Energy Economics Letters
ISSN(e): 2308-2925
DOI: 10.55493/5049.v10i1.4712
Vol. 10, No. 1, 19-34.

URL: www.aessweb.com

Empirical assessment of the environmental Kuznets curve hypothesis in Indonesia, Malaysia, the Philippines, and Thailand using the ARDL and FMOLS techniques

Fukuda, Takashi

Independent Researcher, 5-15-81-401 Toroku, Chuo Ward, Kumamoto, 862-0970, Japan.
Email: takashi@fukuda-kieg.com

Article History
Received: 7 November 2022
Revised: 30 December 2022
Accepted: 12 January 2023
Published: 27 January 2023

Keywords
ARDL
ASEAN
Environmental Kuznets curve
FMOLS
SDGs
Structural break.

JEL Classification:
C32; O13; O44; O53; Q56.

ABSTRACT

The purpose of the present paper is to empirically investigate whether the environmental Kuznets curve (EKC) hypothesis is validated for Indonesia, Malaysia, the Philippines, and Thailand over the period of 1971-2014. The estimation techniques employed are the autoregressive distributed lag (ARDL) and the fully modified ordinary least square (FMOLS), and we conduct the Granger causality tests to draw interpretation. We take CO2 emissions as the dependent variable, and those endogenous variables of economic growth, the square of economic growth, energy consumption, trade openness, and foreign direct investment (FDI), together with the structural break dummy (for the ARDL estimation only). The EKC hypothesis is statistically confirmed for Thailand by both the ARDL and FMOLS estimations, but it is not so for Indonesia, Malaysia, the Philippines. One policy implication is that, regardless of whether the EKC hypothesis is confirmed or not, the four ASEAN countries are required to ensure the compatibility between economic growth and environmental improvement by persistently proposing and implementing effective policies to fight against environmental degradation. Another implication is that, policymakers should consider how to convert their countries from pollution heaven countries to environmentally-friendly ones, correctly evaluating the impact of globalization on economic growth and environmental degradation.

Contribution/ Originality: Based on the argument that different countries may have different EKC results and therefore need different strategies for sustainable development, the present paper contributes to the literature by investigating the empirical validity of Indonesia, Malaysia, the Philippines, and Thailand's EKS hypothesis in the framework of on-going globalization.

1. INTRODUCTION

It has been increasingly recognized worldwide that a persistent decline in environmental quality may exert a negative externality to the economy through affecting human health, and thereby reduce productivity in the long run (Ang, 2008). In 1992, the United Nations Framework Convention on Climate Change was adopted at the Rio World Summit as the first comprehensive approach to combating global environmental problems (United Nations, 1992). In 1997, the Kyoto Protocol was signed by 160 countries, aiming at reducing CO_2 emissions and greenhouse gas (GHG) in the atmosphere (United Nations, 1998). In 2015, as a more comprehensive treaty on climate change at present, the Paris Climate Treaty (Paris Agreement) was agreed by almost all countries to mitigate climate change and its adverse effects (United Nations, 2015). Importantly, as international commitment to achieve sustainable development, United

Nation's sustainable development goals (SDGs) (United Nations, 2022) which consist of 17 goals, were adopted in 2015. Thus, all countries in the world are now required to follow SDGs transparently and to report their achievement of SDGs regularly. In such global movements, the relationship between CO_2 emissions and economic growth has been highlighted in the literature, to which SDG 8 (decent work and economic growth), SDG 12 (responsible consumption and production), and SDG 13 (climate action) are very relevant. With the increasing extent of industrialization, energy becomes an important input of production. Energy consists of fossil fuels or non-renewable energy resources (gas, oil, and coal) which have led to a large amount of GHG in the atmosphere; it is well known that carbon dioxide is a major component of GHG (Lotfalipour, Falahi, & Ashena, 2010). As the pace of economic growth accelerates and population goes on worldwide, a huge amount of energy is consumed and carbon dioxide is emitted, causing various environmental problems.

The environmental Kuznets curve (EKC) hypothesis was initially put forward by Grossman and Krueger (1991) which refers to the inverted U-shape relationship between CO_2 emissions and economic growth, that is, in the early stage of economic growth, CO_2 emissions increase up to a certain level as income goes up, but after that level, the former starts to decline (nonlinearity in the carbon dioxide-growth relationship)[1]. The view that greater economic activity inevitably hurts the environment is based on static assumptions about technology, tastes and environmental investments (Stern, 2004). As incomes rise, the demand for improvements in environmental quality will increase, as will the resources available for investment (World Bank, 1992). Thus, understanding the CO_2 emissions-economic growth linkage is a critical issue, so that several empirical studies of the EKC hypothesis were conducted for both developed and developing countries, using various estimation techniques of time series, cross-section, and panel data. So far, however, no universal consensus has been obtained for the EKC hypothesis.

The objective of the present paper is to empirically investigate whether the EKC hypothesis is validated for Indonesia, Malaysia, the Philippines, and Thailand, which are member countries of the Association of South East Asian Nations (ASEAN), over the period of 1971-2014, using those techniques of the autoregressive distributed lag (ARDL) and the fully modified ordinary least square (FMOLS). To avoid the problem of omitted variables in estimation, we take the globalization variables of trade openness and foreign direct investment (FDI), also considering a possible structural break dummy in the ARDL estimation. These countries have achieved economic growth while consuming a lot of non-renewable energy, emitting a large amount of carbon dioxide, and experiencing high-paced globalization. And now, those countries face a difficult challenge of attaining emission reduction targets—as international pledges—by reconstructing their energy policy to raise energy efficiency.

