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Lee-Li HU
(National Chiao Tung University, Taiwan)

Satoshi HONMA
(Tokai University, Japan)

Yu-Kai CHEN
(National Chiao Tung University, Taiwan)

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Total-Factor Energy and Emission Efficiencies of ASEAN and other Asian Economies

Jin-Li Hu^{1†}, Satoshi Honma², Yu-Kai Chen¹

¹National Chiao Tung University, Taiwan and ²Tokai University, Japan

ABSTRACT

The data envelopment analysis is used to compute the energy and emission efficiencies of ASEAN and other Asian economies during 2001-2017. The panel data regressions are then applied to find the effects on economic growth rates. Empirical results show that efficiency scores of ASEAN economies were behind in 2000s and early 2010s but had been catching up quickly after 2015. The overall technical efficiency has a significantly positive effect while energy efficiency has a significantly negative effect on economic growth rates for all Asian economies during 2001-2015 and turn to significantly positive effect after 2016. The emission efficiency has a significantly negative effect on economic growth for all Asian economies during 2016-2017.

Keywords: Total-Factor Energy Efficiency (TFEE); Total-Factor CO₂ Emission Efficiency (TFCEE); ASEAN economies;

JEL codes: C61, Q43, Q54

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†Corresponding author: Jin-Li Hu, Institute of Business and Management, National Chiao Tung University, No. 118 Chung-Hsiao W. Rd., Sec. 1, Taipei City 10044, Taiwan. Email: jinlihu@g2.nctu.edu.tw.

1. Introduction

Asia's economic growth, especially ASEAN was extraordinary better than the rest of world after financial crisis (Figure 1). ASEAN countries including Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam experienced average annual 5.5% GDP growth during 2010 to 2017. In the meantime, the average annual GDP growth of rest of world was only 2.9%, nearly half of the ASEAN. Sources of economic growth of a country can be decomposed into the factors of production including land, labor, and capital since the classical economics of Adam Smith (1776) and his followers who focus on physical resources. Even contemporary researcher who study modern economic growth still follows the framework (Acemoglu, 2012). The goal of this perspective is purely pursuing maximization of economic results. However, the objectives of a government's macroeconomic policies are not only creating wealth but also making good living conditions for citizens. The productivity of a country's economic development may be overestimated if a research model omits the environmental factors (Lo et al., 2005).

[Insert Fig 1. here.]

However, economic growth needs to be supported by energy inputs. Using energy energy-inefficient technology and equipment, the Asian economies replied input-driven economic growth and inevitably had to slow down their economic growth rates due to the law of diminishing returns (Krugman, 1994). Improving the energy efficiency is a must to maintain Asia's economic growth under resource constraints. For instance, the ASEAN organization has a target to reduce energy intensity by 20% by 2020 and 30% by 2025 using the base year of 2005. Meanwhile, each country has its own target to reduce the energy intensity (UNESCAP, 2019). Improving energy efficiency in Asian economies needs cross-sectoral efforts and cooperation, with respect to buildings, appliances & equipment, lighting, transport, industry, and so on (IEA, 2014).

To cope with global warming, 192 countries under the United Nations Framework Convention on Climate Change (UNFCCC) agreed to reduce greenhouse gas emissions and signed the Kyoto Protocol in Kyoto, Japan, on 11 December 1997. Moreover, 196 countries of UNFCCC members drafted the Paris Agreement in Le Bourget, France and signed on 22 April 2016. The long-term goal of the agreement is to limit global temperature increase below 2°C and to pursue efforts below 1.5°C to repose the impacts of climate change (UNFCCC, 2019). Unfortunately, according to the United Nations Environment Programme (UNEP) Emission Gap Report, 2019 (UNEP, 2019), countries who signed the agreement collectively failed to keep the promise to stop the growth of greenhouse gas (GHG) emissions. If the GHG emissions cut rapidly to 25 Gt by 2030 which reduce 7.6% per year between 2020 and 2030, we can still reach the goal of limiting global temperature rise to 1.5°C.

The relationship between economic growth and GHG emissions have been examined by many researches. Acaravci and Ozturk (2010) examine the causal relationship between

energy consumption, carbon dioxide (CO₂) emissions and economic growth by using autoregressive distributed lag (ARDL) and Granger causality for nineteen European countries. They find a long-run causal relationship from energy consumption to CO₂ emissions and CO₂ emissions has positive long-run correlation with real GDP. Ke and Hu (2011) study CO₂ emissions and productivity for APEC economies. They find developed economies have higher productivity than developing economies if CO₂ abatement is not considered. Luukkanen and Kaivo-oja (2002) analyze the development of energy intensity and CO₂ emission for ASEAN countries during 1971 to 1997. They find the energy intensity has started to increase and CO₂ emission efficiency has started to decrease for ASEAN economies in the 1990s. They conclude the phase of industrialization increases the energy intensity of the economies which may also increase fossil fuels demand and makes CO₂ emissions growth eventually.

The evidence shows that the economies pursue nation wealth need energy consumption as one of the input factors and the main energy supply source is related to CO₂ emissions. What interesting us is the energy and emission efficiencies difference between ASEAN and other Asian economies? Is it true economies have to sacrifice the environment to get the fruits of economic growth? Does the status not change over time even after the Paris Agreement? Is there any way can help us to set GHG emission target for each individual economy? We try to find out these answers in this study.

Section 2 introduces the methodology used in this paper. The environmental DEA technology can take undesirable outputs into account and calculate emission target for each economy. Section 3 describes the data sources and the descriptive statistics of each variable which gives readers a whole picture about the sample economies. Section 4 calculates target numbers of economies and then divides them by actual numbers which become the energy and emission efficiency scores yearly. The periodic scores give us clues to the trend of ASEAN and other Asian Economies. Panel data regressions are applied to examine the relationship between efficiencies and economy variables. Section 5 concludes empirical findings and discusses their policy implications.

2. Methodology

2.1. A DEA with undesirable outputs

The data envelopment analysis (DEA) is a mathematical procedure employs linear programming technique to assess the efficiencies of decision-making units (DMU) which refer to a set of economies in this study. The efficient economies are those located at the efficiency frontier that uses the minimum level of inputs to generate maximum level of outputs. To pursue overall technical efficiency (OTE) with energy inputs, we follow the constant returns to scale (CRS) assumption by Charnes et al. (1978).

However, traditional DEA models could not deal with undesirable outputs. The overall efficiency scores should decrease with an increase in an undesirable output, given other things being equal. Färe et al. (1996) introduced an environmental production

technology which takes desirable and undesirable outputs into account. The slack-based measure (SBM) DEA model with undesirable outputs proposed by Tone (2003) applied by this paper is as follows:

$$\rho^* = \min \frac{1 - \frac{1}{m} \sum_{i=1}^m \frac{s_i^-}{x_{io}}}{1 + \frac{1}{s_1 + s_2} \left(\sum_{r=1}^{s_1} \frac{s_r^g}{y_{ro}^g} + \sum_{r=1}^{s_2} \frac{s_r^b}{y_{ro}^b} \right)}$$

s.t.

$$\begin{aligned} X\lambda &= x_o - s^- \\ Y^g\lambda &= y_o^g + s^g \\ Y^b\lambda &= y_o^b - s^b \\ s^- &\geq 0, s^g \geq 0, s^b \geq 0, \lambda \geq 0 \end{aligned} \quad (2)$$

where there are n economies; o is the number for economy o ; λ is a vector representing the weight of each economy; ρ^* is the overall technical efficiency of economy o ; X is a matrix of m kinds of inputs of all these n economies; Y^g is a matrix of s_1 kinds of desirable (good) outputs of these n economies; Y^b is a matrix of s_2 kinds of undesirable (bad) outputs of these n economies; x_o is the input vector of economy o ; y_o^g is the desirable output vector of economy o ; y_o^b is the undesirable output vector of economy o ; s^- , s^g , and s^b are nonnegative input, desirable output, undesirable output vectors of economy o , respectively; and the left-hand sides of the three constraints denote the target inputs, target desirable outputs, and target undesirable outputs of economy o , respectively.

2.2. Total-Factor Energy Efficiencies

Hu and Wang (2006) employ DEA to analyze regional energy efficiencies in China. They take labor, capital, energy, and farm area as the total inputs to produce economic output which is GDP. An efficiency frontier which is the target line can be found out by the best production efficiency of the regions. The amount of total adjustments for energy input is the gap between target and actual energy input. Therefore, energy efficiency is set as equation (2) which is named total-factor energy efficiency (TFEE) for region i at year t .

$$TFEE(i, t) = \frac{\text{Target Energy Input } (i, t)}{\text{Actual Energy Input } (i, t)} \quad (3)$$

Due to the target energy input is the minimum level of energy input in a region, the actual energy input is larger than or equal to the target energy input. It makes TFEE score to be between zero and one. The TFEE is applied to the Asia-Pacific economy (Hu and Kao, 2007), Japan (Honma and Hu, 2008, 2013), developing countries (Zhang et al., 2011), Taiwan (Hu et al., 2012), and OECD (Honma and Hu, 2014).

2.3 Total-Factor CO₂ Emission Efficiency

Hu and Chang (2016) extend TFEE by further incorporating the undesirable output into the DEA model. Following their concept, we can define total-factor CO₂ emission efficiency (TFCEE) for region i at year t as following equation.

$$TFCEE(i, t) = \frac{Target\ CO_2\ emission\ (i, t)}{Actual\ CO_2\ emission\ (i, t)}, \quad (4)$$

It is noteworthy that emission volume is the less, the better. Therefore, the target emission is always less than or equal to actual emission. It makes TFCEE score to be between zero and one. For further references for DEA studies on energy and the environment, see Sueyoshi and Goto (2018).

2.4 Panel Tobit Model

To investigate the determinants of TFEE and TFCEE obtained in the first stage, the panel Tobit regression is employed in the second stage of the analysis. Since TFEE and TFCEE are censored at zero and unity, OLS estimation is biased. The values of TFEE and TFCEE are run as dependent variables with the range [0, 1]. The random-effects panel Tobit model in our study is defined as follows:

$$Eff_{it}^* = \beta' z_{it} + \lambda_i + \varepsilon_{it}, \quad (5)$$

where Eff_{it}^* denotes TFEE or TFCEE of a country i at year t ; β' is a vector of parameters to be estimated; z_{it} is a vector of the determinants that affect the efficiency; $\lambda_i \sim N(0, \sigma_v^2)$ is a time-invariant individual random effect; and ε_{it} is a time-varying idiosyncratic random error term. The observed efficiencies are

$$Eff_{it}^* = \begin{cases} 1 & \text{if } Eff_{it}^* \geq 1 \\ Eff_{it}^* & \text{if } 0 < Eff_{it}^* < 1. \\ 0 & \text{if } Eff_{it}^* \leq 0 \end{cases} \quad (6)$$

3. Data source and descriptive statistics

The empirical research in this paper is applied to a dataset of 10 ASEAN economies and 37 other Asian (non-ASEAN) economies for the period of 2001 to 2017. The ASEAN economies include Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam. The other Asian Economies include all the data available economies which describe detail in Table 1. Afghanistan and Korea, Dem. Rep. are not included due to lack of data.

There are three inputs, one desirable and one undesirable outputs factor analyzed in this study. The three inputs are capital stock, labor force, and total final energy consumption. The desirable output is gross domestic production (GDP) deflating to 2011 US dollars. The undesirable output is CO₂ Emissions which is generated from burning fossil fuels as well as the second proportion of GHG behind water vapor. We also conduct information and communication (ICT), population, education, and unemployment rate as the control variables in panel data regression.

The data source of real GDP, GDP per capita, population, education, unemployment rate, labor force and ICT which is operated as fixed phone, mobile phone and broadband of all economies except Taiwan comes from *World Development Indicators* (World Bank, 2019). The data of CO₂ Emissions comes from *Emissions Database for Global Atmospheric Research (EDGAR) v5.0* (Muntean et al. 2018). In previous research, capital stock is an intractable variable that needs to use perpetual inventory method to calculate (Berlemann and Wesselhöft, 2014). Fortunately, the capital stock data in 2011 US\$ are now available from *Penn World Tables* (Feenstra et al., 2015) since version 9.0 and we use the newest data of version 9.1 in this study. The education level is operated as human capital index also comes from *Penn World Tables*. The data of total final energy consumption of all economies except Bhutan, Lao PDR, Macao, and Maldives come from *International Energy Agency (IEA) World Energy Statistics and Balances* (IEA, 2019).

