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MIND THE GAP: THE EFFICIENCY CONVERGENCE OF ASEAN PLUS THREE ECONOMIES

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ABSTRACT

This study aims to examine the performance of technical efficiency convergence (Beta and Sigma convergences) of 9 ASEAN economies as well as other three main partners from East Asia, namely China, South Korea, and Japan for the years of 1993-2021, and addresses the determinants of this convergence consisting of foreign direct investment (FDI), export, and import. By using Stochastic Frontier Analysis to estimate technical efficiency as well as panel dynamic of Generalized Methods of Moment (GMM) to test convergence, we found robust findings of convergence moments, both the catching up effect (Beta Convergence) as well as inequality reduction (Sigma Convergence) across the countries.

Keywords: *Technical Efficiency Convergence, ASEAN Economies, Beta Convergence, Sigma Convergence.*
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Introduction

The economic openness and regional integration have been shown affecting the country's economic performances, as shown by Maudos et al. (1999) and Tumwebaze & Ijjo (2015). It is because by implementing economic integration, each country may reach a wider market and provide specialization opportunity to make better resources allocation. This potential performance is also shown by the Association of Southeast Asian Nations (ASEAN) that has been promulgated since 1967 to accelerate the economic growth, thrive the social networking, as well as boost cultural development (Kim, 2011). To evaluate this economic integration, several studies have examined through several methodologies: productivity analysis (Yasin, 2023) as well as economic convergence (Becerril-Torres et al., 2010; Shen et al., 2015; Weill, 2009). However, there are not many studies addresses the convergence of technical efficiency across ASEAN economies.

Theoretically, measuring technical efficiency can help determine how efficiently producers are using inputs to produce varying outputs (Coelli, 1996). This perspective has been pervasive in the microeconomic context. Meanwhile, in the macroeconomic context, measuring technical efficiency may estimate to which degree the resource had by the country can proportionally produce outputs in a form of gross domestic product. As the ASEAN economies has thriven progressively due to regional economic integration agenda, there is an

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indication of its macroeconomic performance, including the technical efficiency. The theory of convergence, as proposed by the seminal work of Barro & Sala-i-Martin (1992), suggests that technical efficiency convergence captures the movement towards a point where inequalities between observations decrease (Purwono et al., 2018). In this regard, it will help determining how efficiently the ASEAN economies are moving towards a common point and how it changes over time, which can show the progress of economic integration across ASEAN economies.

However, it has been argued that the integration of ASEAN economies into the ASEAN economic community was not fully developed until the early 1990s when compared to other regional economic integrations (Gugler & Vanoli, 2017; Kim, 2011). To tackle this issue, the acceleration of trade has been encouraged such as by thriving within ASEAN trade and investment and a rigorous pressure from domestic businesses for a deeper integration, which are essential to unify ASEAN as a union to gain regional stability. The growth of international exposure through foreign direct investment (FDI) in ASEAN has been significant since 1998, with a 50% growth rate. According to World Bank data, FDI inflow in ASEAN countries increased from 1.3% in 2000 to 13.02% in 2018 (Uttama & Peridy, 2010). In this regard, further investigation into how the performance of economic convergence, particularly the factors of production that establish regional productivity, is intriguing and important.

This study aims to examine the performance of technical efficiency convergence of 9 ASEAN economies as well as other three main partners from East Asia, namely China, South Korea, and Japan. The incorporation of these East Asia countries considers the immense collaboration and contribution of ASEAN economies in the East Asia international trade, notably in terms of FDI inflow by about 6.08%-14% (Yasin, 2023). Moreover, this study also addresses the determinants of this convergence consisting of FDI, export, and import. Empirically, some studies have elaborated the convergence analysis of ASEAN economies (Alavi & Ramadam, 2008; Bobowski, 2017; Bunyaratavej & Hahn, 2003; Chien et al., 2015; Gugler & Vanoli, 2017; Ismail, 2008; Lim & McAleer, 2004; Rath, 2019; Yilanci & Korkut Pata, 2020), but none of those studies emphasize how the convergence behaviour from the proportional contribution of factor production captured by technical efficiency[1]. In this regard, this study contributes to the literatures by revealing the convergence behaviour from 12 countries in ASEAN plus three economies as well as determine what factors driving it.