While there are several panel data studies (e.g., (Adeel-Farooq, Raji, & Adeleye, 2020; Guzel & Okumus, 2020; Pata, Dam, & Kaya, 2022)) which have suggested policy implications confirming the empirical validity of the EKC hypothesis among ASEAN countries, many single-country studies also have been conducted for ASEAN countries providing diverse EKC results. We observe that the EKC hypothesis—as an important empirical topic—has been inconclusive so far to present straightforward policy recommendations that are applicable across countries; dependent on the causal directions of economic growth→CO_2 emissions and the square of economic growth→CO_2 emissions are either positive or negative, policy implications are deducted from the point of view of CO_2 reduction, economic performance, energy conservation, and several other policies. Based on the argument that different countries may have different EKC results and therefore need different strategies for sustainable development, the present paper contributes to the literature by investigating the empirical validity of Indonesia, Malaysia, the Philippines, and Thailand's EKS hypothesis in the framework of on-going globalization.

The present paper is structured as follows. In Section 2, the relevant literature of the EKC hypothesis is reviewed. In Section 3, data and methodology that we employ for the analysis are explained. In Section 4, empirical findings are

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[1]Originally, the EKC hypothesis derives its name from the work of Kuznets (1955) who suggested a similar relationship between income inequality and economic development. And the EKC hypothesis is also applicable for the relationship between other pollutants (e.g., NO_2 and SO_2) and economic growth.

reported and discussed. Finally, we provide policy implications and conclusions for the four ASEAN countries in Section 5.

2. LITERATURE REVIEW

In order to clarify the main issue of the EKC hypothesis, we initiate the literature review with the following equation:

$$Y = \beta_0 + \beta_1 X_{it} + \beta_2 X_{it}^2 + \beta_3 Z_{it} + \mu_{it} \quad (1)$$

In Equation 1, Y is CO_2 emissions, X is economic growth (e.g., real per capita gross domestic product (GDP)), X^2 is the square of economic growth, Z includes other variables, β_0 is an intercept, β_1, β_2, and β_3 are the coefficients, and μ is error term. According to the EKC hypothesis, the long-run elasticity estimates of Y with respect to X and X^2 are important, which are expected to be $\beta_1 > 0$ and $\beta_2 < 0$, respectively, so as to prove the EKC validity. This means that, in the early stage, economic growth is a cause of increasing CO_2 emissions (environmental degradation), but when the economy reaches a certain income level at which people become rich having environmental awareness, economic growth ultimately converts into a factor for reducing CO_2 emissions (environmental improvement). Here, a relevant question is deducted: Can economic growth be part of the solution rather than the cause of environmental problem? This is the primary motivation for empirical studies on the EKC hypothesis (Dinda, 2004).

In discussing the EKC hypothesis, the problem of omitted variables has been pointed, that is, the EKC is not a simple phenomenon just consisting of CO_2 emissions and economic growth. For example, Stern (2004) argues that, in analysing the EKC hypothesis, little consideration has been paid to issues of model adequacy (misspecification) such as the possibility of omitted variables bias. Following this argument, we should consider and treat "Z" more carefully in Equation 1. The first omitted variable we assume is energy consumption. Energy is essential for economic growth as well as is the main cause of CO_2 emissions/global warming/climate change. It is proposed straightforward that we can overcome the global environmental problem by reducing energy consumption, specifically non-renewable, fossil fuel (oil, coal, and natural gas) energy. However, such a way is obviously not well designed, just leading to a negative impact on economic growth. Therefore, energy conservation policy should be implemented with caution; otherwise, it damages economic growth (Villanthenkodath, Gupta, Saini, & Sahoo, 2021). Depending upon the nature of long-term relationship among carbon emissions, energy consumption and income, different countries may resort different strategies to fight against global warming (Lotfalipour et al., 2010). For further analysis of the EKC hypothesis, it is inevitable to take the impact of energy consumption into consideration.

As other omitted variables in the EKC assessment, several studies incorporate the impact of globalization, which are generally represented by such variables as trade openness (international trade, i.e., export + import) and foreign direct investment (hereafter, FDI)[2]. Trade openness is considered as a crucial factor to explain the EKC hypothesis. Generated in the production of export goods, pollution is very relevant to consumption of such goods in importing countries, so that the intensity of international trade of an economy might have important implication to the level of that country' pollution (Ozturk & Acaravci, 2013). On the other hand, FDI is indeed coincided with international trade influencing technology transfer and innovation for better production of exporting goods as well as for environment pollution/preservation in developing countries.

In examining the EKC hypothesis, the effects of globalization may either increase or decrease CO_2 emissions depending upon the level of economic growth; as the extent of globalization extends, environmental quality could decline or improve because of opposing directional impacts of scale effect, composition effect, and technique effect

[2] Other than CO_2 emissions, economic growth, and energy consumption, such variables are taken into the ECK estimation as financial development (e.g., Ozturk and Acaravci (2013)) gross capital formation (e.g., Rjoub, Odugbesan, Adebayo, and Wong (2021)) urbanization and population (e.g., Villanthenkodath et al. (2021)) agriculture (e.g., Orhan, Adebayo, Genç, and Kirikkaleli (2021)) crude oil price (e.g., Shahbaz, Sharma, Sinha, and Jiao (2021)) and renewable energy consumption (e.g., Abbas, Kousar, and Pervaiz (2021)).

(Sajeev & Kaur, 2020). In the initial stage of economic development, pollution increases with increasing output for import (scale effect). As the economy transforms from an industrial economy to a service one, the pollution level reaches its peak (composition effect). And with technical progress like the adaption of cleaner technologies, the pollution level further reduces (technique effect).

Moreover, we also discuss the pollution haven hypothesis (PHH). This hypothesis was initiated by Copeland and Taylor (1994) which is the first paper linking the environmental regulation stringency and trade patterns with the level of pollution in a country. If developing economies have less stringent environment regulations, greater trade openness and more FDI are expected to increase pollution. Environmentally-lax countries are assumed to attract FDI in polluting industries, maybe because of lower environmental standards. This incentivizes heavy polluters of developed countries to move to such developing countries. As a result, foreign investors who are limited by environmental protection policies in their own countries, are attracted to developing economies resulting in severe environmental degradation. Thus, the PHH describes the migration or displacement of "dirty" industries from the developed regions to the developing regions (see (Gill, Viswanathan, & Karim, 2018; Sadik-Zada & Ferrari, 2020; Singhania & Saini, 2021)).

