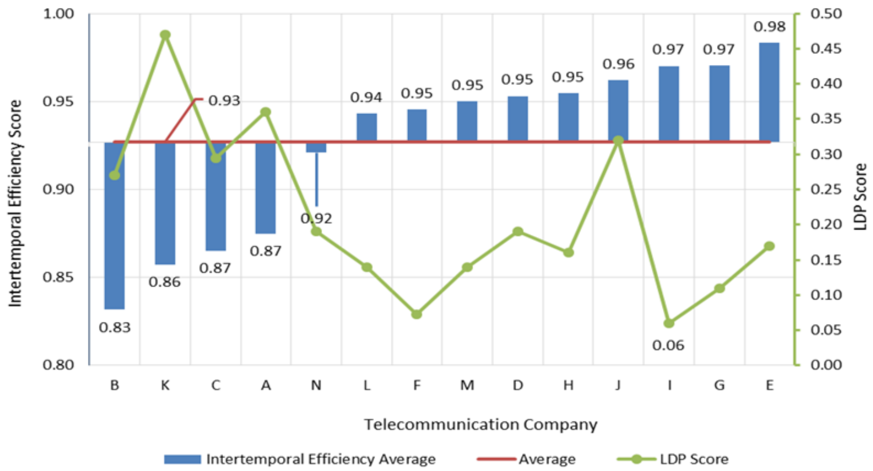


Figure 1: Intertemporal Efficiency Score of Telecommunications Industry in ASEAN-5

Source: Data Processed

Table 3 reports the Long-Distance per Window (LDW), Long Distance per all Period (LDP), and Long Distance per Year (LDY). The measurement exhibits that the firm A, B, C, and K have high LDW scores denoting that the efficiency scores fluctuate almost in all windows. These four firms and firm J seem to have high LDP scores ranging from 0.27 to 0.47. The high LDP score implies a big difference between the lowest and highest firm's efficiency score within the observed periods. The measurement results of the LDY score of firms B and K are relatively high. The LDY score denotes the difference in a firm's efficiency score in a particular year compared to the efficiency score in the same year located in a different window. Based on the results, the LDW, LDP, and LDY yield different analyses of the stability efficiency scores considering the window of time.

Table 3: DEA Window Analysis Estimation Results

DMU	*Window*	2010	2011	2012	2013	2014	2015	2016	*Mean/ Window*	*Mean*	LDW	LDP
	1	0.63	0.7	0.9	0.85				0.77		0.27	
	2		0.64	0.84	0.87	0.9			0.81		0.26	
A	3			0.86	0.95	0.95	0.96		0.93	0.88	0.1	0.36
	4				0.99	0.97	0.99	0.99	0.99		0.02	
	LDY	X	0.06	0.06	0.14	0.07	0.03	X				
	1	0.71	0.82	0.92	0.89				0.84		0.21	
	2		0.79	0.9	0.9	0.92			0.88		0.13	
B	3			0.81	0.81	0.92	0.91		0.86	0.83	0.11	0.27
	4				0.65	0.87	0.74	0.87	0.75		0.22	
	LDY	X	0.03	0.11	0.25	0.05	0.17	X				
	1	0.92	0.74	0.92	0.92				0.88		0.18	
	2		0.74	0.93	0.93	0.95			0.89		0.21	
C	3			0.91	0.9	0.96	0.67		0.86	0.87	0.24	0.3
	4				0.9	0.96	0.66	0.91	0.86		0.3	
	LDY	X	0	0.02	0.03	0.01	0.01	X				
	1	0.97	0.91	0.97	0.98				0.96		0.07	
	2		0.9	0.97	0.97	0.98			0.96		0.08	
D	3			0.98	0.98	0.99	0.92		0.97	0.95	0.07	0.19
	4				0.93	0.97	0.9	0.79	0.93		0.18	
	LDY	X	0.01	0.01	0.05	0.02	0.02	X				
	1	1	1	1	1				1		0	
	2		1	1	0.99	1			0.99		0.01	
E	3			0.98	0.95	0.95	0.98		0.97	0.98	0.03	0.17
	4				0.99	0.98	0.95	0.83	0.97		0.16	
	LDY	X	0	0.02	0.05	0.02	0.05	X				
	1	0.97	0.93	0.94	0.97				0.95		0.04	
	2		0.98	0.92	0.98	0.98			0.96		0.06	
F	3			0.84	0.94	0.91	0.94		0.91	0.95	0.1	0.07
	4				0.98	0.92	0.98	0.98	0.98		0.06	
	LDY	X	0.05	0.1	0.04	0.06	0.04	X				
	1	1	1	1	1				1		0	
	2		0.99	0.99	0.99	0.98			0.99		0.01	
G	3			0.97	0.98	0.89	0.97		0.95	0.97	0.09	0.11
	4				0.97	0.89	0.97	0.97	0.94		0.08	
	LDY	X	0.01	0.03	0.03	0.09	0	X	0.09			
	1	0.95	0.83	0.97	0.95				0.93		0.14	
	2		0.83	0.98	0.98	0.95			0.93		0.15	
H	3			0.98	0.99	0.99	0.99		0.99	0.96	0.01	0.16
	4				0.98	0.96	0.96	0.87	0.97		0.11	
	LDY	X	0	0.01	0.03	0.04	0.03	X				