The rest of the paper is organised as follows: Section 2 presents the theory of convergence in efficiency, section 3 presents the data, methodology and econometric specification employed in this study. Section 4 presents the results. Section 5 presents the conclusions and implications.

Literature Review

The theory of convergence was based on the neoclassical theory, which suggests that the rate of per capita economic growth is directly linked to a person's initial level of output or income (Purwono et al., 2018). As income increases, economic growth slows down and eventually reaches a stable state. There are two types of convergence defined by Barro & Sala-i-Martin (1992), known as sigma (σ) and beta (β) convergences. In terms of efficiency that captures the extent to which producers can efficiently produce different outputs by utilising minimal input or optimise input to produce more outputs (Coelli, 1996), sigma convergence denotes to the reduction of disparities in efficiency scores among countries, while beta convergence represents the process of countries with lower efficiency scores catching up.

[1] Study of Yasin & Nuryitmawan (2020) addressed this topic but did not elaborate it well.

The convergence theory has been studied from various perspectives. In terms of efficiency convergence, several studies have conducted. As technical efficiency in the macro context is defined as to which degree the physical inputs such as labour and capital can proportionally generate outputs in a form of GDP, the magnitude may create specific pattern following regional economic integration. Moreover, the economic growth literature postulated that the income difference is measured by two proximate sources: inputs accumulation and the efficiency for which those inputs are utilized (Caselli, 2005; Mendez, 2020). In this regard, the pattern over the years from efficiency will also imply essential implication about income difference on the region.

Other perspective of convergence is also shown by Giraldo (2016) identifying the trade between similar countries that lead to convergence in economic growth, but trade between vastly different countries results in divergence. Moreover, the convergence occurs when trade leads to higher welfare levels compared to autarky. In contrast, divergence occurs when trade leads to higher welfare in the long run only if technology transfer is present, otherwise, only the country that continues to grow after trade will see an increase in its welfare levels relative to autarky, while the other country experiences a permanent reduction in welfare. Furthermore, Izzeldin et al. (2021) postulated that the speed of convergence associates to the signal of competitiveness. In the country level, it will depict to which degree a country performs in the region.

Another perspective of trade in affecting convergence is from Velde (2011) examining the growth convergence among 100 developing countries, which were divided into different regional integration agreements, such as ASEAN, CEMAC (Economic and Monetary Community of Central Africa), COMESA (Common Market for Eastern and Southern Africa), and EAC (East African Community). Velde (2011) captured that regional integration can stimulate connections among countries, but did not identify a significant effect of intra-regional trade on reducing income disparities. Moreover, Xu et al. (2023) investigated the sustainable innovation efficiency in European Union economies associating environmental outputs. This study reveals that the European Union has captivated great importance to sustainable innovation efficiency, indicating that the EU makes a concerted effort in technological innovation, energy saving, and environmental protection. Meanwhile, Xin-gang et al. (2019) explores the existence of foreign direct investment (FDI) in reducing energy efficiency disparities and reveals that FDI significantly promotes energy efficiency convergence and it is faster in the presence of spatial dependence.

Data and Research Methods

Data

This study uses secondary data spanning the period of 1993-2021 collected from World Bank. There are twelve countries included; those which comprise ASEAN and three other Asian countries. The ASEAN countries are: Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Philippines, Singapore, Thailand, and Vietnam. As for the three other Asian countries, they are: China, South Korea, and Japan.

There are three groups of variables in this study: output, input, and the determinants of convergence. Gross Domestic Product (GDP) (in USD) is proxied as output, while the stock of capital and labour force (in unit) are proxied as inputs. This study refers to the Perpetual Inventory Method (PIM) in calculating stock of capital (Arazmuradov et al., 2014; Dey-Chowdhury et al., 2008) with formula as follows:

$$K_{it} = (1-\delta)K_{t-1} + I_{it} \quad (1)$$

Where K_{it} is the stock of capital in year t of country i, δ is the depreciation assumed as 10% (referred to Arazmuradov et al., 2014), and I_{it} is the investment taken from the gross fixed capital formation (GFCF) (in USD)[2].

For the variables in the convergence model, we consider three main variables, namely foreign direct investment inflows (FDI), total export, and import. All these variables are measured from its geometric means. Table 1 summarizes the statistics of the variables used in this study. The table reports that the variable of intra-ASEAN export is quite lower than that of inter-ASEAN export.