A number of single-country studies have been conducted for ASEAN countries' EKC hypothesis mainly using cointegration techniques[3]. As given in Appendix 1, findings from those studies are very different, maybe due to time period, various characteristics of ASEAN countries, econometric techniques and proxy variables employed in estimation.

3. EMPIRICAL STRATEGY AND DATA

To explain the present study's empirical strategy, we provide the following equation consisting of six variables:

$$COTWO_t = f(EG_t, EGSQ_t, ENC_t, TOP_t, FDI_t) \quad (2)$$

With Equation 2, we express that a cointegration analysis is implemented—employing both techniques of ARDL and FMOLS—so as to check the EKC validity in Indonesia, Malaysia, the Philippines, and Thailand, respectively. COTWO (CO TWO) is CO_2 emissions (metric tons per capita), EG (Economic Growth) is economic growth (real per capita GDP), EGSQ (Economic Growth SQared) is the square of real per capita GDP, ENC (ENergy Consumption) is energy consumption (kg of oil equivalent per capita), TOP (Trade OPenness) is trade openness (exports + imports, per cent of GDP), and FDI (Foreign Direct Investment) is foreign direct investment (net inflows, per cent of GDP). All the underlying variables are converted into logarithm—for data to comply with normality—before initiating estimation.

To validate the EKC hypothesis, the coefficients of EG and EGSQ are most important. The former is expected to be positive, whereas the latter to be negative; in this case, the presence of an inverted U-shaped curve is detected, so that we conclude that as the economy extends, CO_2 emissions increase until a certain level of output is reached after which CO_2 emissions go into a decreasing phase. As regard ENC, since energy is considered as a driving force of economic growth, we assume that it simply increases CO_2 emissions. The last two variables of TOP and FDI are incorporated as the proxies for globalization to address the omission-of-variable problem. We contend that globalization has a significant impact on the EKC hypothesis. The sample ASEAN countries have been exposed to

[3] EKC single-country studies of ASEAN countries are: Saboori and Sulaiman (2013) for Indonesia, Malaysia, the Philippines, Thailand, and Singapore; Sugiawan and Managi (2016) for Indonesia; Ali, Rahman, Zahid, Khan, and Kumail (2020) for Malaysia; Iskandar (2019) for Indonesia; Kisswani, Harraf, and Kisswani (2019) for Indonesia, Malaysia, the Philippines, Singapore, and Thailand; Vo, Vo, and Le (2019) for Indonesia, Myanmar, Malaysia, the Philippines, and Thailand; Ridzuan, Albani, Latiff, Razak, and Murshidi (2020) for Indonesia, Malaysia, and Thailand; Ibraheem and Nasim (2021) for Thailand; Karasoy (2021) for the Philippines; Jahanger et al. (2022) for Malaysia; Massagony and Budiono (2022) for Indonesia; Othman and Bekhet (2021) for Malaysia; Peña, Reyes, and Gonzalez (2022) for the Philippines; and many others.

globalization, committing an increasing extent of international trade and FDI. As anticipated by the PHH, if these countries have less stringent regulations, greater TOP and more FDI might increase environmental pollution.

Regarding the selection of the sample countries, each country's economic scale (represented by its GDP and population), academic and public interests in the country, and data availability were dominant for our consideration. We retrieved annual data series from the World Bank's World Development Indicators (WDI). The sample period covers 1971 to 2014, due to the availability of data series, in particular those of energy consumption and CO_2 emissions which are available until 2014.

4. METHODOLOGY

4.1. ARDL Procedure

For the present study, we employ the autoregressive distributed lag (ARDL) technique of Pesaran, Shin, and Smith (2001). In the ARDL estimation, the presence of a long-run, steady-state equilibrium is confirmed by forming conditional error-correction models (ECMs), and a causal direction is clearly detected by the sign of each underlying variable's coefficient in the cointegrating space. In this way, we seek whether the underlying variables of EG, EGSQ, ENC, TOP and FDI are either positive or negative for COTWO. An ARDL feature is that the mixture of $I(0)$ (integrated order zero) and $I(1)$ variables is accepted, that is, both $I(0)$ and $I(1)$ are okay but $I(2)$ (integrated order two) is not. To check the stationarity/integration of each underlying variable, the ARDL procedure is started by conducting two unit root tests of the GLS augmented Dickey–Fuller (ADF-GLS) (Elliott, Rothenberg, & Stock, 1996) and the Phillips and Perron (PP) (Phillips & Perron, 1988). The ADF-GLS test is an amended version of the Dickey–Fuller unit root test as the former is based on a modified statistics of the latter with generalized least squares (GLS). On the other hand, the PP test is known that its residual variance is robust to autocorrelation.

The ARDL specification of the present study is represented by the following system equation:

$$\Delta COTWO_t = \alpha_{it}\begin{bmatrix} COTWO_t \\ EG_t \\ EGSQ_t \\ ENC_t \\ TOP_t \\ FDI_t \end{bmatrix} + \sum_{j=1}^{p-1}\theta_{1j}\,\Delta COTWO_{t-j} + \sum_{j=1}^{p-1}\theta_{2j}\,\Delta EG_{t-j} + \sum_{j=1}^{p-1}\theta_{3j}\,\Delta EGSQ_{t-j} + \sum_{j=1}^{p-1}\theta_{4j}\,\Delta ENC_{t-j} +$$

$$\sum_{j=1}^{p-1}\theta_{5j}\,\Delta TOP_{t-j} + \sum_{j=1}^{p-1}\theta_{6j}\,\Delta FDI_{t-j} + inpt + u_{it} \qquad (3)$$

