Convergence CO_2 Emission in ASEAN Countries: Augmented Green Solow Model Approach

Edy Yusuf Agung Gunanto*, Tri Wahyu, Jaka Aminata, Banatul Hayati

Department of Economic and Development, Diponegoro University, Indonesia. *Email: edyyusuffebundip@gmail.com

ABSTRACT

The purpose of this study is to analyze convergence and factors that affect CO_2 growth in ASEAN countries. The model used is the Augmented Green Solow Model developed by Rios and Gianmoena (2018) based on Brock and Taylor (2004; 2010) which takes into account spatial effects. This study found that during the period 1971-2019, ASEAN countries experienced convergence which was shown to be a significant and negative coefficient of initial CO_2, but was fairly slow compared to other studies or regions. Significant variables affect CO_2/capita growth in ASEAN countries, namely physical capital investment and trade openness that increases emissions, while human capital significantly reduces emissions. Significant spatial effects occur in initial CO_2/capita, physical capital investment, and human capital. The Kyoto Protocol was found to be insignificant in CO_2/capita growth in ASEAN countries.

Keywords: CO_2, Convergence, Green Solow Model
JEL Classifications: C23, O13, O44, Q53, Q56

1. INTRODUCTION

There is a close relationship between a country's economic growth and environmental damage. Grossman and Krueger (1995) found a positive relationship between the level of development and environmental damage in the proxy of CO_2 emissions. In literature on Environmental Kuznets Curve (EKC) stated that the early stages of growth of a country will increase "environmental demand" as a result of the increase in per capita income. However, as growth and development have reached breaking point, "environmental demand" begins to decline by increasing revenues and forms an inverse U-curve. This was strengthened by Li et al. (2020) where GDP which is an indicator of economic growth can have a positive and negative influence on emissions growth and have a different intensity between developed and developing countries.

On their development, Brock and Taylor (2004; 2010) found a conundrum in the analysis of emissions growth in the framework of Environmental Kuznets Curve (EKC), so they introduced the

Green Solow Model on their completion. In addition to analize the determinants of emission growth, Brock and Taylor (2004; 2010) also sees the convergence of emissions between countries as a strong prediction of the Green Solow Model.

Empirical research in analyzing growth and convergence of emissions using the most CO_2 proxies. Among them are those who researched OECD countries such as; Acar and Lindmark (2017); Barassi et al. (2008; 2011); Camarero et al. (2011); Lee and Chang (2008; 2009); Romero-Avila (2008); Yamazaki et al. (2014).

Countries of the world, Ezcurra (2007) 140 countries; Panopoulou and Pantelidis (2009) 128 countries; Criado and Grether (2011) 166 countries; Herrerias (2013) 162 countries; de Oliveira and de Vargas Mores (2015) 118 countries; Martino and Nguyen-Van (2016) 106 countries; Rios and Gianmoena (2018) 141 countries. In addition to the inter-state level, CO_2 convergence analysis is conducted between provinces or states such as Aldy (2007); Li

et al. (2020) in the US state; Huang and Meng (2013); Zhao et al. (2015) province in China.

Criado and Grether (2011); Ezcurra (2007) uses a nonparametric approach based on Quah (1993; 1996; 1997) takes into account spatial distribution of emissions growth in world countries. Rios and Gianmoena (2018) developed a model from Brock and Taylor (2004; 2010) by introducing the Augmented Green Solow Model that considers spatial dependence in analyzing the convergence of CO_2 emissions in 141 countries of the world. Previously at provincial level, Huang and Meng (2013); Zhao et al. (2015) consider spatial dependence in analyzing emissions convergence in China.

In this study, researchers wanted to analyze convergence at the regional level of ASEAN countries. One of the impacts of ASEAN's establishment is the increase in economic cooperation that might be related to emissions growth activities. We are using the Augmented Green Solow Model developed by Rios and Gianmoena (2018) Rios and Gianmoena (2018) with some adjustment on extended variables. In addition we were also consider the Kyoto Protocol which is an international agreement on emissions control, including ASEAN countries ratifying it.

2. LITERATUR REVIEW

2.1. Green Solow Model
The Green Solow Model was popularized by Brock and Taylor (2004; 2010) in response to pollution data and related empirical work on the Environmental Kuznets Curve (EKC) which presents three puzzles. The first is related to emissions equalization that decreases drastically with relatively static emission reduction costs. The second is what factors caused U-shaped pollution levels to reverse when described with per capita time or income. The third comes from the empirical literature itself.