[Insert Table 1 here.]

The units of real GDP, CO₂ emissions, labor, capital stock, and energy consumption are billions of US\$ in 2011, millions of tons of oil equivalent (Mtoe) per year, 10,000 people, billions of US\$ in 2011, and Mtoe, respectively. Table 2 lists the average annual amounts and growth rates of all variables for each economy. Indonesia, Thailand, Malaysia are the top three economies in respect of real GDP and CO₂ emissions in ASEAN. The average CO₂ emissions growth rates of these three economies are around 3% to 4% less than ASEAN average is 5.6%. However, the CO₂ emissions per year of these three economies are almost twice to triple of ASEAN average. China, Japan, India are the top three economies in respect of real GDP and CO₂ emissions in non-ASEAN. The average CO₂ emissions growth rates of China and India are 7.1% and 5.7%, respectively. The CO₂ emissions per year of China and India are twenty and four times of non-ASEAN average. Notably, though Japan is the third CO₂ emissions per year in non-ASEAN economies, the average growth rate of the research period is only 0.4% which is far less than non-ASEAN average 4.0%.

[Insert Table 2 here.]

Table 3 shows positive correlations among inputs and outputs in our data. The positive correlations among energy consumption, CO₂ emissions, and real GDP were also found by previous studies such as Acaravci and Ozturk (2010). Energy and emission efficiencies of all ASEAN and non-ASEAN economies as well as the relationship between efficiencies and GDP will be further analyzed in this study.

[Insert Table 3 here.]

4. Empirical results and discussion

Plenty of commercial and non-commercial DEA tools are available today (Barr, 2004). However, few of them can deal with undesirable output. We use the software DEA-Solver 13.0, which was originally developed by Tone (Cooper et al., 2006), to solve the linear programming equations in the previous section.

4.1. Total-Factor Energy and Emission Efficiencies

We report OTE, TFEE, and TFCEE scores for each Asian economy during 2001 to 2017 in Appendix I to III. For the area efficiency scores, Hu and Wang (2006) extend the equation (2) by summing each economy of target energy input and divided by summation of actual energy input in the area. Due to the results of this method is no significant difference with arithmetic mean, we use arithmetic mean to calculate area efficiency scores in this study.

Figure 2 shows the OTE of ASEAN and non-ASEAN economies. We observe the similar trends that OTE decrease until 2004 then increase to the top in 2007 for ASEAN and 2009 for non-ASEAN economies. The OTE scores fall again from the tops of both areas to the bottom in 2014 and rise rapidly for ASEAN economies which makes the scores almost the same with non-ASEAN economies in 2016 and 2017. Low OTE scores as inefficiency can attribute to the input and output configuration as well as the operation scale which can be decomposed into pure technical efficiency (PTE) and scale efficiency (SE) (Kumar & Gulati, 2008). We get two insights from the OTE trends. First, the input and output configuration efficiency of ASEAN economies is behind non-ASEAN economies until 2015 and catch up since 2016. It shows that ASEAN economies have enhanced the production efficiency not only by increasing GDP but also improving resource allocation. Secondary, the global economic crisis impacted ASEAN economies earlier and deeper than non-ASEAN economies. The average OTE scores of ASEAN economies started falling from 2008 as the beginning of global economic crisis, showing that ASEAN economies were more vulnerable to external economic change. Tang et al. (2013) mention small and highly open economies such as Singapore, Malaysia, and Thailand in ASEAN are very sensitive to fiscal stimulus that leaks out through higher imports. The OTE score of Singapore fell down almost half from 1 to 0.572 is the main reason why the average OTE score of ASEAN dramatically fall during 2007-2008.

[Insert Fig 2. here.]

Figure 3 shows the TFEE of ASEAN and non-ASEAN economies. Patterns of energy efficiency in the two areas are similar before 2016 that both decrease until 2004 then increase to the top around the global economic crisis. The TFEE fall again to the bottom in

2014 and rise dramatically for ASEAN economies, making their scores exceed non-ASEAN economies in 2016 and 2017.

Figure 4 shows the total final energy consumption growth rate of ASEAN and non-ASEAN economies. Both of these two areas reach the first peak in 2004. It explains the energy consumption growth so fast that may not produce correspond to economic growth which makes the energy use inefficiencies. The energy consumption growth rate hit bottom during the global economic crisis in 2008. Although the energy consumption growth rate of ASEAN even become -0.1% far below 2.6% of non-ASEAN in 2008, the energy efficiency of ASEAN started falling but the energy efficiency of non-ASEAN is still improving until 2009.

There are two main points worth noticing after the global economic crisis: First, the energy consumption growth rate of non-ASEAN start decrease after 2010, but the energy efficiency is falling until 2016. It tells us that non-ASEAN economies may conduct energy conservation policies to restrict energy consumption growth since 2011, however, the energy efficiencies do not improve along with these energy policies. Secondary, TFEE has a big jump improvement for both ASEAN and non-ASEAN economies in 2016, which is the Paris Agreement signature year. TFEE come back to the peak in 2008 for non-ASEAN economies and almost triple from 2015 for ASEAN economies. Economies in these two areas conduct policies to improve energy efficiencies against global warming after signed the Paris Agreement, especially for ASEAN economies.

[Insert Fig 3. here.]

[Insert Fig 4. here.]

Figure 5 presents the TFCEE of ASEAN and non-ASEAN economies. Although rise and fall around 2005 to 2008, the overall trends of CO₂ emission efficiencies for two areas are both falling before 2016. Although previous studies such as Azomahou et al. (2006) showed that CO₂ emission per capita is structurally stably related to GDP per capita, here our empirical results show that CO₂ emission efficiencies deteriorate along with time. Figure 6 shows average CO₂ emission growth rates of ASEAN and non-ASEAN economies.

It is also observed that the CO₂ emission growth rate come to the first valley in 2009 and 2010 for non-ASEAN and ASEAN economies, respectively. In contrast to Figure 5, we find that the emission efficiencies did not improve in spite of the decreasing emission growth rates. The CO₂ emission growth rates of ASEAN economies exceeded non-ASEAN economies since 2013, confirming that non-ASEAN economies once conduct more effective energy policies to restrain CO₂ emission growth rates. However, emission efficiency of ASEAN economies exceeds non-ASEAN economies since 2016 regardless of

emission growth rates, showing that the economic outputs of ASEAN economies increased faster than their CO₂ emission.

[Insert Fig 5. here.]

[Insert Fig 6. here.]

4.2. The efficiencies of main economies for ASEAN and other Asian economies

For better understanding how main economies impact the efficiencies of areas, we focus on the top three economies contributing to most CO₂ emission among ASEAN and other Asian economies. First of all, China is not only the largest economies of other Asian economies but also the second large economies of the worldwide since 2009. As Figure 7 shows, all the efficiencies scores are at low level around 0.1 to 0.27 between 2001 and 2017. The impact of global economic crisis which dropped all efficiencies scores in 2007 but rebounded rapidly in 2008. This strong recovery also improved the energy efficiencies to around 0.2 between 2008 and 2011. Since the slow-down of western economies had adverse impacts on its economy, China's economic growth has been slower since 2012 (Daxue Consulting, 2013). Correspondingly, its overall technical efficiency also dropped to a bottom. The input adjustment did not catch up the economic growth slowdown, it further pushdown the energy and emission efficiencies to the bottom during 2012 to 2015. Although China's economy came to the lowest growth rate among twenty-five years in 2016, the energy and emission efficiencies of China improved up to 2.6 times and 9.4 times, respectively, compared to previous year, respectively.

[Insert Fig 7. here.]

Japan is the second largest economy among non-ASEAN Asian economies, despite of economic stagnation since 1991. As we can see in Figure 8, the overall technical efficiency as well as energy and emission efficiencies are always been the benchmark of the area before 2007 and after 2008 to 2010. Although the efficiencies have impacted by global economic crisis, it recovered quickly to the best in 2009. It represents that Japan is the standard of productivity which other economies could look up to. Unfortunately, earthquake and tsunami in 2011, which caused Fukushima Daiichi nuclear disaster, not only impacted Japan's economic growth but also dropped its energy and emission efficiencies drastically. The power generation has become heavily reliant on fossil fuel during 2011 to 2015. The proportion of fossil fuel is accounted for over 80% of power generation after 2011 (IEA, 2016). As the results of the earthquake and disaster, Japan faced

not only energy and environmental aspects, an increase in fossil fuel dependency in power generation, an increase in CO₂ emissions, thereby, decline in the energy self-sufficiency ratio, but also economic aspect, disruption in the supply chain, rising electricity price, burden of fossil fuel import. It hurts the emission efficiency most that makes the TFCEE scores to bottom of 0.071 in 2015. Between 2011-2015, the TFCEE line is below both OTE and TFEE lines, suggesting that Japan should overcome fossil fuel dependency state. Japan's government has kept in mind that ensures stable energy supply and makes it low cost by enhancing efficiency as well as pursues environment suitability after the nuclear disaster. Electricity rates rose 25 for home use and 38% for industry use from 2010 to 2014 in Japan. The energy policy of Japan has set the direction to secure energy via expanding renewables, introducing the feed-in tariff scheme in 2012. It helps promote the proportion of renewable energy to rise year over year. Between 2012 and 2017, the average annual growth rate of renewable energy capacity was 22%. This might contribute to the energy and emission efficiency improvements since 2016.

[Insert Fig 8. here.]

India is not only the third largest economy of other Asian economies but also the second largest population of the worldwide. Figure 9 shows three efficiencies scores of India. Although India economy soared by around 8% from 2003 to 2007, the overall technical efficiency as well as energy and emission efficiencies dropped continuously far away from 0.1 since 2004. The situation of emission efficiency deteriorated even further since 2008 and TFCEE scores hit the bottom in 2015. The energy consumption source mainly comes from coal, lignite, crude oil and natural gas which account for over 88% until 2015 (MoSPI, 2019). India's government had set a target of installing 175 GW of renewable energy capacity by 2022 and reached 50.1 GW of renewable energy capacity in 2016 (MNRE, 2017). The renewable energy policy has significantly improved the energy and emission efficiencies of India by 2.8 times and 9.8 times in 2016 compared to 2015, respectively.

[Insert Fig 9. here.]

Indonesia is the largest economies of ASEAN economies with strong economic growth after recovering from the Asian financial crisis in 1997. However, as we can see in Figure 10, the overall technical efficiency is always below 0.1 which means the conversion rate from resources input to economic output is low. When we take a further look at energy and emission efficiencies, the situation is also poor before 2015. The oil accounted for 49.7% while coal accounted for 24.5% of national energy mix in 2012 (MPEMR, 2014). Oil plays a major role in energy consumption of end-user sector and coal share in power generation increase year by year to almost 56% in 2015 (Kimura and Phoumin, 2019).

These energy demand structure make CO₂ emission efficiencies not easily to improve. Indonesia's government passed the regulation of national energy policy in 2014, targeting the share of renewable energy in the energy mix being no less than 23% in 2025. The energy and emission efficiencies of Indonesia improved up to 1.8 times and 6.6 times in 2016 compared to 2015, respectively.

[Insert Fig 10. here.]

Although the economic growth of Thailand is not as strong as Indonesia after the Asian financial crisis, the energy and emission efficiencies are slightly better than Indonesia before the global economic crisis. However, the situation reversed after 2008 due to the energy and emission efficiencies of Thailand continued to deteriorate before 2015 as showed in Figure 11. The power generation mainly relies on natural gas which is accounted for 70.6% in 2015 (Kimura and Phoumin, 2019). Although Thailand's government made the 15-Year Renewable Energy Development Plan in 2008 aims to rise the renewable energy percentage to 14.1% in 2022, the gaps between target and actual utilization is clearly observed in 2010 (Chotichanathawewong and Thongplew, 2012). The government ratified energy efficiency plan in 2015 that set a goal to reduce energy intensity by 30% in 2036 (Tippichai, 2016). The energy policy has significantly improved the energy and emission efficiencies of Thailand up to 2.7 times and 9.4 times, respectively, in 2016 compared to 2015.

[Insert Fig 11. here.]