In Equation 3, COTWO is the dependent variable, whereas EG, EGSQ, ENC, TOP, and FDI are the independent variables, respectively. First, we perform the bounds test, which is based on F-statistics, so as to confirm the existence of cointegration between the underlying variables which are either $I(0)$ or $I(1)$ (i.e., not $I(2)$). When computed F-statistics are greater than upper bound critical values, the null hypothesis is rejected and it is judged that there is a cointegrating relationship. In a different case, when F-statistics are estimated between lower and upper bound critical values, this case is inconclusive so that we need to confirm unit root test results. Second, each underlying variable's optimal lag order is set by referring either to the Akaike information criterion (AIC) or to the Schwartz Bayesian criterion (SBC). Third, for providing ARDL interpretation, both the weak and strong exogeneity tests are implemented. The weak exogeneity test addresses the null hypothesis of H_0: $\alpha_i = 0$ to look for the evidence of a long-run causality or the significance of the error correction term (ECT) coefficient, which needs to be significant exhibiting a negative sign. The strong exogeneity test examines the nulls of H_0: all $\alpha_j = \theta_{ij}$'s $= 0$; the overall (long-run + short-run) causality in the ARDL system is identified by the strong exogeneity test, irrespective of time spans (Charemza & Deadman, 1997).

4.2. Structural Break Dummy

Following the argument of Johansen, Mosconi, and Nielsen (2000) who suggest taking the element of structural break into the cointegration analysis, we incorporate the structural break dummy—in the form of either a level shift dummy or a pulse dummy—for the ARDL estimation. It is a well-known fact that the Asian financial crisis severely hit ASEAN countries over the period of 1997-1998. We consider that the Asian financial crisis is very influential to form a long-run, cointegration relationship between CO_2 emissions and other underlying variables in the sample countries. Due to the crisis years of 1997 and 1998, the following level shift dummies are produced: SBLS (Structural Break, Level, ninety-Seven) has a level shift in 1997, and SBLE (Structural Break, Level, ninety-Eight) has it in 1998, respectively. Supplementally, assuming there are other break dates than 1997 and 1998, we perform the structural break test of Zivot and Andrews (1992) (ZA test) for each country's EG (real per capita GDP) series, specify break dates, and create the level shift dummies (SBLZA, Structural Break, Level, Zivot-Andrews) (see Table 1). As far as the pulse dummy is concerned, it has a single pulse either in 1997 (SBPS, Structural Break, Pulse, ninety-Seven) or in 1998 (SBPE, Structural Break, Pulse, ninety-Eight), or two pulses in 1997 and 1998 (SBPTWO, Structural Break, Pulse, TWO).

Table 1. Structural break dummies.

Level shift dummy	SBLS	1997
	SBLE	1998
	SBLZA	1998 (Indonesia); 1992 (Malaysia)
		1984 (The Philippines); 1988 (Thailand)
	SBPS	1997
Pulse dummy	SBPE	1998
	SBPTWO	1997; 1998

4.3. FMOLS Procedure

To put more robustness on the present study, we utilize another technique of the fully modified ordinary least square (FMOLS) developed by Phillips and Hansen (1990). The FMOLS is a modified version of ordinary least squares (OLS) that eliminates the potential endogeneity bias problem, which the standard OLS cannot do so, and addresses the serial correlation problem, based on the standard Wald tests using asymptotic Chi-square statistical inference (Azam, Alam, & Hafeez, 2018). It is considered that the results obtained from the FMOLS estimation are free from serial correlation, small sample bias, and endogeneity issue (Ahmad et al., 2017).

The FMOLS estimation is explained by the following equation:

$$COTWO_t = \beta`_j X_t + inpt + u_t \quad (4)$$

In Equation 4, COTWO is treated as the dependent variable, X_t is a 5×1 vector consisting of the component variables of EG, EGSQ, ENC, TOP, and FDI, *inpt* is the intercept, and u_t is an error term, respectively. In performing the FMOLS estimation, there are two important assumptions: 1) both of the dependent variable and all the component variables are $I(1)$; and 2) the component variables are not cointegrated themselves (Narayan & Narayan, 2005; Pesaran & Pesaran, 2009). More precisely, the FMOLS specification for the present study is given by the following system equation:

$$COTWO_t = \beta_1 EG_t + \beta_2 EGSQ_t + \beta_3 ENC_t + \beta_4 TOP_t + \beta_5 FDI_t + inpt + u_t \quad (5)$$

Equation 5 indicates that, in order to do the FMOLS interpretation, the null hypothesis of H_0: $\beta_j = 0$ is estimated by performing the Wald test for each component variable. After that, the FMOLS findings are analysed and compared with the ARDL ones to draw policy implications for the four ASEAN countries' EKC hypothesis.

5. EMPIRICAL RESULTS

5.1. Initial Procedures

As the first step of the present study, both the ADF-GLS test and the PP test are conducted in terms of "intercept only" and "intercept and trend" to check each variable's stationarity. As the unit root statistics are reported in Appendix 2, we have confirmed that all the sample countries' COTWO, EG, EGSQ, ENC, TOP, and FDI are detected as non-stationary in their levels but are stationary after taking their first-differences at the 1%, 5%, and 10%

significance level, respectively. Thus, all the underlying variables are judged as appropriate (i.e., $I(1)$) for the ARDL and FMOLS estimations.

Next, the ARDL bounds test is carried out for Indonesia, Malaysia, the Philippines, and Thailand, respectively, in which COTWO is the dependent variable, setting the maximum lag order of either 2, 3, or 4. The results are reported in Table 2. Each underlying variable's lag order is selected either by the Akaike criterion (AIC) or by the Schwarz Bayesian criterion (SBC). As seen in the fourth column of the table, the following structural break dummies are included for each sample country: SBPTWO having two pulses of the crisis years of 1997 and 1998 for Indonesia; SBLS having a level shift in the crisis year of 1997 for Malaysia; SBPTWO having two pulses of the crisis years of 1997 and 1998 for the Philippines; and SBLZA having a level shift in 1988 which is estimated by the ZA test. These dummies are such structural break dummies that provide a single cointegration ($r = 1$) passing all the four diagnostic tests (see Table 3). Thus, we consider that the inclusion of the structural break dummy in the ARDL estimation is very important and effective for the present study. As given in the fifth column of Table 2, the ARDL cointegration is found out in all the sample countries at the 5% significance level. Thus, since a cointegrating relationship is confirmed by the bounds test and all the underlying variables are $I(1)$, we can implement the ARDL and FMOLS estimations for the sample countries.