DMU	*Window*	2010	2011	2012	2013	2014	2015	2016	*Mean/ Win-dow*	*Mean*	LDW	LDP
I	1	0.97	0.93	0.94	0.98				0.96	0.97	0.04	0.06
	2		0.94	0.94	0.98	0.97			0.96		0.04	
	3			0.95	0.99	0.99	0.99		0.98		0.04	
	4				0.99	0.99	0.99	0.99	0.99		0	
	LDY	X	0.01	0.01	0.01	0.02	0	X				
J	1	0.99	0.99	0.99	0.99				0.99	0.96	0	0.32
	2		0.68	0.98	0.9	0.91			0.87		0.3	
	3			1	1	1	1		1		0	
	4				1	0.99	1	1	0.99		0.01	
	LDY	X	0.31	0.02	0.1	0.09	0	X				
K	1	1	1	1	1				1	0.86	0	0.47
	2		0.68	0.98	0.9	0.91			0.87		0.3	
	3			0.92	0.89	0.53	0.86		0.8		0.39	
	4				0.91	0.53	0.86	0.85	0.79		0.38	
	LDY	X	0.32	0.08	0.11	0.38	0	X				
L	1	0.83	0.95	0.95	0.95				0.92	0.94	0.12	0.14
	2		0.97	0.95	0.95	0.95			0.96		0.02	
	3			0.97	0.97	0.97	0.9		0.95		0.07	
	4				0.97	0.97	0.9	0.97	0.95		0.07	
	LDY	X	0.02	0.02	0.02	0.02	0	X				
M	1	0.97	0.97	0.99	0.97				0.97	0.95	0.02	0.14
	2		0.96	0.97	0.97	0.98			0.97		0.02	
	3			0.96	0.97	0.97	0.86		0.94		0.11	
	4				0.94	0.95	0.85	0.91	0.91		0.1	
	LDY	X	0.01	0.03	0.03	0.03	0.01	X				
N	1	0.94	0.8	0.94	0.94				0.91	0.92	0.14	0.19
	2		0.78	0.94	0.93	0.93			0.9		0.16	
	3			0.95	0.95	0.95	0.84		0.93		0.11	
	4				0.95	0.95	0.95	0.97	0.95		0.02	
	LDY	X	0.02	0.01	0.02	0.02	0.11	X				

Note: X denotes that there is no windows change.

Source: Data Processed

The results of the Malmquist index are reported in Table 4 and Figure 2. On average, the ASEAN-5 telecommunication firms indicate increasing productivity. The productivity is, on average, experienced an increase of 32.51 percent. Technological progress has driven the rising productivity. TC has increased 21.21 percent while the improvements of TEC and SEC are 5.32 percent and 2.34 percent, respectively. In general, all of the firms experience increasing productivity except firm E. The deterioration productivity occurs in firm E. This is indicated by the score of TFPC, which is less than 1. It is due to all components of TFPC experiencing deterioration. On the other hand, firm L experiences the highest productivity change. The improvement of firm L productivity is 92.62 percent and the majority sourced from technological progress.

There are 12 firms (86 percent), which have improved the technology. The rest experiences technological regress. Among all telecommunication firms, firm L has the most significant improvement of technology. Firm L has successfully improved the technology to 81.34 percent. On the other hand, the TEC scores indicate that firm H has the most significant improvement in production. There are six firms, which have technical efficiency change above the average. It shows that these firms possess managerial skills above the average firms. On the opposite, firms C, D, E, and M experience a decline in technical efficiency over the periods observed. The average scale efficiency change is 2.34 percent. Although this is a relatively small value, this means that firm could increase productivity by changing the production scale. The estimation results imply that firm H has the highest SEC score, which indicates firm H can change the scale production at the optimal level.