Malaysia had the highest efficiencies among the top three of ASEAN economies in 2001. As Figure 12 shows, the overall technical efficiency did not very much during the research period. However, the emission efficiency dropped dramatically since 2002. Chong et al. (2019) find that population, GDP per capita, energy intensity, electricity ratio of end-use sector and fuel-mix of electricity generation are the factors influencing the changes of energy-related CO₂ emissions in Malaysia. Her government passed renewable energy act and sustainable energy development authority act in 2011 to help achieving 20% renewable energy capacity mix by 2025 (SEDA, 2016). This helped improve the energy and emission efficiencies of Malaysia up to 2.4 times and 9.3 times, respectively, in 2016 compared to 2015.

[Insert Fig 12. here.]

4.3. The relationship between economic growth and efficiencies

Although previous researchers have found some proof that energy consumption and CO₂ emission are related to economic growth (Luukkanen and Kaivo-oja, 2002; Acaravci and Ozturk, 2010; Ke and Hu, 2011), the evidence is still not strong enough to conclude the emission is the unavoidable side effect of economic growth. In this subsection, we try to find out whether emission efficiency and economic growth are fish and bear's paw. Barlow (1994) adds lagged fertility to the research model of population growth and economic growth, finding that population growth has a negative effect on economic growth in the three-variable model. Rahman (2013) studies the relationship among GDP, GDP per capita, literacy rate and unemployment rate, finding a significantly negative relationship between GDP per capita and unemployment rate. Niebel (2018) studies the relationship between information and communication (ICT) and economic growth, supporting that ICT capital has a positive relationship with GDP growth. Higón et al. (2017) use five components which are fixed telephone subscribers, mobile phone subscribers, PC owners, individuals using internet percentage, fixed-broadband subscribers to construct the ICT index. They confirm the relationship between ICT and CO₂ emission is an inverse U-shaped relationship. Maudos et al. (1999) include human capital to estimate the total-factor productivity (TFP) evolution in OECD countries, finding that human capital has a significant effect on the measurement of TFP. Therefore, ICT, education, population, and unemployment rate are chosen as control variables here, in order to estimate the relationship between economic growth and three efficiencies.

Table 4 reports panel data regression results of GDP per capita during 2001-2017. Significantly positive relationships exist between OTE and GDP per capita for both ASEAN and non-ASEAN economies. It is intuition that higher productivity economies have better economic output. We also find a significantly negative relationship between TFEE and GDP per capita for ASEAN economies and non-ASEAN economies. The result shows that sacrifice energy efficiency to exchange the GDP per capita growth is commonly exist in all Asian economies for the research period. Finally, we find the relationship between TFCEE and GDP per capita for both ASEAN and non-ASEAN economies are not significant. However, it is interesting the relationship is positive for ASEAN economies. We think it might because ASEAN newly industrializing countries make energy policies to encourage improving emission efficiency while the economic growth.

[Insert Table 4 here.]

As we know from pervious subsections, the efficiencies change dramatically before and after 2016. We hence divide Asian economies into two time periods of 2001-2015 and 2016-2017 to examine whether the relationships are different. Table 5 presents the panel data regression results of GDP per capita for both 2001-2015 and 2016-2017. Significantly positive relationships exist between OTE and GDP per capita for both 2001-2015 and

2016-2017, implying that productivity is significantly positively related to economic outcome no matter which time periods. For energy efficiency, we find a significantly negative relationship between TFEE and GDP per capita for both 2001-2015 and 2016-2017. It is noteworthy that the relationship becomes positive during 2016-2017, showing that all Asian economies sacrifice energy efficiency to exchange the GDP per capita growth during 2001-2015 but change to emphasize both after 2016. Finally, we find a significantly negative relationship between TFCEE and GDP per capita for 2016-2017 but not for 2001-2015, indicating that there is no significant relationship between emission efficiency and economic outcome during 2001-2015 but change to sacrifice emission efficiency to exchange the GDP per capita growth after 2016.

[Insert Table 5 here.]

Table 6 presents the empirical results of the panel Tobit model. Because coefficients of some independent variables are insignificant, independent variables are slightly changed. Since the coefficients of number of fixed phone, mobile phone, and broadband subscribers are insignificant, these independent variables are excluded. Instead, the number of broadband subscribers per 1000 persons and population density are added as the independent variables. Because the efficiency scores considerably changed before and after 2016 as stated in the above, we also estimate the subsample including 2001-2015 while excluding 2016-2017, as shown in columns (7)-(12).

The coefficient of log of GDP per capita is positive and statistically significant for all columns (1)-(12), suggesting that an increase in income level in a country increases energy and emission efficiency in that country. The coefficient of population density is positive and significant for ASEAN economies both for TFEE and TFCEE in full and sub-periods (column 2, 5, 8, and 11), however insignificant for non-ASEAN economies (columns 3, 6, 9, and 12). The former result implies that denser population enhances the demand for a better environment and more stringent environmental regulation. The coefficient of broadband subscriber per 1000 people is positive and significant for column (1), (3) and (6), however, in the subperiod estimates, it is significant for all columns except for (8). This suggests that widespread of broadband improve energy and emissions efficiency. The unemployment rate is insignificant for all columns. The coefficient of education is significantly negative to TFCEE for all and ASEAN economies, as shown by columns (4) and (5). However, in the sub-period, those to TFEE and TFCEE of total and ASEAN economies are also significantly negative, maybe because higher education level in a country raises a wage rate and hence deteriorates the economic performance.

[Insert Table 6 here.]

5. Conclusions and policy implications

This paper, computes overall, energy, and emission efficiencies between ASEAN and other Asian economies during 2001 to 2017. We find ASEAN economies are behind in the beginning and catch up quickly after 2015 especially for energy and emission efficiencies. It may be attributing to the Paris Agreement that make economies care about global warming impact, but more important are governments making energy policies to adjust the power mix. It has to change the foundation of energy supply from fossil-fuel to renewable energy so that we can cut the CO₂ emission from the source.

We examine the efficiencies of main economies for ASEAN and other Asian economies. The impact of global economic crisis is clear to China and Japan around 2007, but not for other main economies. It may be because those economies are still in strong growth stage that mitigates the impact, especially for India. Japan was the benchmark of all efficiencies before Fukushima Daiichi nuclear disaster. The accident hurt Japan's paradigm of energy and emission efficiencies seriously and the recovery is still ongoing. It reminds us to consider the climate change as a factor to secure energy supply and the safety of power generation. India has the second largest population of the worldwide and may exceed China in the near future. Although India's government had set a target to install renewable energy capacity, how to deal with the emission growth come along with population growth is still a severe challenge. Indonesia, Thailand, and Malaysia are newly industrializing economies with strong economic growth in ASEAN. They face the same challenge of satisfying rapid electricity demand growth while mitigating the increase in CO₂ emissions from electricity generation. The renewable energy is one feasible solution but there is still a long way to go.

We go further to find the relationship between economic growth and efficiencies. The overall technical efficiency has a significantly positive effect while energy efficiency has a significantly negative effect on economic growth during 2001-2015 and turn to significantly positive effect after 2016. Although it is not as our expected that improving energy efficiency may bring economic growth before 2016, it may reflect the fact that these economies focus more on economic growth until 2015. Emission efficiency has a significantly negative effect on economic growth during 2016-2017. It may reflect the fact that Asian economies still mainly rely on fossil fuels. If economic growth and clean environment are wanted in the same time, they have to pay more effort to use more other energy sources to replace fossil fuels.

The results of panel Tobit models imply that increase in income level is positively correlated to energy and emission efficiencies. The implication of results is that economic growth contributes to improve the environment in the ASEAN economies.

To sum up, economic growth in ASEAN economies does not necessarily come up with environmental deterioration but can be green by improving energy and emission efficiencies.

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Table 1 Research variables, sample countries, period, and data sources

	Research variables	Unit	Countries	Period	Data source
Dependent variable	Real GDP (deflate by 2011)	Billion US\$			The World Bank ²
	Real GDP per capita (deflate by 2011)	US\$	ASEAN (Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam)		Emission Database for Global Atmospheric Research (EDGAR) v5.0
	CO2 Emissions	Mt CO2/yr			
Independent variable	Capital Stock	Billion US\$	Non-ASEAN (Armenia, Azerbaijan, Bahrain, Bangladesh, Bhutan, China, Cyprus, Georgia, Hong Kong, India, Iran, Islamic Rep., Iraq, Israel, Japan, Jordan, Kazakhstan, Korea, Rep., Kuwait, Kyrgyz Republic, Lebanon, Macao, Maldives, Mongolia, Nepal, Oman, Pakistan, Qatar, Saudi Arabia, Sri Lanka, Syrian Arab Republic, Taiwan, Tajikistan, Turkey, Turkmenistan, United Arab Emirates, Uzbekistan, Yemen)	2001~2017 ¹	Penn World Table
	Labor force	10,000 People			The World Bank ²
	Total Final Energy Consumption	Mt of oil equivalent			International Energy Agency ³
Control variable	Fixed phone				
	Mobile phone	Million subscribers			
	Broadband				The World Bank ²
	Population	10,000 People			
	Unemployment rate	%			
	Human capital index				Penn World Table

Note: 1. Data available for Iraq is 2004-2017; for Syrian Arab Republic is 2001-2007; for Bhutan, Lao PDR, Macao, Maldives is 2001-2015.

2. Data source of Real GDP and Labor force for Taiwan is from its National Statistics.

3. Data source of total final energy consumption for Lao PDR is from Ministry of Energy and Mines, Lao PDR; for Bhutan, Maldives, and Macao are from Sustainable Energy for All (SE4ALL) database.

Table 2 Average annual amounts and growth rates of real GDP, CO₂ emission, labor, capital stock, and energy consumption (2001-2017)