Before discussing the ARDL results, we look at the diagnostic statistics in Table 3. According to them, all the ARDL models indicate no evidence of those estimation problems of serial correlation, inappropriate functional form, non-normality, and heteroscedasticity. Hence, we consider that empirical findings of this study are plausible to draw policy implications for the EKC hypothesis in the sample countries[4].

Table 2. ARDL bounds test results (*F*-statistics).

Dependent variable COTWO		**Endogenous variables EG, EGSQ, ENC, TOP, FDI**		
Country	**Maximum lag**	**Selected lag orders (AIC/SBC)**	**Det. components**	**Statistic**
Indonesia	4	2,0,1,0,4,1 (SBC)	SBPTWO, intercept	7.770**
Malaysia	2	1,0,0,1,2,0 (AIC)	SBLS, intercept	4.961**
Philippines	3	1,1,1,1,0,3 (AIC)	SBPTWO, intercept	5.713**
Thailand	3	1,0,0,0,0,3 (SBC)	SBLZA, intercept	7.608**

Note: (**) 5% level of significance. The selected lag orders are given as (COTWO, EG, EGSQ, ENC, TOP, FDI). The 95% upper and lower bounds of the sample countries are given as follows: Indonesia (4.360~3.013); Malaysia (4.647~3.481); the Philippines (4.365~2.998); and Thailand (4.647~3.423).

Table 3. ARDL diagnostic test results.

Tests	**Indonesia**	**Malaysia**	**Philippines**	**Thailand**
Serial correlation	0.002 [0.962]	2.281 [0.141]	0.528 [0.474]	0.186 [0.670]
Functional form	0.807 [0.378]	0.980 [0.330]	2.624 [0.117]	3.318 [0.079]
Normality	3.979 [0.137]	0.116 [0.944]	5.771 [0.056]	1.187 [0.552]
Heteroscedasticity	1.295 [0.262]	0.116 [0.735]	0.222 [0.640]	3.618 [0.065]

Note: The tests of serial correlation, functional form and heteroscedasticity are based on *F*-version statistics, whereas that of normality is on LM version statistics. In parentheses, *p*-values are provided.

5.2. ASEAN Countries' EKC Results

The EKC results of Indonesia, Malaysia, the Philippines, and Thailand's EKC hypothesis are presented in Table 4, 5, 6, and 7, respectively, whose third columns show the causal direction confirmed by each underlying variable's sign either in the ARDL cointegrating vector or in the FMOLS regression. Based on significant findings of the strong exogeneity test (ARDL) /the Wald test (FMOLS), we have determined the causal direction of each underlying

[4]As the pre-analysis, we attempted to investigate the empirical validity of the EKC hypothesis in the sample countries by using the cointegration technique of the vector error correction model (VECM) of Johansen (1988). From the VECM estimation, however, plausible and diagnostic-problem-free results were not obtained, so that we consider that the ARDL and FMOLS estimations are the best for our research topic.

variable. Importantly, different causal directions are detected from the ARDL and FMOLS estimations because the former is estimated by incorporating the element of structural break, whereas the latter is not so. Properly taking this difference into consideration, we report and analyse the ASEAN countries' EKC results to draw policy implications in the end.

5.2.1. Indonesia's EKC Results

Indonesia's EKC results are reported in Table 4. We first look at the ARDL estimation in which the ECT coefficient is statistically significant at the 1% level—as confirmed by the weakly exogenous test—demonstrating a negative sign and an acceptable size. The ARDL causal directions of both EG and EGSQ are positive at the 1% level, so that the EKC hypothesis is not established. On the other hand, the FMOLS estimation validates the EKC hypothesis showing the positive sign of EG at the 1% level and the negative sign of EGSQ at the 10% level. Combining these EKC results, we observe that Indonesia's EKC hypothesis has not been fully established yet. As far as the other underlying variables are concerned, the causal direction of ENC is positive at the 1% level in the ARDL model and at the 5% level in the FMOLS model, respectively. The coefficients of both TOP and FDI are positive at the 1% level in the ARDL estimation, but there is no significant result in the FMOLS estimation. Therefore, so long as referring to these empirical findings, it seems to be difficult for Indonesia to achieve SDG 8 (decent work and economic growth) and SDG 12 (responsible consumption and production) in managing the effects of globalization.

Table 4. Indonesia's EKC results.

I. ARDL estimation (k =4)		
1. Cointegrating vector		
$COTWO = 0.172EG + 0.178EGSQ + 0.388ENC + 0.695\,TOP + 0.026FDI + 0.037SBPTWO - 5.688$		
2. Weakly exogenous test		
ECT coefficient	Result	
α = -0.735	CHSQR(1) = 19.931 [0.000]***	
3. Strong exogeneity test		
Regressor	Result	Direction
EG & ECT(-1)	CHSQR(2) = 23.100 [0.000]***	Positive
EGSQ & ECT(-1)	CHSQR(2) = 30.516 [0.000]***	Positive
ENC & ECT(-1)	CHSQR(2) = 22.973[0.000]***	Positive
TOP & ECT(-1)	CHSQR(5) = 31.672 [0.000]***	Positive
FDI & ECT(-1)	CHSQR(2) = 23.982 [0.000]***	Positive
II. FMOLS estimation (k =4)		
1. Regression		
$COTWO = 1.0671EG - 0.223EGSQ + 0.610ENC - 0.049\,TOP - 0.0176FDI - 4.480$		
2. Causality test		
Regressor	Result	Direction
EG	CHSQ(1) = 11.317 [.001]***	Positive
EGSQ	CHSQ(1) = 3.692 [0.055]*	Negative
ENC	CHSQ(1) = 5.522 [0.019]**	Positive
TOP	CHSQ(1) = 0.118 [0.731]	—
FDI	CHSQ(1) = 0.226 [0.635]	—

Note: (***) 1%, (**) 5%, and (*) 10% level of significance. CHSQ is Chi-squared (X^2).