Brock and Taylor (2004; 2010) adopted the Solow Model $Y_t = F(K_t, B_tL_t)$, Y_t is output, capital (K_t) and labor (L_t) assumed contant return to scale, and B_t is labor productivity. Capital (K_t) is an accumulation of savings rates s and depreciation δ, so $K_t = sY_t - \delta K_t$.

Emissions (E_t) assumed to be the result of output, so one unit of output will produce pollution of Ω_t. Furthermore, in the economy there is a portion of output (constant and exogenous) ($0 \leq \theta \leq 1$) as a form of emission reduction. If there is a reduction, then obtained one unit of output will produce $a(\theta)\Omega_t$. where $a(\theta)$ is an abatement function which is assumed $a'(\theta) < 0$ and $a''(\theta) > 0$. Then the equation is obtained as:

$$E_t = a(\theta)\Omega_t F(K_t, B_tL_t) \qquad (1)$$

The equation shows emissions will decrease at a constant level in the abatement function due to technological and other advances so as to strengthen the dynamics of Environmental Kuznets Curve (EKC).

Rios and Gianmoena (2018) introduced Augmented Green Solow Model by including technology externality in the output function, which implies spatial dependence between regions.

2.2. Initial Emision (Convergence)
The study of convergence was popularized by Barro and Sala-I-Martin (1992); Mankiw et al. (1992) in case of convergence of income/economic growth. Galor (1996) explained there are three hypotheses in the study of convergence, namely (1) absolute convergence, (2) conditional convergence, and (3) club convergence. In the absolute convergence, income will prevail when the economy is in a state of lower initial per capita income and tends to grow faster than countries that have higher levels of initial emissions. Conditional convergence prevails when the per capita income growth rate decreases and reaches steady state (Barro and Sala-I-Martin, 2004). While the convergence of clubs indicates that the growth rate of areas with similar conditions and structural characteristics (preference, technology, population growth, government policy) tends to converge on the same steady state conditions.

In its development, convergence studies analyze on environmental problems and mostly in cases of CO_2. Among them, Strazicich and List (2003) examined the phenomenon of convergence of CO_2 emissions in 21 industrialized countries in the 1960-1997 period which proves the occurrence of stochastic and conditional convergence. Brock and Taylor (2004; 2010) which popularized the Green Solow Model found the occurrence of CO_2 convergence in many countries in the world. Similarly Rios and Gianmoena (2018) which takes into account spatial dependence found the occurrence of CO_2 convergence in 141 countries in 1970-2014.

Some studies not only produce results from initial CO_2 convergence, but precisely divergence. Emissions divergence found by Herrerias (2013) in all energy sources in 162 countries and Camarero et al. (2011) in 23 OECD countries in the 1870-2006 period.

The results mixed with the occurrence of convergence and divergence of emissions occurred in the research Ahmed et al. (2017) which examined 162 countries and found the occurrence of CO_2 convergence in 38 countries but diverged in 124 countries. This CO_2 divergence is indicated to occur in non-OECD, middle and low income countries. Yavuz and Yilanci (2013) G7 countries; Criado and Grether (2011) convergent in developing countries but divergent in all countries; Lee and Chang (2008) examined OECD countries, 7 convergent countries and 14 divergent countries.

2.3. Physical Capital Investment
Investment in the form of physical capital can improve the process of capital accumulation and in the standard neoclassical macroeconomic growth theory which is generally assumed to be one of the main determinants of economic growth in the long term (Mankiw et al., 1992; Solow, 1956). In theoretical models, emissions are an indirect product of economic activity (Brock and Taylor, 2004; 2010). The effect of investment on per capita emissions is assumed to have a positive effect (Rios and Gianmoena, 2018).

Another finding of investment inflows may reduce the release of CO_2 in developing countries (Pao and Tsai, 2011). Increased investment can reduce CO_2 levels not only in developing countries,

but also in China there is also a decrease in CO_2 concentration levels (Xie et al., 2020).

2.4. Population Growth
The negative relationship between population density and CO_2 per capita can be caused by a variety of effects. The more people mean that there will be the less emissions per capita allocated to each person. In addition, previous research has found that human activity has a negative effect on the growth rate of CO_2 emissions per capita because areas with large population densities have more access to public transportation and other public services. Meanwhile, greater demands to create a low-pollution environment by maintaining a sustainable lifestyle that can facilitate reductions in CO_2 emissions (Ahmed et al., 2017; Flamarz Al-Arkawazi, 2018). Large populations can also drive large consumptions that will lead to faster production efficiency with higher levels of energy savings and emissions reductions (Li et al., 2020).

Higher population growth can hamper the ability of excessive environmental absorption which then creates unsustainable aggregate emissions. Increasing the rate of population growth can decrease the value of per capita output in a steady state and with the merger of outputs, the level of emissions per capita is also expected to decrease.