Economics	Real GDP		CO ₂ Emissions		Capital Stock		Labor		Energy Consumption	
	Billion US\$	%	Mt/yr	%	Billion US\$	%	10,000 People	%	Mt	%
Brunei Darussalam	10.1	4.3	6.6	2.5	98.5	5.7	18.8	1.7	1.2	10.0
Cambodia	9.2	9.3	4.5	10.8	74.0	9.6	766.5	2.3	4.3	5.9
Indonesia	485.8	10.7	399.1	3.2	8373.1	16.4	11270.2	1.7	146.3	2.2
Lao PDR	6.0	13.2	1.6	10.4	70.5	12.8	303.2	2.5	2.2	5.1
Malaysia	183.8	6.4	200.0	4.3	1712.3	6.9	1229.5	2.8	43.8	4.5
Myanmar	30.0	14.9	12.7	7.9	233.9	19.0	2389.7	0.4	13.9	3.6
Philippines	153.4	7.4	88.1	3.4	1690.2	7.5	3748.6	2.1	24.9	2.2
Singapore	175.5	6.8	48.1	1.1	1319.9	10.0	275.9	2.8	15.3	7.0
Thailand	243.5	6.9	232.8	3.0	3615.0	5.1	3837.3	0.5	80.0	4.1
Vietnam	92.6	10.8	126.6	9.0	1032.3	9.9	5008.4	1.7	44.3	5.6
ASEAN Average	139.0	9.1	112.0	5.6	1822.0	10.3	2884.8	1.9	37.6	5.0
Armenia	6.6	10.3	4.7	2.7	53.7	6.0	134.8	0.4	1.8	4.8
Azerbaijan	31.4	13.9	29.5	1.5	118.5	7.0	430.8	2.2	7.7	2.4
Bahrain	19.2	7.2	26.2	4.5	194.2	12.0	61.2	6.4	4.8	4.4
Bangladesh	96.7	8.1	51.7	7.3	1070.6	12.0	5620.1	2.2	22.2	4.1
Bhutan	1.1	9.2	0.9	10.6	26.6	9.8	31.5	2.5	1.3	2.5
China	4781.5	12.9	7740.4	7.1	47882.4	13.8	76933.9	0.4	1499.8	6.0
Cyprus	17.6	3.4	7.4	0.1	123.9	5.8	55.6	1.7	1.6	0.6
Georgia	8.7	8.9	6.5	5.1	81.9	2.5	202.7	-0.2	2.9	5.0
Hong Kong, China	194.4	2.6	44.1	0.7	1467.9	5.1	370.1	0.9	8.4	0.3
India	1156.8	9.4	1576.8	5.7	17147.9	12.6	45918.8	1.4	447.3	4.0
Iran, Islamic Rep.	295.2	7.1	517.1	3.8	3914.9	6.4	2399.9	1.9	150.4	4.3
Iraq	116.4	13.5	119.0	5.5	458.8	13.6	749.1	3.2	19.6	0.7
Israel	181.7	4.7	66.4	0.7	793.9	4.3	340.9	2.2	13.5	1.9
Japan	4188.2	-0.8	1269.3	0.4	21126.4	1.9	6672.2	0.0	314.3	-0.7
Jordan	19.4	8.0	20.7	3.1	195.1	10.8	183.0	4.1	4.8	4.2
Kazakhstan	100.4	13.0	212.4	4.5	769.1	5.1	847.9	1.2	34.9	4.6
Korea, Rep.	883.7	5.2	561.9	1.9	6063.8	6.9	2540.4	1.2	154.3	2.2
Kuwait	90.0	7.7	78.7	3.7	418.3	7.2	161.6	5.2	13.8	5.8
Kyrgyz Republic	3.8	9.3	7.3	5.8	42.6	6.4	239.0	1.4	2.6	6.3
Lebanon	28.3	5.3	19.3	3.1	306.5	11.1	174.1	4.2	4.0	3.7
Macao, China	22.6	11.9	1.5	3.0	98.3	13.2	31.0	3.4	0.5	6.3
Maldives	2.0	9.6	0.8	8.6	10.1	15.6	17.0	6.3	0.2	8.7
Mongolia	5.5	14.2	13.9	6.8	109.4	10.3	114.9	1.9	2.6	5.3
Nepal	11.5	7.5	4.5	6.2	157.8	6.8	1396.3	1.5	10.1	3.1
Oman	42.2	7.4	49.3	7.5	372.5	15.2	147.4	7.6	11.8	12.9
Pakistan	145.0	7.6	143.4	3.5	1251.4	8.0	5637.4	3.2	69.1	3.5
Qatar	88.1	14.6	60.5	6.9	572.6	22.0	118.1	11.8	12.4	7.3
Saudi Arabia	402.8	7.3	429.5	5.6	3678.8	10.0	987.0	4.8	108.6	5.0
Sri Lanka	39.8	9.6	14.9	4.9	511.0	12.4	827.4	0.5	8.6	2.3
Syrian Arab Republic	25.4	8.9	48.6	-2.6	279.0	17.1	529.7	-0.1	10.7	-3.2
Taiwan	362.2	2.3	261.2	1.1	2892.2	6.2	1089.7	1.1	64.5	1.8
Tajikistan	4.0	11.3	3.6	5.2	219.7	13.2	202.0	2.9	2.1	2.9
Turkey	544.1	8.1	291.7	3.5	4348.0	11.5	2528.7	2.4	77.1	4.5
Turkmenistan	17.5	14.8	59.1	4.4	324.8	8.0	223.4	2.1	14.4	4.4
United Arab Emirates	223.5	7.1	150.9	5.4	2019.7	5.7	485.8	8.5	40.1	4.5
Uzbekistan	31.0	9.9	115.2	-1.4	297.6	6.2	1256.9	2.6	32.9	-2.7
Yemen	21.2	5.3	21.1	0.2	167.5	20.1	512.5	2.7	4.5	-0.5
non-ASEAN Average	384.0	8.6	379.2	4.0	3231.6	9.8	4329.0	2.9	86.0	3.6

Table 3 Correlation matrix for all inputs and outputs (2001-2017)

	GDP	CO ₂	Capital	Labor	Energy
GDP	1.000				
CO ₂	0.852	1.000			
Capital	0.935	0.929	1.000		
Labor	0.682	0.885	0.802	1.000	
Energy	0.857	0.992	0.932	0.922	1.000

Table 4 Panel data regression results of GDP per capita during 2001-2017

Dependent variable	GDP per capita 2001-2017		
	(1) All	(2) ASEAN	(3) Non-ASEAN
Samples included			
Constant	-35523.380*** [3290.077]	-32259.760*** [5756.845]	-36567.88*** [5243.757]
Overall Technical Efficiency	30803.650*** [4155.591]	80790.250*** [8673.393]	26628.920*** [4901.241]
Total-Factor Energy Efficiency	-21621.520*** [4201.156]	-50114.380*** [10306.68]	-12322.440** [5269.294]
Total-Factor CO2 Emission Efficiency	-183.331 [1988.902]	1690.009 [4867.769]	-4227.724 [2446.416]
Fixed phone	-8.933 [6.2]	-76.917 [58.788]	-8.235 [6.421]
Mobile phone	-3.783465*** [0.91]	52.353*** [7.903]	-3.280*** [0.947]
Broadband	15.515*** [3.837]	-1033.202*** [362.892]	12.573*** [4.231]
Population	-0.005 [0.017]	-0.646*** [0.112]	-0.005 [0.022]
Unemployment rate	-902.162*** [175.57]	1334.929*** [340.861]	-979.267*** [197.753]
Education	19689.470*** [1483.558]	13210.130*** [2942.811]	20527.320*** [2178.778]
R ²	0.361	0.844	0.316
<i>n</i>	601	153	448

Note: Standard errors are shown in squared brackets. *** P < 0.01, ** P < 0.05, and * P < 0.1.

Table 5 Panel data regression results of GDP per capita during 2001-2015 and 2016-2017

Dependent variable	GDP per capita				
	2001-2015			2016-2017	
	(1)	(2)	(3)	(4)	(5)
	All	ASEAN	Non-ASEAN	All	Non-ASEAN
Samples included					
Constant	-39244.870*** [4564.861]	-33742.540*** [7266.534]	-38402.110*** [6204.592]	-16695** [7032.807]	-10701.63 [9277.702]
Overall Technical Efficiency	33719.400*** [5627.361]	87114.930*** [11372.74]	26516.840*** [6777.609]	23344.910*** [5608.499]	19701.690*** [6093.716]
Total-Factor Energy Efficiency	-23971.950*** [4837.727]	-53247.100*** [11393.06]	-11407.750* [6450.096]	19100.760*** [6554.122]	20646.750** [8466.1]
Total-Factor CO2 Emission Efficiency	-380.329 [3025.904]	-1656.690 [6085.718]	-5545.896 [3912.509]	-12986.300** [6213.104]	-14404.720* [7729.004]
Fixed phone	-11.949 [7.241]	27.870 [72.183]	-11.007 [7.04]	-7.262 [21.495]	-26.535 [34.56]
Mobile phone	-6.249*** [1.238]	44.353*** [11.894]	-4.583*** [1.193]	-8.689 [9.592]	-26.968 [17.335]
Broadband	28.196** [9.297]	-1450.596** [627.2]	22.346** [9.212]	14.338 [10.992]	36.128* [18.098]
Population	0.010 [0.019]	-0.666*** [0.152]	0.001 [0.024]	0.027 [0.087]	0.172 [0.159]
Unemployment rate	-966.025*** [204.311]	1151.483** [537.823]	-1071.776*** [230.282]	-760.275*** [255.253]	-956.531*** [321.284]
Education	21223.750*** [2052.508]	14154.310*** [3658.282]	21534.430*** [2631.06]	9906.329*** [2803.518]	8986.211** [3713.643]
R ²	0.357	0.825	0.317	0.601	0.544
<i>n</i>	530	135	395	71	53

Note: Standard errors are shown in squared brackets. *** P < 0.01, ** P < 0.05, and * P < 0.1.

Table 6 Panel Tobit regression results of TFEE and TFCEE during 2001-2017 and 2001-2015

Dependent variable	TFEE				TFCEE			TFEE			TFCEE		
	2001-2017				2001-2015								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	
Samples included	All	ASEAN	Non-ASEAN	All	ASEAN	Non-ASEAN	All	ASEAN	Non-ASEAN	All	ASEAN	Non-ASEAN	
Constant	-0.337 [0.328]	-0.542 [0.351]	-0.303 [0.411]	-0.167 [0.387]	-0.892** [0.358]	-0.123 [0.489]	0.208 [0.361]	0.406 [0.408]	0.046 [0.452]	0.487 [0.411]	0.562 [0.376]	0.408 [0.519]	
ln GDP per capita	0.131*** [0.028]	0.060*** [0.020]	0.149*** [0.035]	0.126*** [0.034]	0.097*** [0.021]	0.142*** [0.043]	0.140*** [0.032]	0.101*** [0.039]	0.138*** [0.038]	0.117*** [0.035]	0.093*** [0.033]	0.112*** [0.041]	
ln population density	0.034* [0.019]	0.071*** [0.010]	0.031 [0.024]	0.034 [0.022]	0.082*** [0.010]	0.035 [0.027]	0.025 [0.020]	0.053*** [0.018]	0.032 [0.024]	0.027 [0.022]	0.056*** [0.015]	0.034 [0.026]	
log of broadband subscribers	0.024* [0.012]	-0.008 [0.017]	0.027* [0.015]	0.023 [0.015]	-0.026 [0.017]	0.030* [0.018]	0.045*** [0.013]	0.026 [0.019]	0.044*** [0.016]	0.051*** [0.016]	0.037** [0.018]	0.052*** [0.019]	
Unemployment rate	-0.003 [0.005]	0.005 [0.008]	-0.003 [0.006]	-0.004 [0.006]	-0.004 [0.008]	-0.003 [0.007]	0.000 [0.005]	0.005 [0.010]	0.000 [0.006]	-0.001 [0.006]	0.007 [0.010]	-0.001 [0.007]	
Education	-0.053 [0.049]	0.000 [0.046]	-0.098 [0.070]	-0.106* [0.058]	-0.168*** [0.047]	-0.134 [0.084]	-0.179*** [0.062]	-0.314*** [0.070]	-0.125 [0.078]	-0.194*** [0.070]	-0.387*** [0.063]	-0.136 [0.087]	
σ_u	0.176*** [0.027]	0.000 [0.022]	0.208*** [0.037]	0.201*** [0.032]	0.000 [0.018]	0.233*** [0.044]	0.194*** [0.031]	0.044** [0.020]	0.211*** [0.037]	0.205*** [0.032]	0.035** [0.017]	0.225*** [0.040]	
σ_{ϵ}	0.130*** [0.005]	0.095*** [0.007]	0.137*** [0.006]	0.155*** [0.006]	0.097*** [0.007]	0.167*** [0.008]	0.125*** [0.005]	0.064*** [0.006]	0.137*** [0.007]	0.149*** [0.007]	0.066*** [0.006]	0.165*** [0.008]	
Log likelihood	135.571	80.348	80.783	72.657	78.728	27.805	121.088	95.419	62.443	69.531	93.924	21.725	
n	407	95	312	407	95	312	340	79	261	340	79	261	

Note: Standard errors are shown in squared brackets. *** P < 0.01, ** P < 0.05, and * P < 0.1. The coefficients of year dummies are omitted to save space.

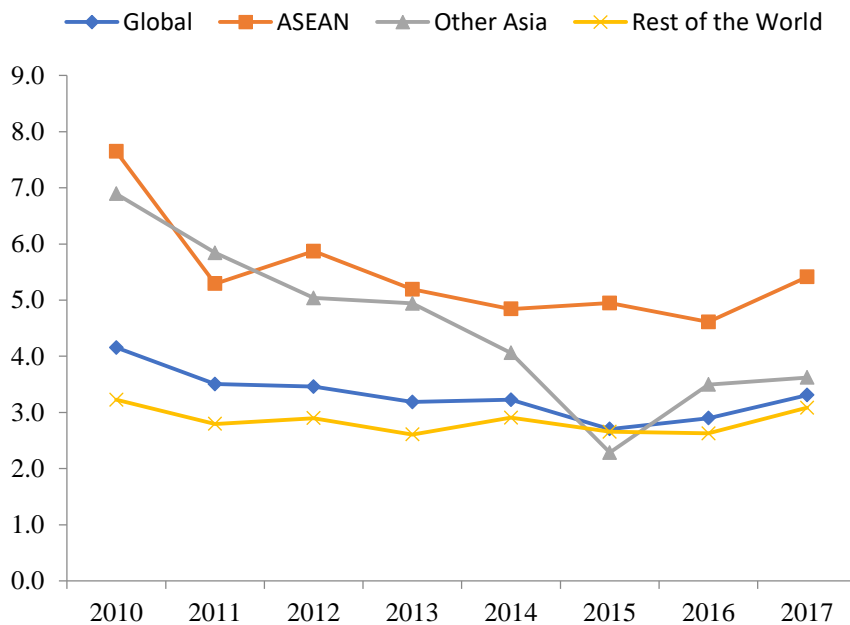


Figure 1 Average GDP growth rate of world (Unit: %).