Table 1: Descriptive Statistics

Variable	Units	Obs	Mean	Std. Dev	Min	Max
Gross Domestic Products	million USD	348	1157102.00	2416838.00	3190.36	15800000.00
Stock of Capital	million USD	348	2681367.00	5848801.00	3665.23	40900000.00
Labour Force	million people	348	91.95	203.26	0.12	795.57
Foreign Direct Investment (FDI) Net Inflow	million USD	348	20116.02	48691.31	-4845.36	333979.00
Total Exports	million USD	343	290045.90	490873.90	284.96	3553510.00
Total Imports	million USD	343	264624.70	442395.60	413.82	3091260.00

Methodology and Empirical Strategy

This study employs two approaches. The first approach, the parametric approach of Stochastic Frontier Analysis (SFA), is used to estimate technical efficiency. Instead of non-parametric approach such as Data Envelopment Analysis (DEA), SFA will reveal the significance and elasticity of inputs in producing output. The second approach, the panel dynamic approach of The Generalized Method of Moments (GMM), is considered to capture the convergence behaviour accommodating endogeneity that occurs when panel static such as fixed effect and random effect are taken.

The specification for the SFA in this study refers to the Greene (2005a) and Greene (2005b) extended to the Transcendental Logarithmic (Translog) specification as follows (Islamiya et al., 2022).

$$y_{it} = \beta_0 + \beta_1 k_{it} + \beta_2 l_{it} + \beta_3 \tfrac{1}{2} k_{it}^2 + \beta_4 \tfrac{1}{2} l_{it}^2 + \beta_5 (k_{it} \times l_{it}) + \beta_6 t + \beta_7 \tfrac{1}{2} t^2 + \beta_8 (k_{it} \times t) + \beta_9 (l_{it} \times t) + v_{it} - u_{it} \quad (2)$$

Where y is the total output, k represents input of capital, l denotes labour force, and t is time. All output and inputs are expressed in the natural logarithm (ln) and in deviation from their geometric means by country. Subscript i and t denote i-th firm and t-th year. v_{it} is the $iid.N(0,\sigma_v^2)$ random variable and u_{it} is a non-negative random variable assumed as the half-truncated normal $(N^+(u_i,\sigma_u^2))$ in distribution. To examine the robustness test of the production function in (1), we also reveal the alternative production function namely Hicks-Neutral ($\beta_8 = \beta_9 = 0$), No Technological Progress ($\beta_6 = \beta_7 = \beta_8 = \beta_9 = 0$), and Cobb-Douglas $\beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = \beta_8 = \beta_9 = 0$. The technical efficiency is calculated from Jondrow et al. (1982) as follows.

$$TE_{it} = \frac{y_{it}}{\widehat{y}_{it}} \quad (3a)$$

[2] We exclude Myanmar due to unavailability of the reliable data of capital stock. Meanwhile, the Gross Fixed Capital Formation of Lao PDR is also unavailable in 1993-1999. In this regard, we merely take the capital stock.

$$= \frac{f(x_{it};\beta).\exp(v_{it}-u_{it})}{f(x_{it};\beta).\exp(v_{it})} \quad (3b)$$

$$= \exp(-u_{it}) \quad (3c)$$

where y_{it} is the realised output and $\widehat{y}_{it}$ is the potential maximum output. Meanwhile, TE is the ratio of y_{it} and $\widehat{y}_{it}$, it ranges between 0 and 1. When TEs are closer to 1, the realised outputs are closer to their optimal output value.

The second strategy is to reveal the convergence behaviour. Instead of using panel static that is prone to the endogeneity, we use panel dynamic of Generalized Method of Moments (GMM) from Arellano & Bond (1991) with the Autoregressive degree 1 (AR1). There are two strategies in capturing the convergence: β-convergence and σ-convergence. Referred to the seminal work of Barro & Sala-i-Martin (1992), β-convergence refers to the catching-up effects to the more developed countries by which the speed of left-behind countries is shown. Meanwhile, σ-convergence captures the disparity reduction across countries over time. The specification of β-convergence for technical efficiency is as follows.

$$\ln EFF_{it} - \ln EFF_{i,t-1} = \alpha_0 + \alpha_1 \ln EFF_{i,t-1} + \alpha_2 \ln FDI_{it} + \alpha_3 \ln Export_{it} + \alpha_4 Import_{it} + \varepsilon_{it} \quad (4)$$

Where EFF_{it} is the technical efficiency of country i in year t. FDI_{it} is the net inflow foreign direct investment of country i in year t. $Export_{it}$ is the total export. $Import_{it}$ is the total import. ε_{it} is the error term. The β-convergence occurs if $\alpha_1 < 0$ as an increase of efficiency from year $t-1$ period will cause lower reduction of efficiency in year t.