Based on research conducted by Brock and Taylor (2004; 2010), population growth with CO_2 emission growth has a negative and insignificant impact depending on the sample state. Cole and Neumayer (2004) used aggregate levels of CO_2 emissions as dependent variables and user populations as regressors. These result shows elasticity below one and are consistent with negative impacts in per capita specifications. *Martínez-Zarzoso* et al. (2007) also had similar results for a sample of EU members.

2.5. Extended Variable
2.5.1. Human capital
The increase in accumulation of human capital will increase the level of output and increased output itself will also increase emissions. This suggests that the increase of human capital might be further worsen the quality of the environment. In empirical studies, environmental quality has an impact on health that will affect the accumulation of human capital. But it depends on the value of its structural parameters (Hartman and Kwon, 2005).

On the other hand, Raffin (2014) assumes that human capital can have a "technique effect" that can increase the reduction of technology and/or "green awareness effect," so that individuals whose living in countries with higher levels of human resources might be better understand the costs and benefits of efforts in achieving better environmental conditions with the existence of retirement to reduce emissions.

2.5.2. Trade openness
International trade may lead to increased carbon emissions as a result of increased production or revenue (Churchill et al., 2020; Copeland and Taylor, 1994; Frankel and Romer, 1999). Trade

openess can have the opposite impact on the environment: "scale impact" and "compositional impact." The impact of scale refers to the impact of trade on the level of economic activity, while the compositional impact refers to the influence of trade on the productive structure of the economy. Increased trade openness may lead to greater economic activity and may have an impact on environmental degradation (Rios and Gianmoena, 2018). Trade openess that led to the increase in emissions was found by Managi et al. (2009).

On the other hand, the openness of trade/economy significantly shows the negative value of emissions growth found by Antweiler et al. (2001); Frankel and Rose (2005). Frankel and Rose (2005) stated that increased trade can have positive value including to the environment through multi-national companies that tend to introduce advanced production techniques from the home country that apply high standards to host countries that do not know it yet.

Meanwhile, research conducted by Ezcurra (2007); Rios and Gianmoena (2018); Sharma (2011); You et al. (2015) shows insignificant results.

2.5.3. Kyoto protocol
The Kyoto Protocol, adopted in 1997, is an international treaty aimed to reduce Greenhouse Gas emissions. Iwata and Okada (2014) said investigating the impact of the Kyoto Protocol could have policy implications for the global warming problem and contribute to research on sustainable development.

Kim et al. (2020) showed that participation as a part of Annex I (Kyoto Protocol) has a significant positive impact on the reduction of CO_2 emissions, but negatively impacts the GDP of participants in the long run. Meanwhile, Rios and Gianmoena (2018) has found no impact from the Kyoto Protocol on CO_2 emissions in the countries of the world.

ASEAN countries have ratified the Kyoto Protocol including Thailand, Malaysia, Vietnam and Cambodia in 2002. Myanmar, the Philippines, and Laos in 2003. Indonesia in 2004 and Singapore in 2006.

3. METHOD

3.1. Data
In this study using data of ASEAN countries (Indonesia, Malaysia, Thailand, Singapore, Vietnam, Philippines, Myanmar, Cambodia, Laos, and Brunei Darussalam). East Timor is not included because of the new country (established in 1999). Data period from 1971 to 2019. Table 1 shows variable used in this research.

3.2. Spatial Econometric
3.2.1. Model
In general, the Augmented Green Solow Model in this study adopted a model from Rios and Gianmoena (2018) with some differences in extended variables and followed the steps of Belloti et al. (2017), which became the initial reference model is Spatial Durbin Model,

$$\ln CO2_{it} - \ln CO2_{it-1} = \beta_0 + \beta_1 \ln CO2_{it-1} +$$
$$\beta_2 s_{it}^K + \beta_3 g_{it} + \beta_4 s_{it}^H + \beta_5 TO_{it} + \beta_6 Kyoto_{it} +$$
$$\theta_1 \sum_{j=1}^{N} w_{ij} \ln CO2_{it-1} + \theta_2 \sum_{j=1}^{N} w_{ij} s_{it}^K + \theta_3 \sum_{j=1}^{N} w_{ij} g_{it} +$$
$$\theta_4 \sum_{j=1}^{N} w_{ij} s_{it}^H + \theta_5 \sum_{j=1}^{N} w_{ij} TO_{it} + \theta_6 \sum_{j=1}^{N} w_{ij} Kyoto_{it} +$$
$$\rho_1 \sum_{j=1}^{N} w_{ij} \left(\ln CO2_{it} - \ln CO2_{it-1} \right) + u_{it}$$