5.2.2. Malaysia's EKC Results

In Table 5, we present Malaysia's EKC results. In the ARDL estimation, the ECT coefficient is statistically significant at the 1% level having a negative sign and an acceptable size, so that it is mentioned that there is a long-run, steady state in Malaysia's EKC. Both of the ARDL strong exogeneity test and the FMOLS causality test come to the same EKC result, that is, the causal direction of EG is negative, whereas that of EGSQ is positive exhibiting a U-shaped curve relationship between CO_2 emissions and economic growth in Malaysia, which is not assumed by the EKC hypothesis. The ENC causal direction is positive at the 1% level in the ARDL model, and at the 5% level in the

FMOLS model, respectively. According to the globalization variables' results, the TOP coefficient is positive at the 1% level, and the FDI coefficient is negative in the ARDL estimation; the TOP coefficient is positive at the 10% level, and the FDI coefficient is statistically insignificant in the FMOLS estimation. These empirical findings of the EKC hypothesis indicate that Malaysia needs drastic structural reforms to attain SDG 8 and SDG 12.

5.2.3. The Philippines' EKC results

In Table 6, the Philippines' EKC results are reported. According to the ARDL results, the ECT coefficient is statistically significant at the 1% level having a negative sign and an acceptable size, so that a long-run, steady state is detected in the Philippines' EKC. The ARDL causal direction of EG is negative at the 1% level, whereas that of EGSQ is positive at the 1% level. The FMOLS also exhibits the same directions, that is, the EG causal direction is negative at the 5% level, and the EGSQ direction is positive at the 5% level. Thus, as we find out a U-shaped relationship between CO_2 emissions and economic growth, the EKC hypothesis is not established in the Philippines. The ENC results from the two estimations are different: while the causal direction is negative at the 1% level in the ARDL estimation, it is positive at the 5% level in the FMOLS estimation. As regard the globalisation variables, the TOP coefficient is positive at the 1% level in the ARDL model, and at the 10% level in the FMOLS model, respectively; the FDI coefficient is positive at the 1% significance level, and no significant result is found out in the FMOLS estimation. These empirical findings of the EKC hypothesis indicate that in order to be sustainable achieving SDGs 8 and 12, the Philippines needs to overcome many difficulties, which is the same as Malaysia.

Table 5. Malaysia's EKC results.

I. ARDL estimation (k = 2)		
1. Cointegrating vector		
$COTWO = -6.874EG + 0.719EGSQ + 0.395ENC + 0.804TOP - 0.040FDI - 0.373SBLS + 10.83$		
2. Weakly exogenous test		
ECT coefficient	Result	
α = -0.634	CHSQR(1) = 26.056 [0.000]***	
3. Strong exogeneity test		
Regressor	Result	Direction
EG & ECT(-1)	CHSQR(2) = 28.670 [0.000]***	Negative
EGSQ & ECT(-1)	CHSQR(2) = 28.855 [0.000]***	Positive
ENC & ECT(-1)	CHSQR(2) = 47.078 [0.000]***	Positive
TOP & ECT(-1)	CHSQR(3) = 29.412 [0.000]***	Positive
FDI & ECT(-1)	CHSQR(2) = 26.632 [0.000]***	Negative
II. FMOLS estimation (k = 2)		
1. Regression		
$COTWO = -2.063EG + 0.257EGSQ + 0.351\ ENC + 0.3557TOP - 0.010\ FDI + 0.736$		
2. Causality test		
Regressor	Result	Direction
EG	CHSQ(1) = 3.562 [0.059]*	Negative
EGSQ	CHSQ(1) = 6.826 [0.009]***	Positive
ENC	CHSQ(1) = 4.541 [0.033]**	Positive
TOP	CHSQ(1) = 10.939 [0.001]*	Positive
FDI	CHSQ(1) = 0.342 [0.559]	—

Note: (***) 1%, (**) 5%, and (*) 10% level of significance. CHSQ is Chi-squared (X^2).

Table 6. The Philippines' EKC results.

I. ARDL estimation (k = 3)		
1. Cointegrating vector		
$COTWO = -45.91EG + 3.372EGSQ - 0.047ENC + 0.009\,TOP + 0.358FDI + 0.178\,SBPTWO + 155.9$		
2. Weakly exogenous test		
ECT coefficient	Result	
α = -0.244	CHSQR(1) = 13.5635 [0.000]***	
3. Strong exogeneity test		
Regressor	Result	Direction
EG & ECT (-1)	CHSQR(2) = 15.170 [0.001] ***	Negative
EGSQ & EC T(-1)	CHSQR(2) = 15.075 [0.001] ***	Positive
ENC & ECT (-1)	CHSQR(2) = 19.420 [0.000] ***	Negative
TOP & ECT (-1)	CHSQR(2) = 13.902 [0.001] ***	Positive
FDI & ECT (-1)	CHSQR(4) = 17.277 [0.002] ***	Positive
II. FMOLS estimation (k = 3)		
1. Regression		
$COTWO = -23.109EG + 1.712EGSQ + 0.843ENC + 0.309\,TOP - 0.071FDI + 71.330$		
2. Causality test		
Regressor	Result	Direction
EG	CHSQ(1) = 4.220 [0.040]**	Negative
EGSQ	CHSQ(1) = 4.423 [0.035]**	Positive
ENC	CHSQ(1) = 3.932 [0.047]**	Positive
TOP	CHSQ(1) = 7.015 [0.008]*	Positive
FDI	CHSQ(1) = 1.274 [0.259]	—

Note: (***) 1%, (**) 5%, and (*) 10% level of significance. CHSQ is Chi-squared (X^2).