Source: World Bank (Accessed on October 5, 2019), averaged by authors.

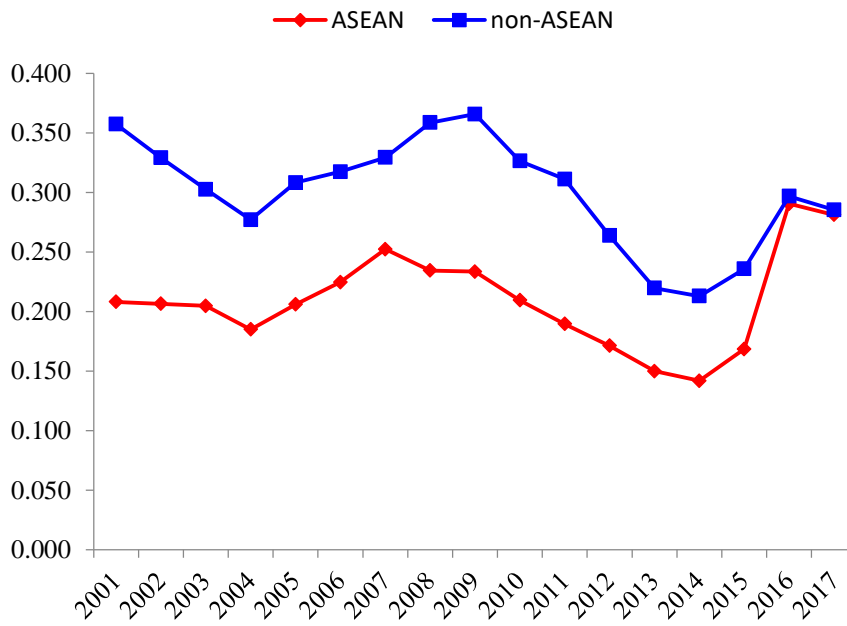


Figure 2 Average OTE scores of ASEAN and non-ASEAN economies.

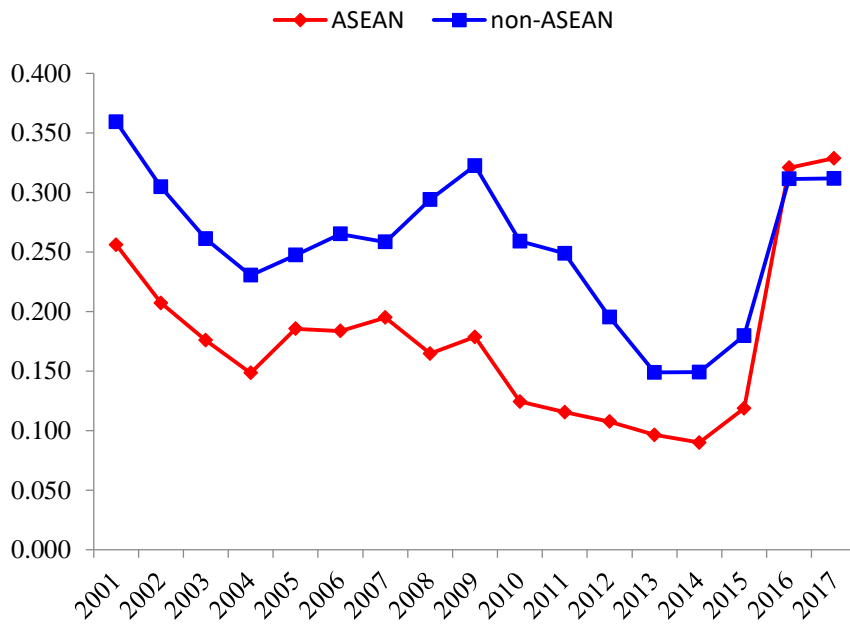


Figure 3 Average TFEF scores of ASEAN and non-ASEAN economies.

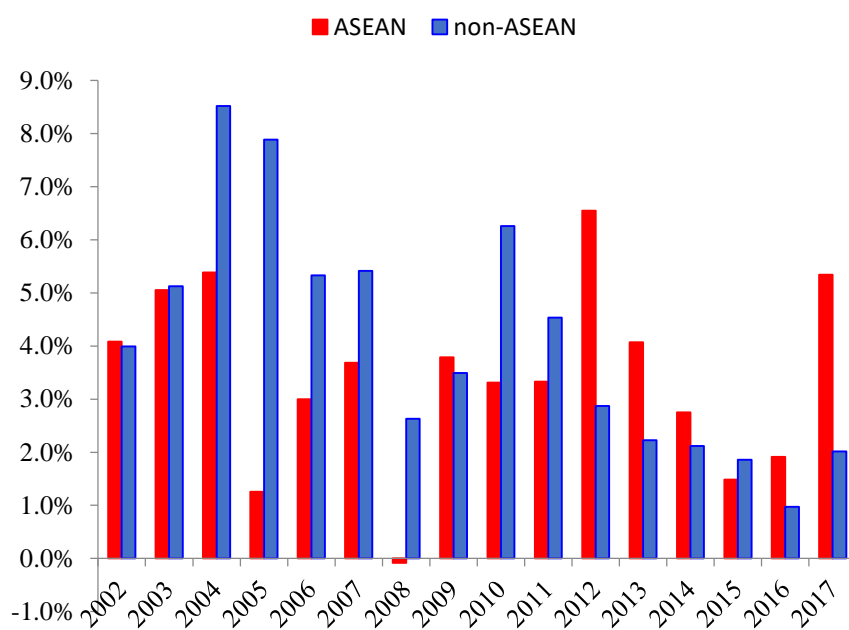


Figure 4 Average total final energy consumption growth rates of ASEAN and non-ASEAN economies.

Source: International Energy Agency.

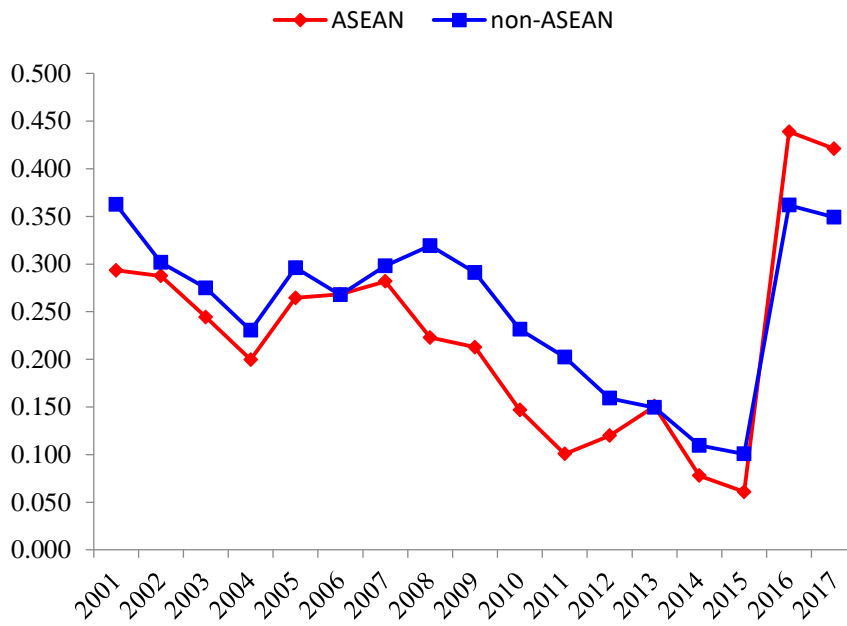


Figure 5 Average TFCEE scores of ASEAN and non-ASEAN economies.

Source: Authors' calculations.

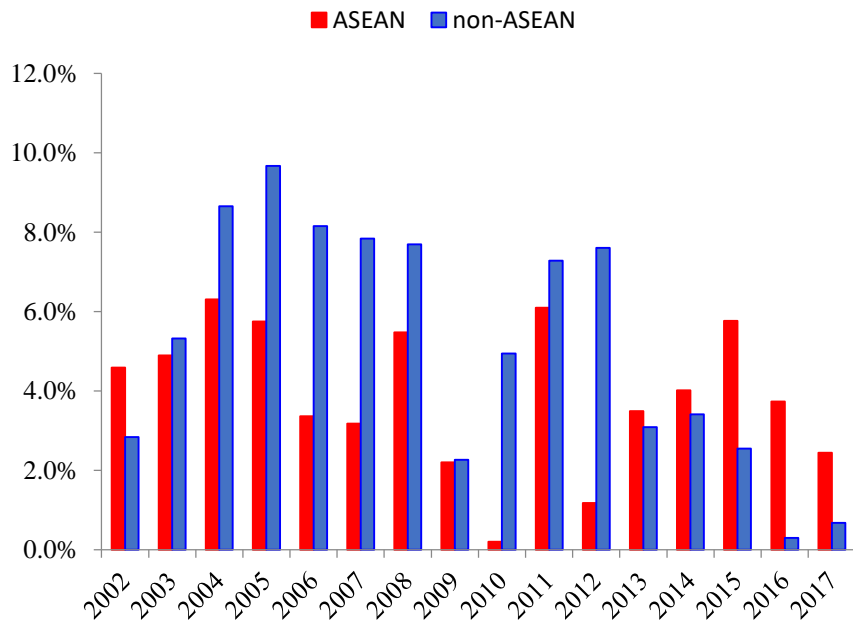


Figure 6 Average CO₂ emission growth rates of ASEAN and non-ASEAN economies.

Source: EDGAR v5.0.

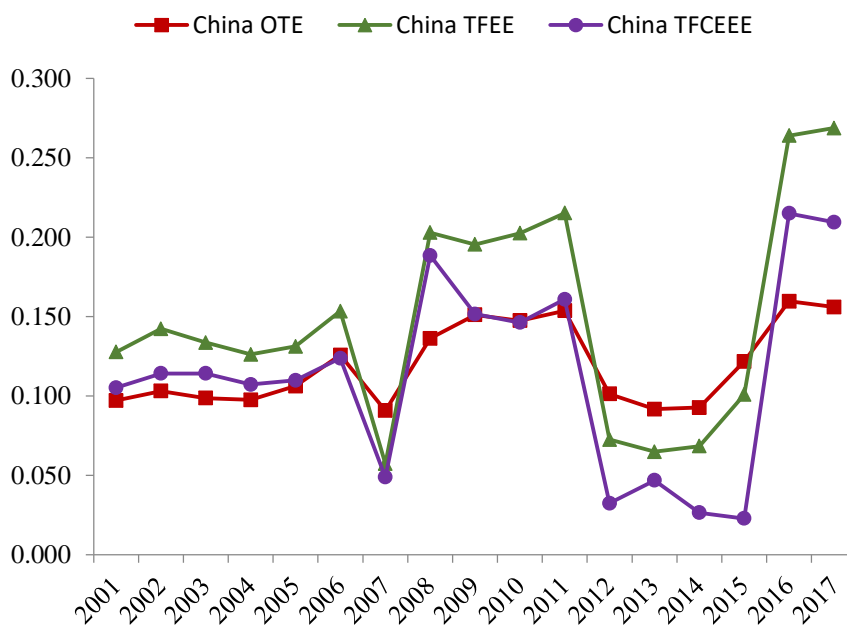


Figure 7 OTE, TFEE, TFCEE scores of China.

Source: Authors' calculations.