The specification of σ-convergence for technical efficiency is referred to the Purwono et al. (2020) as follows.

$$\Delta W_{it} = \varphi_0 + \varphi_1 W_{i,t-1} + \varphi_2 \ln FDI_{it} + \varphi_3 \ln Export_{it} + \varphi_4 Import + \varepsilon_{it} \quad (5)$$

Where W_{it} is the technical efficiency of country i in year t subtracted by the mean of technical efficiency in year t. ΔW_{it} is the W_{it} subtracted by W_{it-1}. FDI_{it} is the net inflow foreign direct investment of country i in year t. $Export_{it}$ is the total export. $Import_{it}$ is the total import. ε_{it} is the error term. The σ-convergence occurs if $\varphi_1 < 0$.

By using the GMM, several assumptions are enforced and should be tested (Gnangnon, 2019). First, there should be serial correlation across in the first-order differentiated error (AR(1)) but not in the second-order autocorrelation (AR(2)) (Purwono et al., 2021). Accordingly, AR (1) should be significant while AR(2) should insignificant. Second, a test of overidentifying restrictions (OIR test) that determines the validity of the population moment conditions, shown by The Sargan test. If Chi-Square value's probability is lower than its significance rate at 10%, then the model is not valid (Purwono & Yasin, 2020).

Finding and Discussion

Table 2 reports the estimates of the Translog production function using Stochastic Frontier Analysis (SFA). The alternative production functions are also reported.

According to the Table 2, the coefficients in the production functions are mainly significant and captured robust estimation. However, the coefficient in the Translog production function cannot be directly interpreted. Instead, we should calculate the production elasticity of each inputs to ensure monotonicity condition and Inada condition (Yasin, 2021b). The results of elasticity shows that the production elasticity of capital is averagely 0.47, while the production elasticity of labour is 0.59. The distribution of these elasticities is reported in Figure 1. This result concludes that the positive contribution of capital and labour force in encouraging gross domestic products.

Table 2: Production Function from SFA

	(1)	(2)	(3)	(4)
	Translog	Hicks-Neutral	No Technological Progress	Cobb Douglas
k	0.624***	0.323***	0.492***	0.461***
	(0.109)	(0.000)	(0.024)	(0.019)
l	2.307***	0.855***	1.278***	1.468***
	(0.494)	(0.000)	(0.069)	(0.055)
k^2	0.246**	0.120***	0.061	
	(0.100)	(0.000)	(0.043)	
l^2	5.841***	0.691***	-1.622***	
	(1.850)	(0.000)	(0.514)	
k x l	0.128	-0.586***	-0.442***	
	(0.291)	(0.000)	(0.154)	
t	0.031***	0.023***		
	(0.009)	(0.000)		
t^2	-0.001	-0.000***		
	(0.001)	(0.000)		
k x t	-0.010			
	(0.007)			
l x t	-0.114***			
	(0.033)			
Observations	348	348	348	348
Number of Country	12	12	12	12

Note: Standard errors in parentheses.

