Jaruwan Chontanawat

Article

Relationship between energy consumption, CO_2 emission and economic growth in ASEAN: Cointegration and causality model

Energy Reports

Provided in Cooperation with:
Elsevier

Suggested Citation: Jaruwan Chontanawat (2020) : Relationship between energy consumption, CO_2 emission and economic growth in ASEAN: Cointegration and causality model, Energy Reports, ISSN 2352-4847, Elsevier, Amsterdam, Vol. 6, Iss. 1, pp. 660-665, https://doi.org/10.1016/j.egyr.2019.09.046

This Version is available at:
https://hdl.handle.net/10419/243805

Available online at www.sciencedirect.com
ScienceDirect
Energy Reports 6 (2020) 660–665
www.elsevier.com/locate/egyr

6th International Conference on Energy and Environment Research, ICEER 2019, 22-25 July, University of Aveiro, Portugal

Relationship between energy consumption, CO_2 emission and economic growth in ASEAN: Cointegration and causality model

Jaruwan Chontanawat

Department of Social Sciences and Humanities, School of Liberal Arts, King Mongkut's University of Technology Thonburi, 126 Prachu-Uthit Rd., Thungkru, Bangkok 10140, Thailand

Received 28 July 2019; accepted 16 September 2019
Available online 4 October 2019

Abstract

The main objective of the research is to examine the dynamic relationship between energy consumption, CO_2 emissions and economic output in ASEAN for the period 1971–2015 using cointegration and causality models. The empirical results from the models suggest that there is a long-run relationship and there is causality between these variables, indicating that energy consumption and output are related to CO_2 emissions. The results provide useful information in terms of policy implications. Policies aiming to reduce or conserve energy consumption could be implemented as it would help to reduce the level of CO_2 emission, without having much effect on economic growth.

Peer-review under responsibility of the scientific committee of the 6th International Conference on Energy and Environment Research, ICEER 2019.

Keywords: Energy; CO_2 emission; Economy; Cointegration; Causality; ASEAN

1. Introduction

It is without doubt that one of the most severe problems of the modern world is climate change and its important negative consequences to the environment. Human activity, especially the consumption of energy, has been considered one of the main factors contributing to the changing climate in the previous decades, [1]. Because of the global warming problem, there is a growing concern about scarce energy sources on one hand, and a new paradigm of a green economy on the other. The causal relationship between economic growth, energy consumption and environmental damage, has been intensively debated over the recent decades [2,3]. For instance, higher economic growth and energy consumption has led to greater CO_2 emission and greater environmental damage. Southeast Asia is a region that has experienced rapid economic and population growth with high energy dependency and also a significant rise in energy consumption and pollution emissions in recent decades. Continuous urban growth has resulted in people's life-styles changing and an improvement in their living standards, which has stimulated energy consumption dramatically [4]. Therefore it is very interesting to understand how the economic growth, energy

E-mail address: jaruwan.cho@mail.kmutt.ac.th.

https://doi.org/10.1016/j.egyr.2019.09.046

Peer-review under responsibility of the scientific committee of the 6th International Conference on Energy and Environment Research, ICEER 2019.

Nomenclature

E	Energy consumption in Mtoe
CO_2	CO_2 emission flux in Mt of CO_2 emissions
GDP	real GDP: defined and measured at constant price in million 2010 USD
P	Population in million persons
E_t	Energy consumption per capita (E_t = E/P) in Mtoe per million persons
C_t	CO_2 emission per capita (C_t = CO_2/P) in Mt of CO_2 emissions per million persons
Y_t	GDP per capita (Y_t = GDP/P) in million 2010 USD per million persons
Note:	E_t, C_t, and Y_t are transformed into logarithm term.

consumption and carbon emission in the region evolved during the last few decades and how these variables link to each other. This can be investigated by the following model.

2. Materials and methods

The objective of the study is to investigate the relationship between CO_2 emissions, energy consumption and economic output for the ASEAN (the Association of Southeast Asian Nations) region using the Cointegration and Causality model. This model has been widely accepted among scholars worldwide for the last couple of decades for analyzing the relationship between energy and economy. The pioneer work was conducted by [5] and following on, a number of studies have used this framework. A comprehensive list of studies is summarized in [3,6,7]. Recently the model has been expanded by incorporating emission pollution in the model. The most recent works across the countries are from [8–15]. However, few studies have been conducted for Southeast Asian countries. Most studies in the literature agree that the model is a widely utilized framework based on econometric theory to explain the relationship between the variables such as energy, emission and economic output. The main variables used in the models consist of energy consumption, gross domestic product, population, and CO_2 emissions. This study uses the annual data (from 1971 to 2015) for ASEAN which comprise of Brunei, Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam. Cambodia and Lao are excluded as the data is not available. Data is drawn from the IEA database [16]. The econometric software program, EVIEW 7 was used for modeling.