$$(2)$$

Where $\ln CO_{2it} - \ln CO_{2it-1}$ = CO_2/cap emissions growth; $\ln CO_{2it-1}$ = initial CO_2/cap emissions; s_{it}^K = physical capital investment (GFCF/GDP); g_{it} = population growth; s_{it}^H = human capital (index); TO_{it} = Trade Openness ((Export+Import)/GDP)); $Kyoto_{it}$ = Kyoto Protocol (Dummy); β_0 = intersep; β_{1-6} = coefficient of independent variables; $\theta_{1...6}$ = spatial coefficient of independent variables; ρ_1 = spatial coefficient of dependent variables; w_{ij} = spatial weight matrix; u_{it} = error term; λ = spatial coefficient of term error.

3.2.2. Maximum likelihood model selection
To determine the panel model (fixed or random), we use hausman test. Furthermore, to determine whether or not its a spatial dependence, we use Pesaran Cross-Sectional Dependence (CD) Test (Pesaran, 2004) so that it is obtained:

The results in Table 2 showed that the panel model selected was fixed effect (Prob <0.05), and based on the test reasoning showed that there was a spatial dependency (Prob <0.05).

Next to determine the econometric spatial model, we followed the steps of Belloti et al. (2017) using quasi-maximum likelihood approach. With the Spatial Durbin Model (HR) reference model,

Table 1: Variables used

Variable	Symbol	Description	Source
Emission	CO_{2it}	CO_2 emissions per capita	Edgar
Physical capital investment	s_{it}^K	GFCF/ GDP	PWT
Population growth	g_{it}	-	WB
Human capital	s_{it}^H	Index	PWT
Trade openess	TO_{it}	(Export +Import)/ GDP	WB
Kyoto protocol	$Kyoto_{it}$	Dummy (0 = before ratification; 1 = after ratification)	UN

Source: Writer, 2021. GFCF = Gross Fixed Capital Formation; GDP = Gross Domestic Product, EDGAR - Emissions Database for Global Atmospheric Research; PWT – Penn World Table; WB – World Bank; UN – United Nation

Table 2: Hausman test and pesaran (CD) cross-sectional dependence test

Hausmana test		Pesaran CD test	
χ^2	Prob. χ^2	Pesaran's test	Probability
16.74	0.0103	3.633	0.0003

Source: Processed from secondary data, 2021

testing whether there is no spatial dependence on independent variables ($\theta = 0$) and there is spatial dependence on dependent variables ($\rho \neq 0$) then selected Spatial Autoregressive (SAR)/ Spatial Lag Model (SLM). And if $\theta = -\beta\rho$ then the Spatial Error Model (SEM) is chosen. Furthermore in the context of fixed effect compared to Spatial Autoregressive Combined (SAC) by looking at the smaller Akaike Information Criterion (AIC).

Table 3 Shows that the best model in this analysis is the Durbin Spatial Fixed Effect Model.

4. DISCUSSION

4.1. Descriptive
Chart 1 tries to illustrate the growth trend of CO_2/capita in 10 ASEAN countries (Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam) from 1971 to 2019.

The results showed that the only country experiencing the Environmental Kuznets Curve (EKC) trend is Singapore because of the inverted U curve that is in line with Katircioğlu (2014). While Malaysia, Thailand and Indonesia began to experience emissions reductions, which were strengthened by Darwanto et al. (2019); Ridzuan et al. (2020) in the long run the curve will decrease. Brunei Darussalam and the Philippines tend to be flat volatile. Cambodia, Laos, Myanmar and Vietnam experienced significant increases in CO_2/capita.

4.2. Analysis
Table 4 displays non-spatial and spatial models in analyzing CO_2/ capita growth. Spatial models show faster convergence speeds than non-spatial models, represented by the initial CO_2/capita coefficient. Other variables produce the same results except human capital. Anselin et al. (2001) revealed the neglect of spatial dependence will result in the estimation of parameters become inefficient even biased so it is feared that missleading occurs.

4.2.1. Convergence
The initial variable CO_2 as an indicator of convergence shows significant and convergent. These convergent results are in line with Brock and Taylor (2004; 2010); Rios and Gianmoena (2018) which examines the countries of the world. Robalino-López et al. (2016) found club convergence in 10 South American countries. Solarin (2014) in countries in Africa and Barassi et al. (2008) OECD countries.