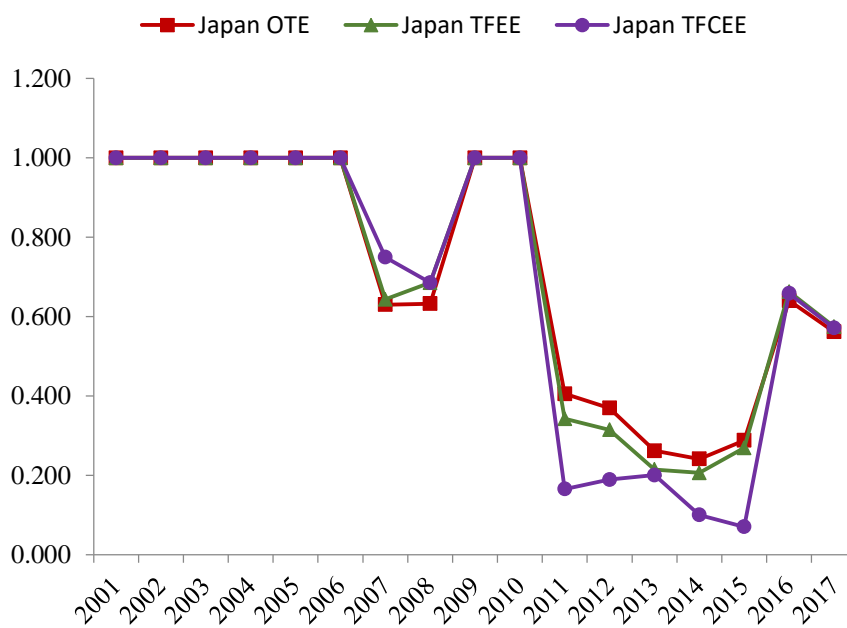


Figure 8 OTE, TFEE, TFCEE scores of Japan.

Source: Authors' calculations.

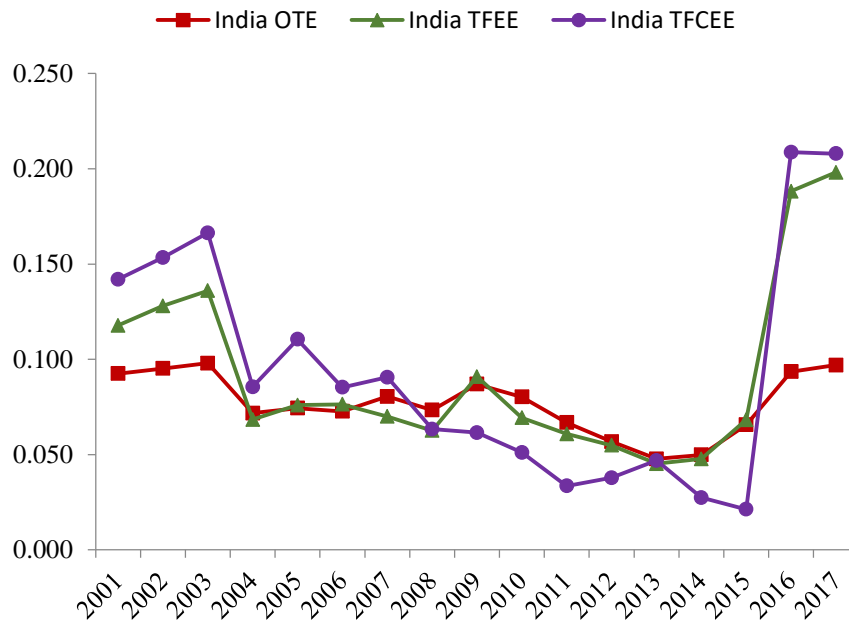


Figure 9 OTE, TFEE, TFCEE scores of India.

Source: Authors' calculations.

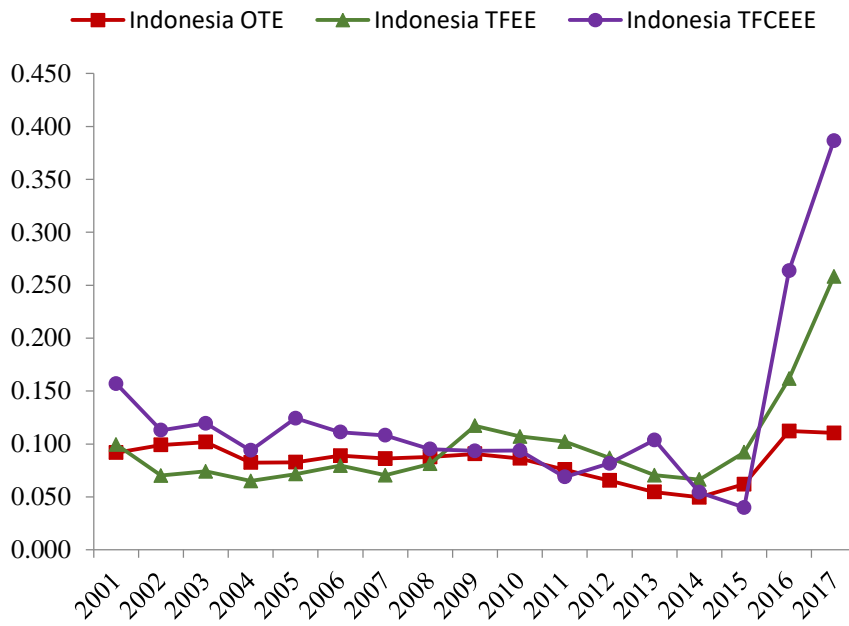


Figure 10 OTE, TFEE, TFCEE scores of Indonesia.

Source: Authors' calculations.

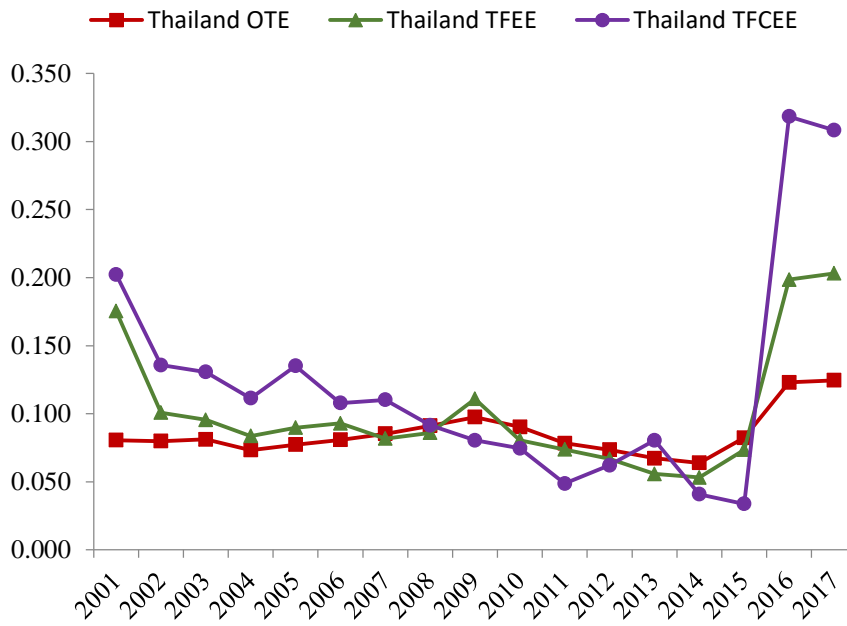


Figure 11 OTE, TFEE, TFCEE scores of Indonesia.

Source: Authors' calculations.

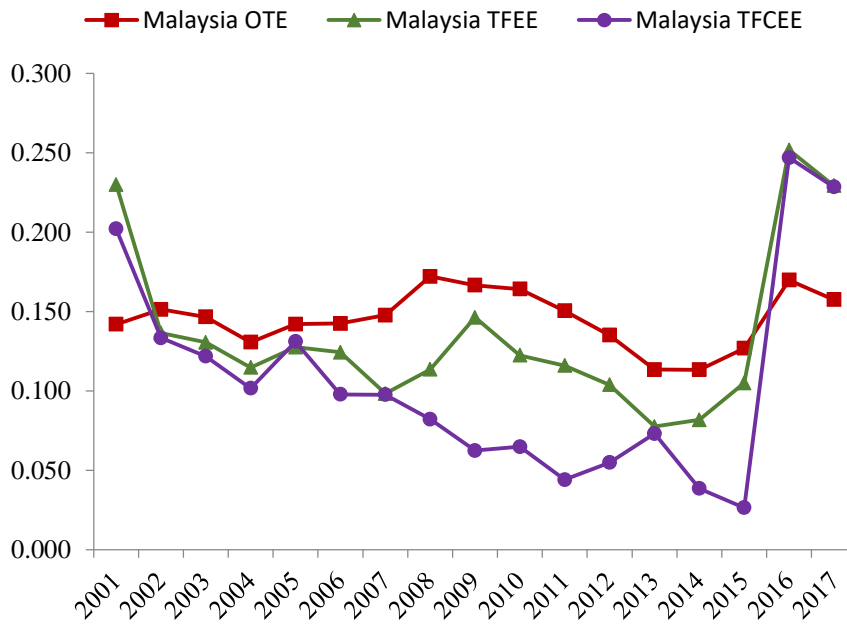


Figure 12 OTE, TFEE, TFCEE scores of Malaysia.

Source: Authors' calculations.

Appendix I Overall technical efficiency (OTE) score for Asia countries (2001-2017)

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Average	
Brunei Darussalam	0.421	0.438	0.457	0.440	0.554	0.589	0.477	0.522	0.381	0.366	0.378	0.332	0.286	0.246	0.238	0.337	0.333	0.400	
Cambodia	0.156	0.141	0.131	0.116	0.131	0.131	0.142	0.168	0.178	0.155	0.139	0.129	0.116	0.117	0.154	0.193	0.182	0.146	
Indonesia	0.119	0.130	0.133	0.108	0.108	0.116	0.113	0.115	0.118	0.113	0.099	0.086	0.071	0.065	0.081	0.140	0.136	0.109	
Lao PDR	0.112	0.094	0.090	0.079	0.084	0.091	0.094	0.110	0.125	0.115	0.108	0.104	0.101	0.099	0.132			0.102	
Malaysia	0.181	0.199	0.191	0.171	0.185	0.186	0.194	0.224	0.215	0.213	0.196	0.176	0.149	0.149	0.165	0.216	0.201	0.189	
Myanmar	0.132	0.141	0.198	0.143	0.142	0.141	0.171	0.252	0.335	0.285	0.222	0.169	0.126	0.116	0.122	0.157	0.137	0.176	
Philippines	0.147	0.139	0.129	0.113	0.125	0.133	0.144	0.161	0.175	0.153	0.137	0.135	0.123	0.122	0.158	0.254	0.225	0.151	
Singapore	0.599	0.590	0.534	0.521	0.560	0.680	1.000	0.572	0.560	0.468	0.415	0.383	0.343	0.320	0.390	1.000	1.000	0.584	
Thailand	0.104	0.104	0.106	0.096	0.101	0.106	0.111	0.120	0.127	0.119	0.103	0.097	0.089	0.084	0.108	0.154	0.157	0.111	
Vietnam	0.111	0.091	0.079	0.064	0.072	0.074	0.079	0.102	0.123	0.107	0.100	0.101	0.095	0.102	0.137	0.163	0.161	0.104	
ASEAN Average	0.208	0.207	0.205	0.185	0.206	0.225	0.252	0.235	0.234	0.210	0.190	0.171	0.150	0.142	0.169	0.291	0.281	0.209	
Armenia	0.093	0.096	0.102	0.105	0.138	0.163	0.220	0.282	0.244	0.222	0.200	0.178	0.138	0.122	0.145	0.197	0.194	0.167	
Azerbaijan	0.088	0.094	0.099	0.093	0.136	0.207	0.709	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.324	0.226	0.221	0.541
Bahrain	0.301	0.292	0.270	0.262	0.285	0.270	0.263	0.281	0.264	0.228	0.203	0.189	0.167	0.163	0.190	0.262	0.256	0.244	
Bangladesh	0.218	0.185	0.174	0.143	0.140	0.122	0.115	0.124	0.149	0.123	0.104	0.092	0.086	0.092	0.128	0.217	0.213	0.143	
Bhutan	0.059	0.062	0.060	0.051	0.058	0.053	0.066	0.069	0.074	0.072	0.064	0.053	0.044	0.047	0.060			0.060	
China	0.126	0.134	0.128	0.127	0.138	0.163	0.120	0.166	0.194	0.189	0.196	0.133	0.121	0.122	0.159	0.202	0.197	0.154	
Cyprus	0.379	0.421	0.503	0.461	0.465	0.424	0.435	0.475	0.489	0.357	0.316	0.255	0.213	0.208	0.219	0.396	0.400	0.377	
Georgia	0.080	0.075	0.079	0.081	0.099	0.110	0.136	0.184	0.191	0.173	0.176	0.171	0.151	0.150	0.162	0.192	0.183	0.141	
Hong Kong, China	1.000	1.000	1.000	0.693	1.000	0.604	0.546	0.520	0.560	0.450	0.383	0.359	0.328	0.322	0.445	1.000	1.000	0.660	
India	0.120	0.124	0.127	0.094	0.097	0.095	0.106	0.097	0.114	0.106	0.088	0.075	0.063	0.066	0.086	0.120	0.124	0.100	
Iran, Islamic Rep.	0.102	0.102	0.107	0.107	0.116	0.120	0.142	0.162	0.177	0.167	0.159	0.145	0.097	0.088	0.100	0.133	0.133	0.127	