5.2.4. Thailand's EKC Results

In Table 7, we present Thailand's EKC results. The ARDL weakly exogenous test shows that the ECT coefficient is statistically significant at the 1% level with a negative sign and an acceptable size, indicating the existence of a long-run, steady state in Thailand's EKC. The ARDL causal direction of EG is positive at the 1% significance level, whereas that of EGSQ is negative at the 1% level. This is the same as the FMOLS estimation in which we find out the positive EG causality at the 1% level and the negative EGSQ causality at the 1% level, respectively. Thus, Thailand's EKC hypothesis is fully confirmed by both of the ARDL and FMOLS estimations where we see an inverted U-shaped curve relationship between CO_2 emissions and economic growth. The ENC causal direction is negative at the 1% level in the ARDL model and is positive at the 5% level in the FMOLS model, respectively. As far as the globalisation variables are concerned, the two approaches' results coincide: the TOP coefficient is negative at the 1% level in the ARDL estimation, and at the 5% level in the FMOLS, respectively; and the FDI coefficient is positive at the 1% level in both of the two estimations. Referring to these findings, we can mention that Thailand has been on a good way of achieving sustainable development.

6. CONCLUSION AND POLICY IMPLICATIONS

The present paper explored the empirical validity of the EKC hypothesis in Indonesia, Malaysia, the Philippines, and Thailand over the period of 1971-2014, by employing the ARDL and FMOLS techniques. While we took CO_2 emissions as the dependent variable, economic growth, the square of economic growth, energy consumption, trade openness, and FDI were treated as the endogenous variables in estimation. To draw interpretation, the strong exogeneity and weak exogeneity tests were conducted for the ARDL estimation, and the Wald test was done for the FMOLS estimation, respectively.

Table 7. Thailand's ARDL and FMOLS results.

I. ARDL estimation (k =3)		
1. Cointegrating vector		
$COTWO = 4.905EG - 0.354EGSQ + 0.899ENC - 0.215\,TOP + 0.014FDI - 0.138\,SBLZA + 21.40$		
2. Weakly exogenous test		
ECT coefficient	Result	
α = -0.542	CHSQR (1) = 40.604 [0.000]***	
3. Strong exogeneity test		
Regressor	Result	Direction
EG & ECT(-1)	CHSQR(2) = 40.783 [0.000]***	Positive
EGSQ & ECT(-1)	CHSQR(2) = 41.016 [0.000]***	Negative
ENC & ECT(-1)	CHSQR(2) = 43.163 [0.000]***	Positive
TOP & ECT(-1)	CHSQR(2) = 42.940 [0.000] ***	Negative
FDI & ECT(-1)	CHSQR(4) = 59.576 [0.000]***	Positive
II. FMOLS estimation (k = 3)		
1. Regression		
$COTWO = 4.788EG - 0.360EGSQ + 1.180ENC - 0.269\,TOP + 0.042FDI - 22.043$		
2. Causality test		
Regressor	Result	Direction
EG	CHSQ(1) = 49.305 [0.000]***	Positive
EGSQ	CHSQ(1) = 34.160 [0.000]***	Negative
ENC	CHSQ(1) = 47.268 [0.000]***	Positive
TOP	CHSQ(1) = 5.447 [0.020]**	Negative
FDI	CHSQ(1) = 7.644 [0.006]***	Positive

Note: (***) 1% and (**) 5% level of significance. CHSQ is Chi-squared (X^2).

The present study's EKC results of the four ASEAN countries are summarized in Table 8, according to which, only for Thailand, the EKC hypothesis is statistically confirmed (positive EG and negative EGSQ), but for the other three countries, it is not so (for comparison with other studies' results, see Appendix 1). Indonesia's results exhibit the inconsistent conclusions between the ARDL (positive EG and positive EGSQ) and FMOLS (positive EG and negative EGSQ) estimations; although the FMOLS estimation provides support for the EKC hypothesis, we should put more importance on the ARDL estimation where the structural break dummy, which has two pulses of the crisis years of 1997 and 1998, is incorporated. On the other hand, both Malaysia and the Philippines' results simply indicate that the higher economic growth (positive EG and positive EGSQ), the more CO_2 emissions, so that it seems to be very difficult for the two countries to grow being environmentally friendly. Thus, while several panel data studies have validated the EKC hypothesis in ASEAN countries, the present study of a single country analysis concludes that environmental pollution will not uniformly and automatically go away by itself with economic prosperity in Indonesia, Malaysia, the Philippines, and Thailand. It clearly points to the fact that economic growth alone cannot be the solution to environmental problems.

One policy implication is that, regardless of whether the EKC hypothesis is confirmed or not, Indonesia, Malaysia, the Philippines, and Thailand are required to ensure the compatibility between economic growth and environmental improvement by persistently proposing and implementing effective policies to fight against environmental degradation. To this end, policymakers need to demonstrate strong political will together with planning ability to form energy and environmental policy framework directed towards encouraging heavy investments in renewable energies such as solar power, hydropower, wind, and others. It is evident that taking no action and staying only in expectation of rising public awareness about environmental issues are "too late". Another policy implication is that, policymakers should consider how to convert their countries from pollution heaven countries to environmentally-friendly ones, correctly evaluating the impact of globalization on economic growth and environmental degradation. As an effective strategy, it is important to export and import such products that fully comply with SDGs, and to invite such FDI projects that contribute to the spread of environmental protection technologies to host countries. Thus, the four ASEAN countries can transform from such a unfavored scenario that developing countries are more likely to attract polluting industries due to lower environmental standards.

In the end, although the present study's sample period is confined to 1971-2014 due to data availability, for future studies, we are required to examine the EKC hypothesis in emerging economies, covering the post COVID-19 period.

Table 8. Summary of the EKC results.