Table 3: Selection of the best spatial models

Parameters	SDM versus SAR	SDM versus SEM	SDM versus SAC
Initial Hypotheses/ testing	test $\theta = 0$	test1 $\theta = -\beta\rho$	Compare AIC
Result	Prob.: 0.0003	Prob.: 0.0007	AIC SDM: −626.3829 AIC SAC: −608.7922
Selected model	SDM	SDM	SDM

Source: Processed from secondary data, 2021

Graph 1: Trend LnCO$_2$/capita ASEAN countries by 1971–2019 period
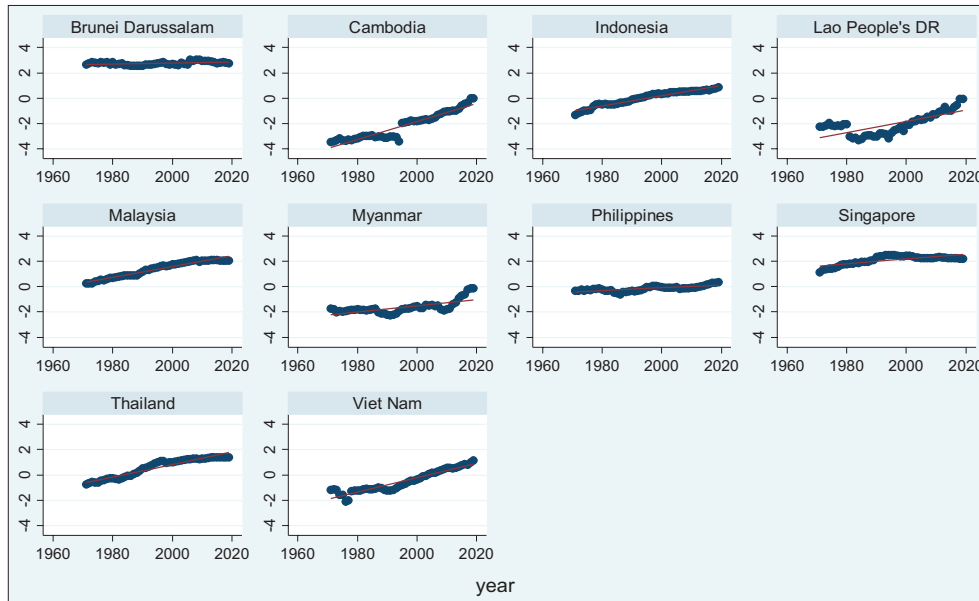
Source: Processed from secondary data, 2021

Table 4: Regression results

[ln CO$_{2it}$–ln CO$_{2it-1}$]

	Fixed effect	SDM FE
Main		
Constanta	−0.144** (0.062)	
ln CO$_{2it-1}$	−0.058*** (0.017)	−0.084*** (0.018)
s_{it}^K	0.287*** (0.081)	0.229*** (0.087)
g$_{it}$	0.066 (0.773)	−0.146 (0.786)
s_{it}^H	0.009 (0.025)	−0.063* (0.034)
TO$_{it}$	0.086*** (0.026)	0.078*** (0.026)
Kyoto	0.016 (0.02)	−0.043 (0.038)
WX		
w$_{ij}$ln CO$_{2it-1}$		−0.116* (0.071)
$w_{ij}s_{it}^K$		0.531** (0.26)
w$_{ij}$g$_{it}$		−8.395*** (2.601)
$w_{ij}s_{it}^H$		0.227*** (0.085)
w$_{ij}$TO$_{it}$		−0.093 (0.058)
Kyoto		0.049 (0.046)
Spatial		
w$_{ij}$ [ln CO2$_{jt}$ CO2$_{jt-1}$] (Spatial rho)		0.061 (0.091)
AIC	−608.0995	−626.3829
Implied β	0.1209%	0.1785%
Half-life convergence	573.2169	388.311

Source: Processed from secondary data, 2021

Speed of convergence in the case of ASEAN countries on non-spatial models was 0.121% and spatial models was 0.179%. This value was much slower than Rios and Gianmoena (2018) which examined 141 world countries with a speed of convergence of 1.02% on non-spatial models and 0.96% on spatial models. Including research of Marrero et al. (2021) shows CO$_2$ emissions per capita in Europe are experiencing a rapid convergence over time. Absolute speed convergence on OLS models is 4.55% and fixed effect is 10.11%

Convergence in developed and developing countries has differences. Countries with advanced economies have a faster rate of convergence than countries with a growing economic rate. This difference can be identified from the specific differences of industrial and energy efficiency (Li et al., 2020).

4.2.2. Determinant Green Solow Model
The determinant of the Green Solow Model is physical capital investment and population growth. Physical investment shows significant positive results towards CO$_2$ growth. This indicates that physical capital investment will increase output which also increases emissions. This result is also found by Rios and Gianmoena (2018).