*** p<0.01, ** p<0.05, * p<0.1

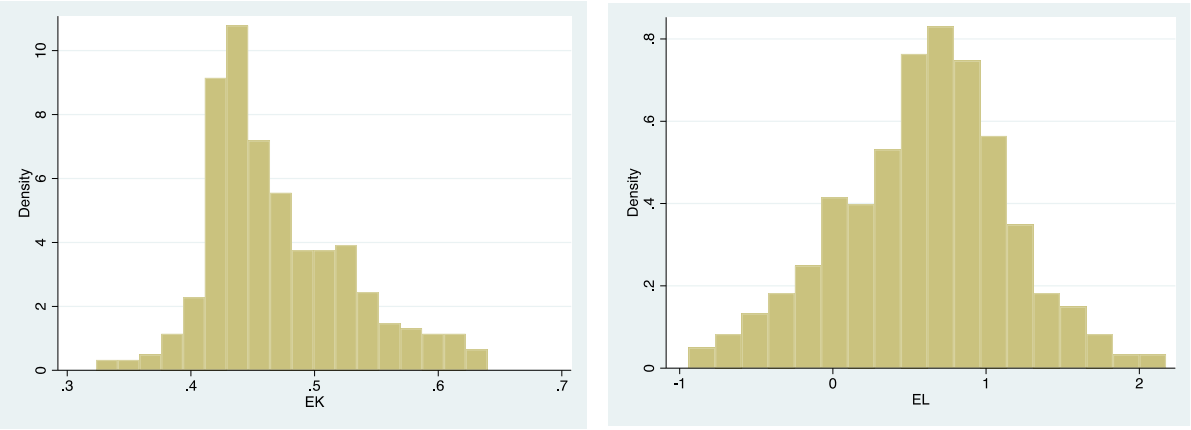

Figure 1: Elasticity of Capital (left-panel) and Labour (right-panel)

After the production function is estimated, technical efficiency is then calculated using (2a-2c). The distribution of the technical efficiency is shown in Figure 2.

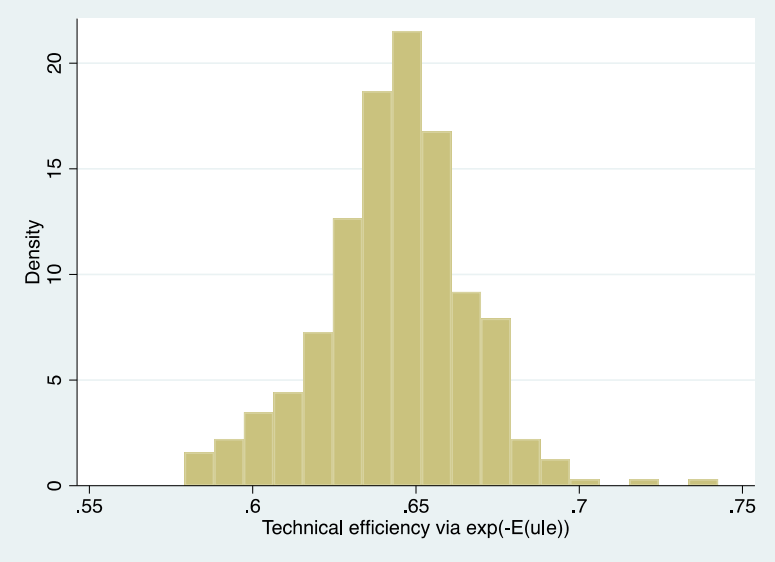

Figure 2: Technical Efficiency Distribution

According to the Figure 2, technical efficiency scores of our observation range between 0.57 to the 0.74. Meanwhile, the distribution of technical efficiency over years is shown in Figure 3.