Country	Is the EKC hypothesis validated?	ARDL	FMOLS
Indonesia	No	EG(Positive)*** EGSQ(Positive)***	EG(Positive)*** EGSQ(Negative)*
Malaysia	No	EG(Negative)*** EGSQ(Positive)***	EG(Negative)* EGSQ(Positive)***
The Philippines	No	EG(Negative)*** EGSQ(Positive)***	EG(Negative)** EGSQ(Positive)**
Thailand	Yes	EG(Positive)*** EGSQ(Negative)***	EG(Positive)*** EGSQ(Negative)***

Note: (***) 1%, (**) 5%, and (*) 10% level of significance.

Funding: This study received no specific financial support.
Competing Interests: The author declares that there are no conflicts of interests regarding the publication of this paper.

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Appendix 1. Indonesia, Malaysia, the Philippines, and Thailand's EKC results.

Country	The EKC is validated (Inverted U-shaped curve is found)	The EKC is not validated (Inverted U-shaped curve is not found)
Indonesia		The present study Saboori and Sulaiman (2013); Iskandar (2019); Kisswani et al. (2019); Vo et al. (2019); Ridzuan et al. (2020); Massagony and Budiono (2022)
Malaysia	Ridzuan et al. (2020); Jahanger et al. (2022); Othman and Bekhet (2021)	The present study Saboori and Sulaiman (2013); Ali et al. (2020) Kisswani et al. (2019); Vo et al. (2019)
The Philippines		The present study Saboori and Sulaiman (2013); Kisswani et al. (2019); Vo et al. (2019); Karasoy (2021) Peña et al. (2022)
Thailand	The present study Saboori and Sulaiman (2013); Kisswani et al. (2019); Ridzuan et al. (2020)	Vo et al. (2019); Ibraheem and Nasim (2021)

Appendix 2. Unit root test results (ADF-GLS and PP tests, $k = 4$).

(a) Indonesia

Variable	ADF-GLS test		PP test	
	Inpt. only	Inpt. & trend	Inpt. only	Inpt. & trend
COTWO	-0.510	-2.084	-2.290	-1.745
ΔCOTWO	-2.463**	-2.707	-5.042***	-5.358***
EG	0.511	-2.140	-0.784	-2.245
ΔEG	-2.722***	-2.804*	-4.767***	-4.720***
EGSQ	0.770	-1.619	1.795	-1.131
ΔEGSQ	-2.012*	-2.743	-4.431***	-4.735***
ENC	-0.256	-1.543	-1.078	-1.275
ΔENC	-1.860	-2.039	-6.583***	-6.673***
TOP	-0.797	-1.504	-3.654**	-3.572**
ΔTOP	-2.072*	-3.646**	-9.410***	-9.916***
FDI	-2.169*	-2.617	-3.149**	-3.056
ΔFDI	-3.725***	-4.184***	-7.256***	-7.231***

Note: (***) 1%, (**) 5% and (*) 10% level of significance.

(b) Malaysia

Variable	ADF-GLS test		PP test	
	Inpt. only	Inpt. & trend	Inpt. only	Inpt. & trend
COTWO	-0.091	-2.224	-0.791	-2.140
ΔCOTWO	-2.621**	-2.653	-7.603***	-7.550***
EG	0.442	-1.836	-1.544	-4.396***
ΔEG	-2.076*	-2.860*	-9.927***	-10.099***
EGSQ	0.494	-2.270	-1.076	-4.552***
ΔEGSQ	-2.395**	-2.918**	-10.393***	-10.354***
ENC	0.135	-1.726	-1.202	-1.816
ΔENC	-1.627	-2.160	-7.145***	-7.527***
TOP	-0.923	-1.095	-1.779	0.322
ΔTOP	-1.436	-1.702	-5.116***	-5.931***
FDI	-2.731**	-2.875*	-5.571***	-5.559***
ΔFDI	-4.010***	-4.029***	-12.471***	-12.286***

Note: (***) 1%, (**) 5% and (*) 10% level of significance.

(c) The Philippines

Variable	ADF-GLS test		PP test	
	Inpt. only	Inpt. & trend	Inpt. only	Inpt. & trend
COTWO	-1.455	-2.376	-1.204	-1.819
ΔCOTWO	-1.471	-2.270	-5.803***	-5.771***
EG	1.287	-1.088	0.355	-0.690
ΔEG	-2.151*	-2.583	-3.300**	-3.367*
EGSQ	1.325	-1.059	0.489	-0.585
ΔEGSQ	-2.111*	-2.576	-3.276**	-3.364**
ENC	-1.807	-2.779*	-2.616	-2.562
ΔENC	-2.527*	-2.560	-8.312***	-8.319***
TOP	-1.042	-1.443	-1.626	-0.681
ΔTOP	-2.204*	-2.514	-5.067***	-5.399***
FDI	-1.142	-1.918	-2.921*	-3.541**
ΔFDI	-2.732***	-3.168**	-9.371***	-9.255***

Note: (***) 1%, (**) 5% and (*) 10% level of significance.

(d) Thailand

Variable	ADF-GLS test		PP test	
	Inpt. only	Inpt. & trend	Inpt. only	Inpt. & trend
COTWO	-0.490	-1.706	-1.267	-1.061
ΔCOTWO	-1.954*	-2.446	-4.185***	-4.220**
EG	-0.194	-1.792	-1.162	-1.318
ΔEG	-2.159*	-2.507	-3.885***	-4.009**
EGSQ	-0.014	-2.071	-0.775	-1.679
ΔEGSQ	-2.207**	-2.566	-4.009***	-4.020**
ENC	0.269	-2.030	-0.144	-2.006
ΔENC	-2.399**	-2.579	-4.978***	-4.906***
TOP	0.088	-1.741	-1.368	-2.136
ΔTOP	-2.700**	-3.234**	-7.021***	-7.068***
FDI	-0.943	-2.420	-2.497	-3.603**
ΔFDI	-3.960***	-3.449**	-9.128***	-9.020***

Note: (***) 1%, (**) 5% and (*) 10% level of significance.