Population growth in ASEAN is insignificant to emissions growth, albeit negatively. The same result was shown by Brock and Taylor (2004; 2010) in the countries of the world. While Martínez-Zarzoso et al. (2007) find population growth is significantly negative to emissions growth in EU countries.

4.2.3. Extended Variable and Spatial Effect
Human capital in ASEAN countries has the impact of lowering emissions levels. The results support the assumption from Raffin (2014) that human capital can have a "technique effect" that can increase the reduction of technology and/or "green awareness effect," so that individuals living in countries with higher levels of human resources might be better understand about the costs and benefits of efforts in achieving better environmental conditions with the existence of retirement to reduce emissions.

Trade Openness has a significant positive relationship to CO$_2$ growth in ASEAN countries. Churchill et al. (2020) reinforced

that it shows trade activities between ASEAN countries that will increase production and revenue and further impact on rising emissions. The findings are also in line with Managi et al. (2009) in OECD countries.

The Kyoto Protocol does not show significant results on emissions growth in ASEAN countries, albeit negatively. On spatial variables, significant influences are indicated by initial CO_2 per capita (negative), physical capital investment (positive), population growth (negative), and human capital (positive) on CO_2/capita growth of neighboring countries.

5. CONCLUSION

The results showed that during the 1971-2019 period ASEAN countries experienced CO_2/capita convergence but were fairly slow when compared to Brock and Taylor (2004; 2010); Rios and Gianmoena (2018) country of the world and the European Union (Marrero et al., 2021). ASEAN countries are in fact developing countries and CO_2/capita growth patterns (Graph 1) shows that only Singapore has decreased.

The positive findings of physical capital investment to CO_2/capita growth in ASEAN countries are a consequence due to the orientation towards economic development. But this becomes a job where the business orientation of economic development is also in line with the orientation to environmental sustainability. Li et al. (2020) advises to encourage clean energy and energy efficiency, as well as choosing low-carbon technologies. Such conditions will create a win-win solution, which encourages economic growth and the quality of environment.

The positive influence of human capital in lowering emissions levels in ASEAN countries is one indicator of how human awareness is increased about good environmental conditions by lowering emissions. It is good and needs to be encouraged through formal and informal education in such a community forum.

Trade openness that has an effect on increasing CO_2 emissions is a consequence such as increased physical capital investment due to export and import activities. In the future, this trade openness is expected to have a good impact on the environment as the findings of Frankel and Rose (2005). They also explained that increased trade can have positive value through multi-national companies that tend to introduce advanced production techniques from their home countries that apply high standards to host countries that do not know it yet.

Furthermore, it is necessary to review the growth activities of ASEAN countries because the ratification of the Kyoto Protocol conducted in the early 2000s that has been implemented for more than 15 years is not significant in regulating emissions growth. The emergence of the Paris Agreement in 2015 may make the world in its development oriented in addition to economic growth as well as maintaining the quality of the environment, especially ASEAN countries.

REFERENCES

Acar, S., Lindmark, M. (2017), Convergence of CO_2 emissions and economic growth in the OECD countries : Did the type of fuel matter ? Energy Sources, Part B: Economics, Planning, and Policy, 12(7), 618-627.

Ahmed, M., Maqbool, A., Bibi, S., Zakaria, M. (2017), Convergence of per capita CO_2 emissions across the globe : Insights via wavelet analysis. Renewable and Sustainable Energy Reviews, 75, 86-97.

Aldy, J.E. (2007), Divergence in state-level per capita carbon dioxide emissions. Land Economics, 83(3), 353-369.

Anselin, L., Cohen, J., Cook, D., Gorr, W., Tita, G. (2001), Spatial analysis of crime. Criminal Justice, 4, 193-215.

Antweiler, W., Copeland, B.R., Taylor, M.S. (2001), Is free trade good for the environment? American Economic Review, 91(4), 877-908.

Barassi, M.R., Cole, M.A., Elliott, R.J.R. (2008), Stochastic divergence or convergence of per capita carbon dioxide emissions: Re-examining the evidence. Environmental and Resource Economics, 40(1), 121-137.

Barassi, M.R., Cole, M.A., Elliott, R.J.R. (2011), The stochastic convergence of CO_2 emissions: A long memory approach. Environmental and Resource Economics, 49(3), 367-385.

Barro, R.J., Sala-I-Martin, X. (1992), Convergence. Journal of Political Economy, 100(2), 223-251.

Barro, R.J., Sala-I-Martin, X. (2004), Economic growth. In: Water Quality International. 2nd ed., Vol. 9-10. United States: The MIT Press.