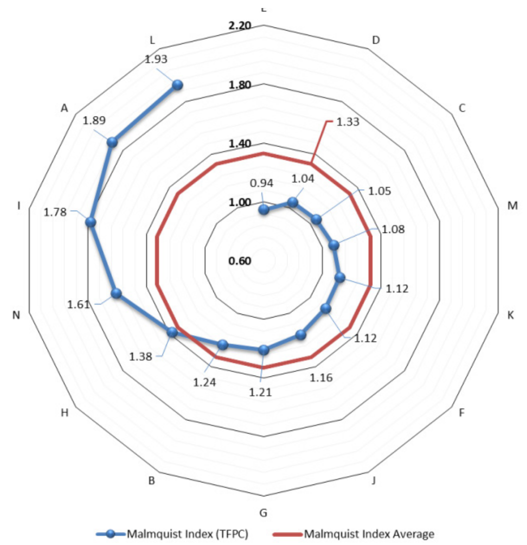


Figure 2: Malmquist Index of Telecommunication Firms in ASEAN-5

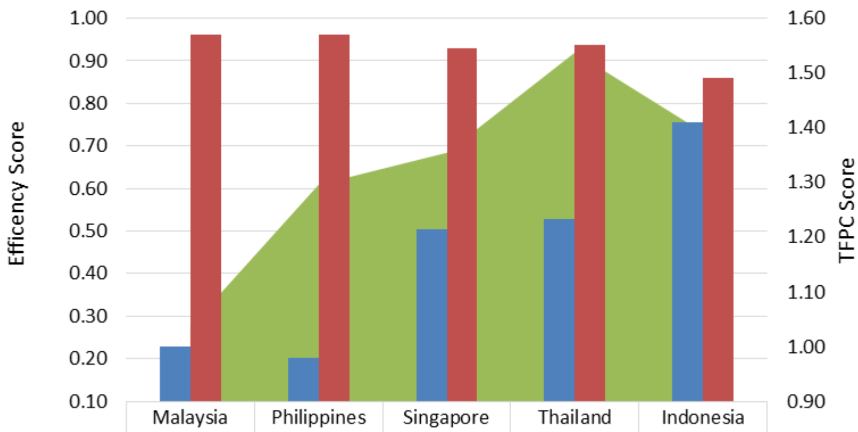
Source: Data Processed

Table 4: Malmquist Index Estimation Results on ASEAN-5 Telecommunications Industry

Countries	DMU	SEC	TEC	TC	TFPC
Indonesia	A	1.0495	1.0480	1.7309	1.8906
Indonesia	B	1.0000	1.0996	1.1319	1.2374
Indonesia	C	1.0000	0.9805	1.0737	1.0467
Malaysia	D	0.9939	0.9919	1.0449	1.0400
Malaysia	E	0.9916	0.9891	0.9825	0.9449
Malaysia	F	1.0909	1.0037	1.0465	1.1241
Philippines	G	1.0113	1.0984	1.0856	1.2076
Philippines	H	1.1286	1.2081	0.9902	1.3840
Singapore	I	1.0121	1.0119	1.4794	1.7816
Singapore	J	1.0103	1.1359	1.0079	1.1619
Singapore	K	1.0131	1.0582	1.0654	1.1195
Thailand	L	1.0110	1.0339	1.8134	1.9262
Thailand	M	1.0134	0.9922	1.0631	1.0783
Thailand	N	1.0091	1.0938	1.4540	1.6082
Average		1.0234	1.0532	1.2121	1.3251

Source: Data Processed

The results of DEA bootstrap, DEA window, and Malmquist index are summarized in Figure 3. The increasing productivity of Thailand firms is the greatest compared to the other 4 ASEAN countries. On average, Thailand telecommunication firms can gain productivity by 54 percent. The technical efficiency of Indonesian telecommunication firms is the highest within ASEAN-5 countries. These firms have the potential to increase the output by around 24 percent to be more efficient. However, the estimation result from the DEA window implies that the intertemporal efficiency is the lowest (0.86). Although the intertemporal efficiency does not well-performed, Indonesia possesses the second-highest productivity change. Malaysia and the Philippines possess the highest intertemporal efficiency scores. However, both countries' total factor productivity change and technical efficiency become the lowest compared to other countries.



	Malaysia	Philippines	Singapore	Thailand	Indonesia
TFPC	1.04	1.30	1.35	1.54	1.39
Technical Eficiency	0.23	0.20	0.50	0.53	0.76
Intertemporal Efficiency	0.96	0.96	0.93	0.94	0.86

Figure 3. TFPC, Technical Efficiency, and Intertemporal Efficiency of Telecommunication Firms Catagorized by Country in ASEAN-5

Source: Data Processed

Conclusion

The telecommunication firms in ASEAN-5 from 2010 to 2016 operate inefficiently with an average efficiency score of 0.46. It indicates that there is potential to increase output by 54 percent to achieve efficient conditions. The DEA bootstrap results imply that half of the total firms have technical efficiency above the average. Two Indonesian telecommunication firms are having the highest and the second-highest technical efficiency. The DEA window results exhibit the LDP score of the firm I is 0.06, which is the most stable among other firms. It denotes that firm I can maintain its efficiency score around 0.97. The mean of each window is relatively high, but the LDP and LDW scores tend to be high. It implies that the firms are relatively efficient, but the efficiency scores fluctuate. The analysis from the Malmquist index elucidates that, on average, there is a productivity improvement, which is mainly driven by technological progress.

The government policy should induce firms to operate more efficiently. Due to the technical efficiency of the top three telecommunication firms in each country in ASEAN-5 still relatively low. The firms could improve the managerial and produce the innovative product. The firms should have a promotion strategy, which can gain the number of new customers. At the same time, the firm should maintain the quality of the product. Therefore, the customers continue to subscribe.

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