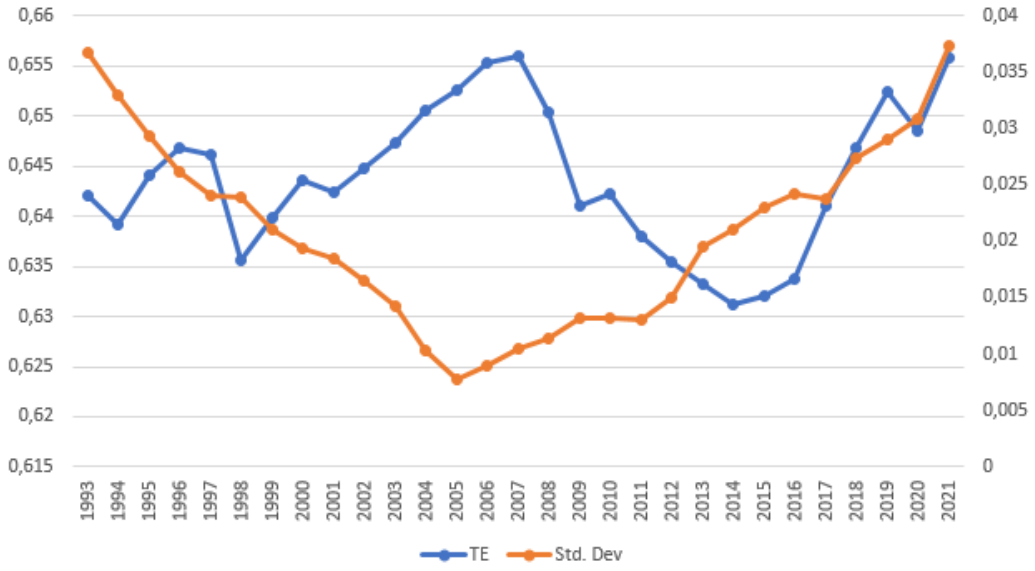

Figure 3: Technical Efficiency (LHS) and its standard deviation (RHS) Across Years

According to Figure 3, technical efficiency (Left Hand Side, LHS) shows increasing trend until around 2007. However, the following years revealing decreasing trend until the year of 2015. Meanwhile, the standard deviation of technical efficiency (Right Hand Side, RHS) reveals decreasing trend since 1990 until the year of 2005 and increasing for the following years.

The following test is to examine the convergence behaviour of ASEAN plus tree economies in 1993-2021. Table 3 reports the β-convergence of technical efficiency to capture whether there is catching-up effect due ASEAN poorer countries' efficiency grow faster than those countries with higher efficiency. The result reveals that the β-convergence significantly occurs, shown by the rigorous negative coefficient of . This finding is consistent with the study Gugler & Vanoli (2017) concluding the catching-up effect across ASEAN economies because of productivity asymmetry as well as labour utilization gaps, such as for Cambodia.

The speed of convergence is between 0.43 to 0.52, reported in column (1)-(4). An intriguing finding is that the speed of convergence for full sample including the China, South Korea, and Japan is slower than that the speed of only ASEAN sample, concluding the quicker phase of catching-up moment across ASEAN economies. This finding is plausible as the initiation of ASEAN Economic Community (AEC) in 2015 accelerate the economic development across ASEAN economies. In terms of its association with East Asian Countries, such as China, Chien et al. (2015) addresses that financial integration with China and ASEAN-5 (Singapore, Thailand, Philippines, Malaysia, and Indonesia) causes the convergence, notably in a post 1998 crisis period which enforces ASEAN countries to cooperate and integrate for economic development.

In terms of control variables, the result in Table 3 reports significant effects. The effect of FDI inflow to the growth of technical efficiency growth is insignificant, signaling that inflowing FDI cannot promote efficiency growth for ASEAN economies. In contrast, the growth of export affects positively to the efficiency growth by about 1%-1.8%. This finding concludes that exports of ASEAN countries contributes to the growth of efficiency, which is plausible as the exposure to the international market leads to the learning-by-exporting of the domestic country as the economic agents are enforced to meet the stringent standards (Damijan et al., 2009; De Loecker, 2013; Yasin, 2021a). By exporting, countries are enforced to utilize capital and labour forces accordingly, hence resulting better efficiency. Meanwhile, import has insignificant effect in the full sample of the period. However, it shows significant positive effect in the year of 1993-2007. This finding supports Yasin (2021b) arguing the importance of minimum level of domestic components policy to enhance economic efficiency. Our results also indicate that the ASEAN plus three countries' goods and services are competitively able to contribute to the country's efficiency improvements, instead of the imported ones. To catch up with the better countries, poor countries might deaccelerate imported goods and services.

Table 3: Regression Results of Efficiency β-convergence

	(1)	(2)	(3)	(4)
	Full	1993-2007	2008-2021	ASEAN
$ln\ EFF_{t-1}$	-0.439***	-0.529***	-0.500***	-0.446***
	(0.132)	(0.102)	(0.175)	(0.168)
$lnFDI$	0.001	-0.001	0.001	0.002
	(0.002)	(0.001)	(0.002)	(0.002)
$ln\ Export$	0.010**	0.003	0.018***	0.004
	(0.004)	(0.005)	(0.007)	(0.004)
$ln\ Import$	-0.000	0.017**	-0.008	0.003
	(0.008)	(0.008)	(0.006)	(0.010)
$Constant$	-0.195***	-0.220***	-0.232***	-0.198***
	(0.059)	(0.043)	(0.079)	(0.075)
$AR(1)-p-value$	0.0698	0.1213	0.0327	0.1623
$AR(2)-p-value$	0.4248	0.1905	0.6763	0.4977
$Sargan\ Test$	1.000	1.000	1.000	1.000
$Observations$	290	133	157	218
$Number\ of\ Country$	12	12	12	9

Note: Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 4 reports the results for the efficiency σ-convergence capturing the inequalities alleviation across ASEAN plus three economies. The results show that ASEAN plus three

economies experience technical efficiency inequalities reduction for the years of 1993-2021. The result is robust across different strategies such as the years of 1993-2007, 2008-2021, as well as re-sample of ASEAN economies. This finding concludes that in addition to the catching-up effects across ASEAN economies, there is also disparity reduction of technical efficiency.