Belloti, F., Hughes, G., Mortari, A.P. (2017), Spatial panel-data models using stata. The Stata Journal, 17(1), 139-180.

Brock, W.A., Taylor, M.S. (2004), The green solow model. Journal of Economic Growth, 15, 127-153.

Brock, W.A., Taylor, M.S. (2010), The green solow model. Journal of Economic Growth, 15(2), 127-153.

Camarero, M., Mendoza, Y., Ordonez, J. (2011), Re-examining CO_2 Emissions. Is The Assessment of Convergence Meaningless? Castellón: Working Papers Economics Department, Universitat Jaume.

Churchill, S.A., Inekwe, J., Ivanovski, K. (2020), Stochastic convergence in per capita CO_2 emissions : Evidence from emerging economies, 1921-2014. Energy Economics, 86(104659), 1-11.

Cole, M.A., Neumayer, E. (2004), Examining the impact of demographic factors on air pollution. Population and Environment, 26(1), 5-21.

Copeland, B.R., Taylor, M.S. (1994), North-South trade and the environment. The Quarterly Journal of Economics, 109(3), 755-787.

Criado, C., Grether, J. (2011), Convergence in per capita CO_2 emissions: A robust distributional approach. Resource and energy economics. Resource and Energy Economicsnergy Economics, 33(3), 637-665.

Darwanto, D., Santosa, P.B., Handayani, H.R., Aminata, J., Arianti, F., Gozhali, I. (2019), Does formal constraints reduce CO_2 emissions? Indonesia's empirical case. International Journal of Energy Economics and Policy, 10(1), 236–241.

de Oliveira, G., de Vargas Mores, G. (2015), Convergence in per Capita Carbon Dioxide Emissions: A Panel Data Approach. Available form: https://www.econpapers.repec.org/RePEc: spa:wpaper:2015wpecon35.

Ezcurra, R. (2007), Is there cross-country convergence in carbon dioxide emissions. Energy Policy, 35(2), 1363-1372.

Flamarz Al-Arkawazi, S.A. (2018), Measuring the influences and impacts of signalized intersection delay reduction on the fuel consumption, operation cost and exhaust emissions. Civil Engineering Journal, 4(3), 552-560.

Frankel, J.A., Romer, D.H. (1999), Does trade cause growth ? American Economic Review, 89(3), 379-399.

Frankel, J.A., Rose, A.K. (2005), Is trade good or bad for the environment? sorting out the causality. Review of Economics and Statistics, 87(1), 85-91.

Galor, O. (1996), Convergence? Inferences from theoretical models. Economic Journal, 106(437), 1056-1069.

Grossman, G.M., Krueger, A.B. (1995), Economic growth and the environment. The Quarterly Journal of Economics, 110(2), 353-377.

Hartman, R., Kwon, O.S. (2005), Sustainable growth and the environmental Kuznets Curve. Journal of Economic Dynamics and Control, 29(10), 1701-1736.

Herrerias, M.J. (2013), The environmental convergence hypothesis: Carbon dioxide emissions according to the source of energy. Energy Policy, 61, 1140-1150.

Huang, B., Meng, L. (2013), Convergence of per capita carbon dioxide emissions in Urban China: A spatio-temporal perspective. Applied Geography, 40, 21-29.

Iwata, H., Okada, K. (2014), Greenhouse gas emissions and the role of the Kyoto protocol. Environmental Economics and Policy Studies, 16(4), 325-342.

Katircioğlu, S.T. (2014), Testing the tourism-induced EKC hypothesis: The case of Singapore. Economic Modelling, 41, 383-391.

Kim, Y., Tanaka, K., Matsuoka, S. (2020), Environmental and economic effectiveness of the Kyoto protocol. PLoS One, 15(7), e0236299.

Lee, C.C., Chang, C.P. (2008), New evidence on the convergence of per capita carbon dioxide emissions from panel seemingly unrelated regressions augmented Dickey-Fuller tests. Energy, 33(9), 1468-1475.

Lee, C.C., Chang, C.P. (2009), Stochastic convergence of per capita carbon dioxide emissions and multiple structural breaks in OECD countries. Economic Journal, 26(6), 1375-1381.

Li, C., Zuo, J., Wang, Z., Zhang, X. (2020), Production- and consumption-based convergence analyses of global CO$_2$ emissions. Journal of Cleaner Production, 264, 121723.

Managi, S., Hibiki, A., Tsurumi, T. (2009), Does trade openness improve environmental quality? Journal of Environmental Economics and Management, 58(3), 346-363.

Mankiw, N.G., Romer, D., Weil, D.N. (1992), A contribution to the empirics of economic growth. Energy, Economic Growth, and the Environment, 1992, 3541.