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Average
Iraq				0.213	0.264	0.319	1.000	0.912	0.541	0.410	0.463	0.489	0.290	0.266	0.248	0.300	0.298	0.430
Israel	0.685	0.650	0.613	0.521	0.534	0.497	0.503	0.742	1.000	1.000	1.000	0.418	0.402	0.395	1.000	1.000	1.000	0.703
Japan	1.000	1.000	1.000	1.000	1.000	1.000	0.700	0.718	1.000	1.000	0.500	0.460	0.336	0.308	0.361	0.733	0.650	0.751
Jordan	0.203	0.197	0.174	0.143	0.139	0.144	0.140	0.174	0.200	0.172	0.148	0.135	0.125	0.127	0.169	0.234	0.217	0.167
Kazakhstan	0.065	0.075	0.082	0.092	0.113	0.146	0.173	0.224	0.227	0.246	0.264	0.251	0.230	0.196	0.208	0.181	0.197	0.175
Korea, Rep.	0.336	0.393	0.393	0.354	0.388	0.379	0.368	0.311	0.314	0.307	0.274	0.240	0.217	0.222	0.276	0.415	0.406	0.329
Kuwait	0.340	0.381	0.419	0.473	1.000	1.000	1.000	1.000	1.000	0.575	1.000	1.000	0.390	0.331	0.283	0.345	0.339	0.640
Kyrgyz Republic	0.063	0.062	0.071	0.070	0.078	0.086	0.112	0.161	0.167	0.148	0.155	0.130	0.100	0.081	0.092	0.101	0.103	0.105
Lebanon	0.334	0.319	0.266	0.198	0.186	0.177	0.183	0.196	0.251	0.212	0.176	0.161	0.144	0.140	0.181	0.289	0.274	0.217
Macao, China	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000			1.000
Maldives	1.000	1.000	1.000	1.000	0.344	1.000	0.662	0.462	0.500	0.310	0.243	0.210	0.197	0.197	0.275			0.560
Mongolia	0.051	0.046	0.041	0.036	0.041	0.048	0.054	0.071	0.066	0.083	0.093	0.094	0.081	0.077	0.099	0.121	0.111	0.071
Nepal	0.085	0.078	0.075	0.067	0.075	0.072	0.078	0.093	0.102	0.099	0.091	0.081	0.070	0.070	0.094	0.117	0.119	0.086
Oman	0.425	0.401	0.353	0.313	0.335	0.315	0.290	0.372	0.293	0.260	0.222	0.205	0.169	0.159	0.163	0.194	0.183	0.274
Pakistan	0.150	0.134	0.133	0.121	0.125	0.138	0.136	0.147	0.156	0.130	0.126	0.117	0.105	0.108	0.153	0.183	0.178	0.138
Qatar	1.000	1.000	0.472	0.499	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.419	0.364	0.338	0.320	0.444	0.437	0.723
Saudi Arabia	0.274	0.282	0.288	0.306	0.367	0.357	0.332	0.376	0.311	0.283	0.270	0.246	0.206	0.192	0.203	0.277	0.267	0.285
Sri Lanka	0.152	0.136	0.130	0.106	0.114	0.112	0.110	0.130	0.147	0.147	0.129	0.115	0.107	0.107	0.136	0.243	0.233	0.138
Syrian Arab Republic	1.000	0.431	0.232	0.146	0.129	0.132	0.148											0.317
Taiwan	0.420	0.439	0.409	0.371	0.379	0.337	0.309	0.299	0.301	0.262	0.227	0.204	0.181	0.181	0.231	0.353	0.352	0.309
Tajikistan	0.029	0.028	0.031	0.032	0.033	0.035	0.039	0.052	0.057	0.047	0.042	0.040	0.033	0.031	0.034	0.048	0.047	0.039
Turkey	0.224	0.290	0.339	0.336	0.396	0.332	0.321	0.350	0.339	0.290	0.246	0.210	0.188	0.165	0.186	0.298	0.257	0.280
Turkmenistan	0.030	0.039	0.047	0.046	0.052	0.060	0.068	0.095	0.115	0.100	0.098	0.099	0.090	0.093	0.094	0.113	0.106	0.079

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Average
United Arab Emirates	0.372	0.393	0.392	0.408	0.468	0.543	0.396	0.412	0.323	0.278	0.262	0.244	0.217	0.216	0.241	0.359	0.351	0.346
Uzbekistan	0.065	0.054	0.051	0.049	0.055	0.062	0.077	0.088	0.124	0.127	0.122	0.119	0.112	0.143	0.193	0.205	0.132	0.105
Yemen	1.000	0.441	0.237	0.137	0.120	0.123	0.131	0.169	0.184	0.186	0.167	0.161	0.147	0.150	0.235	0.298	0.247	0.243
<i>non-ASEAN Average</i>	<i>0.357</i>	<i>0.329</i>	<i>0.303</i>	<i>0.277</i>	<i>0.308</i>	<i>0.317</i>	<i>0.329</i>	<i>0.359</i>	<i>0.366</i>	<i>0.327</i>	<i>0.311</i>	<i>0.264</i>	<i>0.220</i>	<i>0.213</i>	<i>0.236</i>	<i>0.297</i>	<i>0.286</i>	<i>0.300</i>
Average	0.325	0.303	0.281	0.258	0.287	0.298	0.313	0.332	0.337	0.301	0.285	0.244	0.205	0.198	0.221	0.296	0.285	0.280

Source: Authors' calculations.

Appendix II Total-factor energy efficiency (TFEE) score for Asia countries (2001-2017)

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Average
Brunei Darussalam	0.777	0.509	0.503	0.473	0.719	0.515	0.357	0.427	0.302	0.209	0.182	0.155	0.210	0.150	0.179	0.246	0.403	0.372
Cambodia	0.078	0.055	0.052	0.062	0.073	0.076	0.067	0.077	0.074	0.049	0.046	0.043	0.037	0.038	0.055	0.147	0.148	0.069
Indonesia	0.099	0.070	0.074	0.065	0.072	0.079	0.071	0.081	0.117	0.107	0.102	0.087	0.070	0.066	0.092	0.264	0.258	0.104
Lao PDR	0.066	0.048	0.048	0.046	0.051	0.053	0.045	0.051	0.074	0.057	0.059	0.061	0.054	0.058	0.083			0.057
Malaysia	0.230	0.252	0.131	0.115	0.128	0.124	0.098	0.114	0.146	0.122	0.116	0.104	0.078	0.082	0.105	0.252	0.229	0.143
Myanmar	0.086	0.110	0.034	0.028	0.031	0.034	0.035	0.056	0.127	0.087	0.078	0.065	0.051	0.052	0.065	0.172	0.149	0.074
Philippines	0.187	0.153	0.142	0.129	0.150	0.166	0.150	0.171	0.228	0.169	0.162	0.162	0.137	0.136	0.181	0.451	0.414	0.193
Singapore	0.770	0.722	0.628	0.439	0.490	0.641	1.000	0.532	0.536	0.315	0.291	0.285	0.231	0.222	0.295	1.000	1.000	0.553
Thailand	0.175	0.101	0.096	0.084	0.090	0.093	0.082	0.086	0.111	0.081	0.074	0.067	0.056	0.053	0.073	0.199	0.203	0.101
Vietnam	0.093	0.054	0.052	0.045	0.054	0.056	0.046	0.053	0.073	0.048	0.047	0.049	0.042	0.043	0.059	0.156	0.154	0.066
ASEAN Average	0.256	0.207	0.176	0.149	0.186	0.184	0.195	0.165	0.179	0.124	0.116	0.108	0.097	0.090	0.119	0.321	0.329	0.176
Armenia	0.110	0.095	0.088	0.082	0.095	0.108	0.103	0.115	0.139	0.102	0.086	0.077	0.067	0.073	0.096	0.237	0.228	0.112
Azerbaijan	0.068	0.040	0.042	0.038	0.055	0.082	0.785	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.226	0.197	0.203	0.514
Bahrain	0.214	0.236	0.237	0.249	0.125	0.124	0.109	0.117	0.149	0.101	0.097	0.095	0.072	0.069	0.090	0.239	0.249	0.151
Bangladesh	0.193	0.146	0.136	0.123	0.126	0.112	0.090	0.097	0.148	0.101	0.092	0.084	0.077	0.085	0.125	0.357	0.358	0.144
Bhutan	0.034	0.022	0.023	0.021	0.024	0.023	0.022	0.022	0.030	0.024	0.022	0.019	0.015	0.016	0.025			0.023
China	0.128	0.142	0.134	0.126	0.131	0.153	0.057	0.266	0.196	0.202	0.215	0.073	0.065	0.068	0.101	0.264	0.269	0.152
Cyprus	0.547	0.340	0.377	0.366	0.385	0.374	0.324	0.354	0.466	0.299	0.281	0.255	0.221	0.212	0.247	0.387	0.388	0.343
Georgia	0.122	0.074	0.076	0.080	0.096	0.103	0.094	0.114	0.137	0.088	0.081	0.077	0.058	0.053	0.061	0.155	0.152	0.095
Hong Kong, China	1.000	1.000	1.000	0.934	1.000	0.756	0.606	0.602	0.752	0.559	0.495	0.471	0.405	0.410	0.621	1.000	1.000	0.742
India	0.118	0.128	0.136	0.068	0.076	0.076	0.070	0.063	0.091	0.069	0.061	0.055	0.045	0.048	0.068	0.188	0.198	0.092
Iran, Islamic Rep.	0.098	0.101	0.105	0.054	0.059	0.057	0.052	0.058	0.080	0.062	0.061	0.057	0.035	0.030	0.038	0.104	0.103	0.068

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Average
Iraq				0.070	0.090	0.147	1.000	0.929	0.538	0.393	0.348	0.359	0.113	0.138	0.183	0.430	0.421	0.369
Israel	0.851	0.660	0.562	0.391	0.395	0.370	0.309	0.677	1.000	1.000	1.000	0.285	0.264	0.274	1.000	1.000	1.000	0.649
Japan	1.000	1.000	1.000	1.000	1.000	1.000	0.644	0.640	1.000	1.000	0.343	0.315	0.215	0.207	0.269	0.663	0.733	0.708
Jordan	0.197	0.118	0.109	0.091	0.091	0.098	0.082	0.111	0.158	0.117	0.106	0.092	0.086	0.087	0.123	0.300	0.273	0.132
Kazakhstan	0.079	0.053	0.052	0.056	0.062	0.079	0.063	0.265	0.101	0.077	0.076	0.077	0.070	0.073	0.083	0.159	0.177	0.094
Korea, Rep.	0.314	0.366	0.368	0.185	0.212	0.214	0.173	0.150	0.189	0.139	0.127	0.114	0.099	0.105	0.143	0.370	0.369	0.214
Kuwait	0.325	0.373	0.348	0.394	1.000	1.000	1.000	1.000	1.000	0.378	1.000	1.000	0.139	0.120	0.114	0.267	0.273	0.572
Kyrgyz Republic	0.080	0.040	0.039	0.039	0.044	0.045	0.037	0.046	0.138	0.042	0.038	0.029	0.027	0.028	0.036	0.092	0.096	0.053
Lebanon	0.377	0.252	0.240	0.188	0.201	0.221	0.224	0.191	0.245	0.197	0.178	0.144	0.134	0.132	0.176	0.453	0.431	0.234
Macao, China	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000			1.000
Maldives	1.000	1.000	1.000	1.000	0.224	1.000	0.573	0.392	0.492	0.191	0.166	0.138	0.131	0.121	0.195			0.508
Mongolia	0.061	0.037	0.036	0.036	0.042	0.043	0.039	0.049	0.054	0.054	0.059	0.058	0.047	0.047	0.068	0.157	0.143	0.061
Nepal	0.042	0.032	0.029	0.028	0.030	0.030	0.025	0.029	0.040	0.032	0.031	0.029	0.022	0.022	0.033	0.078	0.082	0.036
Oman	0.413	0.412	0.394	0.224	0.207	0.134	0.099	0.130	0.143	0.096	0.077	0.070	0.057	0.055	0.061	0.152	0.147	0.169
Pakistan	0.106	0.059	0.059	0.054	0.058	0.063	0.050	0.055	0.075	0.051	0.051	0.048	0.040	0.041	0.060	0.154	0.149	0.069
Qatar	1.000	1.000	0.246	0.272	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.187	0.161	0.143	0.157	0.394	0.403	0.645
Saudi Arabia	0.215	0.217	0.220	0.227	0.131	0.127	0.099	0.109	0.122	0.088	0.093	0.085	0.071	0.067	0.082	0.216	0.216	0.140
Sri Lanka	0.128	0.100	0.101	0.090	0.101	0.105	0.088	0.112	0.162	0.129	0.123	0.108	0.105	0.109	0.146	0.241	0.383	0.137
Syrian Arab Republic	1.000	0.355	0.086	0.075	0.069	0.069	0.060											0.245
Taiwan	0.433	0.452	0.411	0.193	0.204	0.174	0.140	0.142	0.189	0.131	0.126	0.116	0.095	0.097	0.136	0.354	0.362	0.221
Tajikistan	0.047	0.030	0.034	0.035	0.039	0.042	0.037	0.052	0.081	0.058	0.057	0.055	0.050	0.050	0.057	0.075	0.073	0.051
Turkey	0.293	0.184	0.206	0.214	0.254	0.228	0.200	0.227	0.268	0.197	0.172	0.157	0.141	0.137	0.165	0.413	0.358	0.224
Turkmenistan	0.029	0.037	0.040	0.019	0.022	0.025	0.020	0.115	0.048	0.031	0.031	0.032	0.029	0.031	0.036	0.094	0.093	0.043