The effect of FDI is again insignificant in reducing the inequalities of efficiency. A plausible reason of this finding is that because of FDI in affecting economy should be incorporated to the human capital (Yasin, 2023). As limited availability of this variable, we cannot catch the interaction effect of FDI and human capital. An intriguing result is shown by the export that reveals positive significance in affecting efficiency gap. This result shows that an increase of the total ratio of export to the GDP will increase the gap growth between efficiency in a country and the average efficiency in a year. This finding indicates that export enhances the efficiency gap across ASEAN economies. A plausible reason of this finding is that although export promotes countries to catch up with more efficiency countries, but apparently this effect enlarges the gap across the countries, indicating different speed of convergence across the countries. Meanwhile, import discourages efficiency gap to enlarge, indicating that import substitution remains unable to be implemented in some countries to obtain efficiency. Although using different observation and proxy, our finding is consistent with Purwono et al. (2021) for which imports promotes productivity of Indonesian provincial economies.

Table 4: Regression Results of Efficiency σ-convergence

	(1)	(2)	(3)	(4)
	Full	1993-2007	2008-2021	ASEAN
W_{it}	-0.313***	-0.476***	-0.718**	-0.416***
	(0.092)	(0.181)	(0.332)	(0.137)
lnFDI	0.002	-0.001	0.002	0.002
	(0.001)	(0.001)	(0.001)	(0.001)
ln Export	0.010**	0.007	0.011	-0.002
	(0.005)	(0.010)	(0.007)	(0.004)
ln Import	-0.010***	-0.005	-0.011**	-0.001
	(0.004)	(0.008)	(0.005)	(0.005)
Constant	-0.000	0.000	-0.002	-0.000
	(0.001)	(0.002)	(0.003)	(0.001)
$AR(1) - p - value$	0.0031	0.0572	0.1080	0.2018
$AR(2) - p - value$	0.1579	0.7177	0.5298	0.0467
Sargan Test	1.000	1.000	1.000	1.000
Observations	290	133	157	218
Number of Country	12	12	12	9

Note: Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Conclusion

This study has demonstrated the convergence performance of efficiency in the ASEAN plus three economies. The result found robust findings of convergence, both the catching up effect as well as inequality reduction across the countries. Coupled to this, a higher export growth affects positively to the efficiency growth by about 1%-1.8%. Likewise, importing causes increasing efficiency growth. However, export reveals positive significance in affecting efficiency gap. This result shows that an increase of the total ratio of export to the GDP will increase the gap growth between efficiency in a country and the average efficiency in a year.

Meanwhile, import discourages efficiency gap to enlarge, indicating that import substitution remains unable to be implemented in some countries to obtain efficiency.

This study leads to two policy implications. First, the strategic collaboration amidst ASEAN economies is a main prerequisite to strengthen the efficiency convergence trend, a "country centric" may occur amidst member. In this regard, ASEAN as well as other three East Asia Countries (China, South Korea, and China) roadmap should address prioritized challenges in which three ASEAN community pillars have addressed, such as coordination of the macroeconomic, political security, and potential cultural conflicts. Secondly, systemic uncertainty in the global economy should be well acknowledged by ASEAN members as well as other three East Asia Countries as it will affect regional economic stability. Ultimately, the integration of ASEAN can be sounding and stronger in line with other macroeconomic regions.

Declaration

The research presented in this article does not pose any conflicts of interest with regard to individuals, organizations, or any other entities. We are committed to making all data and materials used in this study available upon request, subject to any ethical or legal restrictions that may apply. This research did not receive financial support. We extend our heartfelt acknowledgments to Universitas Jember for their invaluable contributions and unwavering support throughout the duration of this research endeavor.

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