Marrero, A.S., Marrero, G.A., Gonzalez, R.M., Lopez, J.R. (2021), Convergence in road transport CO$_2$ emissions in Europe. Energy Economics, 99, 105322.

Martínez-Zarzoso, I., Bengochea-morancho, A., Morales-lage, R. (2007), The impact of population on CO$_2$ emissions: Evidence from European countries. Environmental and Resource Economics, 38, 497-512.

Martino, R., Nguyen-Van, P. (2016), Environmental Kuznets Curve and Environmental Convergence: A Unified Empirical Framework for CO$_2$ Emissions. Working Papers of BETA. Strasbourg: Bureau d'Economie Théorique et Appliquée, UDS.

Panopoulou, E., Pantelidis, T. (2009), Club convergence in carbon dioxide emissions. Environmental and Resource Economics, 44(1), 47-70.

Pao, H.T., Tsai, C.M. (2011), Multivariate granger causality between CO$_2$ emissions, energy consumption, FDI and GDP: Evidence from a panel of BRIC (Brazil, Russian Federation, India, and China) countries. Energy, 36(1), 685-693.

Pesaran, M.H. (2004), General Diagnostic Tests for Cross-sectional Dependence in Panels. Germany: IZA Discussion Paper No. 1240.

Quah, D.T. (1993), Galton's fallacy and tests of the convergence hypothesis. The Scandinavian Journal of Economics, 95(4), 427-443.

Quah, D.T. (1996), Twin peaks : Growth and convergence models of distribution dynamics. The Economic Journal, 106, 1045-1055.

Quah, D.T. (1997), Empiris for growth and distribution: Stratification, polarization, and convergence clubs. Journal of Economic Growth, 1, 27-59.

Raffin, N. (2014), Education and the political economy of environmental protection. Annals of Economics and Statistics, 115-116, 379-407.

Ridzuan, N.H.A., Marwan, N.F., Khalid, N., Ali, M.H., Tseng, M.L. (2020), Effects of agriculture, renewable energy, and economic growth on carbon dioxide emissions: Evidence of the environmental Kuznets Curve. Resources, Conservation and Recycling, 160, 104879.

Rios, V., Gianmoena, L. (2018), Convergence in CO$_2$ emissions : A spatial economic analysis with cross-country interactions. Energy Economics, 75, 222-238.

Robalino-López, A., García-Ramos, J.E., Golpe, A.A., Mena-Nieto, A. (2016), CO$_2$ emissions convergence among 10 South American countries. A study of Kaya components (1980-2010). Carbon Management, 7(1-2), 1-12.

Romero-Avila, D. (2008), Convergence in carbon dioxide emissions among industrialised countries revisited. Energy Economics, 30(5), 2265-2282.

Sharma, S.S. (2011), Determinants of carbon dioxide emissions: Empirical evidence from 69 countries. Applied Energy, 88(1), 376-382.

Solarin, S.A. (2014), Convergence of CO$_2$ emission levels: Evidence from African countries. Journal of Economic Research, 19(1), 65-92.

Solow, R. (1956), A contribution to the theory of economic growth: Old and new. Journal of Economics and International Finance, 70(1), 65-94.

Strazicich, M.C., List, J.A. (2003), Are CO$_2$ emission levels converging among industrial countries? Environmental and Resource Economics, 24(3), 263-271.

Xie, Q., Wang, X., Cong, X. (2020), How does foreign direct investment affect CO$_2$ emissions in emerging countries? New findings from a nonlinear panel analysis. Journal of Cleaner Production, 249, 119422.

Yamazaki, I., Tomov, S., Dongarra, J. (2014), Deflation Strategies to Improve the Convergence of Communication-Avoiding GMRES. New Orleans, LA: Proceedings of ScalA 2014: 5th Workshop on Latest Advances in Scalable Algorithms for Large-Scale Systems. Held in Conjunction with SC 2014. The International Conference for High Performance Computing, Networking, Storage and Analysis. p39-46.

Yavuz, N.C., Yilanci, V. (2013), Convergence in per capita carbon dioxide emissions among G7 countries: A TAR panel unit root approach. Environmental and Resource Economics, 54(2), 283-291.

You, W.H., Zhu, H.M., Yu, K., Peng, C. (2015), Democracy, financial openness, and global carbon dioxide emissions: Heterogeneity across existing emission levels. World Development, 66, 189-207.

Zhao, X., Wesley Burnett, J., Lacombe, D.J. (2015), Province-level convergence of china's carbon dioxide emissions. Applied Energy, 150, 286-295.