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Average
United Arab Emirates	0.292	0.339	0.351	0.397	0.385	0.497	0.178	0.182	0.181	0.129	0.126	0.118	0.095	0.100	0.115	0.317	0.320	0.243
Uzbekistan	0.024	0.011	0.011	0.011	0.014	0.015	0.014	0.067	0.069	0.079	0.023	0.022	0.024	0.032	0.056	0.165	0.115	0.044
Yemen	1.000	0.518	0.106	0.099	0.112	0.116	0.097	0.109	0.134	0.116	0.121	0.135	0.086	0.090	0.283	0.602	0.525	0.250
non-ASEAN Average	0.359	0.305	0.261	0.231	0.248	0.265	0.258	0.294	0.323	0.259	0.249	0.195	0.149	0.149	0.180	0.311	0.312	0.256
Average	0.337	0.284	0.243	0.213	0.234	0.248	0.245	0.266	0.291	0.230	0.220	0.176	0.138	0.136	0.167	0.313	0.315	0.239

Source: Authors' calculations.

Appendix III Total-factor CO₂ emission efficiency (TFCEE) score for Asia countries (2001-2017)

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Average
Brunei Darussalam	0.331	0.304	0.256	0.200	0.359	0.537	0.400	0.479	0.091	0.087	0.081	0.097	0.122	0.063	0.040	0.243	0.348	0.238
Cambodia	0.353	0.356	0.340	0.285	0.405	0.297	0.278	0.209	0.175	0.118	0.083	0.102	0.139	0.081	0.061	0.484	0.415	0.246
Indonesia	0.157	0.113	0.119	0.094	0.124	0.111	0.108	0.095	0.093	0.094	0.069	0.082	0.104	0.054	0.040	0.396	0.386	0.132
Lao PDR	0.485	0.481	0.383	0.337	0.399	0.365	0.370	0.291	0.295	0.207	0.165	0.180	0.248	0.113	0.130			0.297
Malaysia	0.202	0.219	0.122	0.102	0.131	0.098	0.098	0.082	0.063	0.065	0.044	0.055	0.073	0.039	0.027	0.247	0.229	0.111
Myanmar	0.287	0.350	0.197	0.125	0.177	0.143	0.186	0.218	0.710	0.396	0.228	0.263	0.246	0.121	0.062	0.514	0.458	0.275
Philippines	0.177	0.201	0.184	0.153	0.206	0.165	0.196	0.163	0.143	0.125	0.083	0.110	0.149	0.076	0.060	0.538	0.455	0.187
Singapore	0.571	0.611	0.622	0.512	0.609	0.784	1.000	0.533	0.419	0.259	0.176	0.209	0.290	0.159	0.130	1.000	1.000	0.523
Thailand	0.202	0.136	0.131	0.111	0.135	0.108	0.110	0.092	0.080	0.075	0.049	0.062	0.080	0.041	0.034	0.318	0.308	0.122
Vietnam	0.170	0.104	0.090	0.076	0.099	0.073	0.073	0.065	0.058	0.042	0.028	0.038	0.056	0.032	0.025	0.211	0.191	0.084
ASEAN Average	0.293	0.288	0.244	0.200	0.264	0.268	0.282	0.223	0.213	0.147	0.101	0.120	0.151	0.078	0.061	0.439	0.421	0.223
Armenia	0.102	0.116	0.144	0.129	0.199	0.154	0.193	0.163	0.102	0.101	0.073	0.080	0.095	0.057	0.043	0.440	0.421	0.154
Azerbaijan	0.059	0.043	0.045	0.039	0.072	0.076	0.831	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.227	0.240	0.223	0.521
Bahrain	0.146	0.156	0.164	0.175	0.125	0.087	0.082	0.074	0.057	0.047	0.032	0.041	0.055	0.029	0.021	0.201	0.186	0.099
Bangladesh	0.358	0.317	0.298	0.243	0.297	0.203	0.182	0.153	0.140	0.110	0.071	0.082	0.114	0.069	0.061	0.577	0.569	0.226
Bhutan	0.304	0.232	0.217	0.226	0.405	0.192	0.213	0.200	0.121	0.067	0.044	0.045	0.046	0.042	0.036			0.159
China	0.105	0.114	0.114	0.107	0.110	0.124	0.049	0.317	0.152	0.146	0.161	0.032	0.047	0.027	0.023	0.215	0.209	0.121
Cyprus	0.427	0.303	0.338	0.286	0.372	0.280	0.290	0.249	0.210	0.157	0.111	0.124	0.169	0.104	0.071	0.450	0.421	0.257
Georgia	0.173	0.157	0.190	0.176	0.245	0.171	0.179	0.148	0.130	0.092	0.075	0.080	0.099	0.054	0.033	0.296	0.266	0.151
Hong Kong, China	1.000	1.000	1.000	0.624	1.000	0.507	0.474	0.364	0.335	0.247	0.188	0.216	0.302	0.170	0.143	1.000	1.000	0.563
India	0.142	0.153	0.166	0.086	0.110	0.085	0.091	0.063	0.062	0.051	0.034	0.038	0.047	0.027	0.021	0.209	0.208	0.094
Iran, Islamic Rep.	0.104	0.105	0.115	0.061	0.081	0.062	0.067	0.056	0.052	0.044	0.033	0.039	0.040	0.019	0.014	0.141	0.133	0.069

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Average
Iraq				0.056	0.087	0.094	1.000	0.929	0.494	0.294	0.182	0.230	0.075	0.038	0.023	0.209	0.189	0.279
Israel	0.635	0.491	0.427	0.295	0.345	0.272	0.263	0.735	1.000	1.000	1.000	0.138	0.189	0.121	1.000	1.000	1.000	0.583
Japan	1.000	1.000	1.000	1.000	1.000	1.000	0.750	0.780	1.000	1.000	0.166	0.189	0.201	0.101	0.071	0.658	0.684	0.682
Jordan	0.168	0.112	0.101	0.090	0.106	0.084	0.082	0.078	0.080	0.064	0.045	0.056	0.069	0.041	0.033	0.317	0.307	0.108
Kazakhstan	0.049	0.035	0.035	0.035	0.052	0.049	0.049	0.328	0.031	0.033	0.026	0.031	0.046	0.022	0.016	0.114	0.119	0.063
Korea, Rep.	0.319	0.367	0.395	0.199	0.272	0.216	0.207	0.139	0.113	0.101	0.065	0.075	0.104	0.061	0.049	0.457	0.437	0.210
Kuwait	0.184	0.197	0.225	0.247	1.000	1.000	1.000	1.000	1.000	0.276	1.000	1.000	0.102	0.047	0.029	0.240	0.230	0.516
Kyrgyz Republic	0.090	0.071	0.061	0.050	0.067	0.057	0.066	0.057	0.200	0.035	0.030	0.032	0.036	0.021	0.015	0.133	0.135	0.068
Lebanon	0.334	0.212	0.201	0.166	0.202	0.147	0.153	0.153	0.136	0.091	0.063	0.081	0.101	0.057	0.045	0.425	0.426	0.176
Macao, China	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000			1.000
Maldives	1.000	1.000	1.000	1.000	0.309	1.000	0.994	0.708	0.703	0.161	0.102	0.099	0.104	0.073	0.109			0.557
Mongolia	0.040	0.028	0.027	0.027	0.041	0.034	0.032	0.032	0.024	0.027	0.023	0.030	0.037	0.018	0.015	0.134	0.087	0.039
Nepal	0.314	0.304	0.352	0.295	0.432	0.301	0.363	0.330	0.282	0.199	0.127	0.134	0.157	0.089	0.067	0.677	0.596	0.295
Oman	0.222	0.212	0.203	0.100	0.153	0.124	0.096	0.099	0.074	0.062	0.042	0.048	0.059	0.032	0.021	0.179	0.168	0.111
Pakistan	0.193	0.119	0.123	0.110	0.133	0.116	0.103	0.080	0.075	0.058	0.046	0.056	0.076	0.043	0.037	0.347	0.307	0.119
Qatar	1.000	1.000	0.186	0.219	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.093	0.122	0.067	0.041	0.349	0.341	0.613
Saudi Arabia	0.201	0.206	0.211	0.224	0.159	0.122	0.111	0.101	0.071	0.061	0.045	0.056	0.071	0.037	0.025	0.217	0.203	0.125
Sri Lanka	0.246	0.268	0.263	0.209	0.288	0.215	0.240	0.213	0.213	0.222	0.154	0.162	0.212	0.142	0.099	0.536	0.718	0.259
Syrian Arab Republic	1.000	0.199	0.078	0.070	0.094	0.062	0.063											0.224
Taiwan	0.378	0.393	0.374	0.177	0.224	0.159	0.142	0.110	0.100	0.089	0.058	0.070	0.098	0.055	0.045	0.416	0.394	0.193
Tajikistan	0.111	0.081	0.091	0.093	0.105	0.095	0.100	0.093	0.090	0.092	0.067	0.093	0.113	0.074	0.036	0.179	0.173	0.099
Turkey	0.254	0.210	0.235	0.228	0.332	0.246	0.237	0.189	0.146	0.132	0.087	0.101	0.138	0.076	0.054	0.493	0.409	0.210
Turkmenistan	0.026	0.033	0.039	0.018	0.025	0.021	0.022	0.168	0.022	0.021	0.015	0.020	0.028	0.016	0.011	0.100	0.092	0.040

Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Average
United Arab Emirates	0.337	0.325	0.343	0.359	0.366	0.435	0.195	0.170	0.105	0.089	0.066	0.081	0.105	0.056	0.041	0.369	0.352	0.223
Uzbekistan	0.027	0.014	0.013	0.013	0.018	0.016	0.018	0.130	0.092	0.104	0.014	0.017	0.024	0.020	0.017	0.161	0.116	0.048
Yemen	1.000	0.284	0.117	0.093	0.129	0.096	0.092	0.083	0.069	0.057	0.040	0.061	0.096	0.042	0.036	0.460	0.401	0.186
non-ASEAN Average	0.362	0.302	0.275	0.230	0.296	0.268	0.298	0.319	0.291	0.231	0.202	0.159	0.149	0.110	0.101	0.362	0.349	0.253
Average	0.347	0.299	0.268	0.224	0.289	0.268	0.295	0.298	0.274	0.213	0.180	0.151	0.150	0.103	0.092	0.378	0.365	0.247

Source: Authors' calculations.