Regarding the theoretical framework, the relationship between economic growth, energy consumption and carbon emissions can be illustrated as follows.

$$C_t = f(E_t, Y_t) \tag{1}$$

The objective of the estimation is to examine how the variables are related in the long-run and to find the dynamic causal relationship between them. The testing procedure involves three main steps: unit root test, cointegration test and the causality test as per the detail shown below.

2.1. Unit root test

The first step of the testing procedure is to perform an integration analysis. The objective is to test for the stationarity of the time series variables in the model. According to [17], a linear combination of the non-stationary series can be stationary and if such a stationary exists, the series are considered to be cointegrated. This requires that the series have the same order of integration. Therefore, the augmented Dickey–Fuller (ADF) test [18] was performed to test whether the series are stationary or non-stationary. The test involves estimating a form of the following equation by Ordinary Least Square (OLS) method:

$$\Delta X_t = \alpha_1 + \alpha_2 T + \delta X_{t-1} + \sum_{i=1}^{n} \lambda_i \Delta X_{t-i} + \varepsilon_t \quad t = 1, \ldots n \tag{2}$$

where X_t denotes any variables in the model (C_t, E_t and Y_t) over time. T is time trend. Δ is the different operator. The coefficient of particular interest is δ. The null hypothesis is that X_t is non-stationary or $\delta = 0$ which means that there is a unit root problem against the alternative $\delta < 0$.

2.2. Cointegration test

Once the variables are found to be non-stationary at their level and are in the same order of the integration i.e. integrated of order one or so called I(1), the Johansen and Juselius cointegration test [19] can be applied by beginning with an unrestricted vector auto-regressive (VAR) model in which a vector of variables ($X \times 1$) at time t are related to the vector of past variables. According to the Granger representation theorem, the vector X_t has a vector auto-regressive error correction representation in the following specification:

$$\Delta X_t = \alpha_1 + \alpha_2 T + \Pi X_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Phi D_t + \omega_t \tag{3}$$

where $\Pi = \sum_{i=1}^{p} A_i - I \quad and \quad \Gamma_i = -\sum_{j=i+1}^{p} A_j$

X_t is a ($X \times 1$) dimension vector corresponding to the number of the variables (C_t, E_t and Y_t) in which all the variable are ~I(1), the Π, Γ_i and Φ are parameter matrices to be estimated, D_t is a vector with deterministic elements (constant and trend) and ω_t is a matrix of random error that follows a usual Gaussian white noise process with zero mean and constant variances. The specific interest of testing is, the rank of matrix Π which contains long-run information and the speed of adjustment. If rank of matrix Π is equal to one, there is one single cointegrating vector or one linear combination which is stationary such that the cointegrating rank matrix Π can be decomposed into $\Pi = \alpha\beta'$ where α is the vector of speed of the adjustment and β is the vector of long-run equilibrium. In this case X_t is I(1) but the combination $\beta' X_{t-1}$ is I(0). The Johansen method is to estimate the Π matrix from and unrestricted VAR and to test whether we can reject the restriction implied by the reduced rank Π. There are two methods of testing for the reduced rank (Π), the trace test and maximum eigenvalue which are as follows.

$$\lambda_{trace} = -T \sum_{i=r+1}^{n} \ln(1 - \lambda_i^2)$$

$$\lambda_{max}\,(r, r+1) = -T \ln(1 - \lambda_{r+1})$$

where λ_i is the estimated ordered eigenvalue obtained from the estimated matrix and T is the number of observations after lag adjustment. The trace statistics tests the null hypothesis that the number of distinct cointegration vector is less than or equal to r against a general alternative. The maximal eigenvalue tests the null that the number of cointegrating vector is r against the alternative of $r + 1$ cointegrating vector.

2.3. Causality test

According to [17], if the variables in the model are cointegrated, an error correction term (ECM) must be included in the model. A vector error-correction model (VECM) is formulated, therefore allowing for long-run equilibrium and short-run dynamics. The model can be expressed as follows.

$$\Delta C_t = a_1 + \sum_{i=1}^{j} a_{1i} \Delta C_{t-i} + \sum_{i=1}^{j} b_{1i} \Delta E_{t-i} + \sum_{i=1}^{j} c_{1i} \Delta Y_{t-i} + \Phi_1 ECM_{t-1} + \varepsilon_{1t} \tag{4}$$

$$\Delta E_t = a_2 + \sum_{i=1}^{j} a_{2i} \Delta C_{t-i} + \sum_{i=1}^{j} b_{2i} \Delta E_{t-i} + \sum_{i=1}^{j} c_{2i} \Delta Y_{t-i} + \Phi_2 ECM_{t-1} + \varepsilon_{2t} \tag{5}$$

$$\Delta Y_t = a_3 + \sum_{i=1}^{j} a_{3i} \Delta C_{t-i} + \sum_{i=1}^{j} b_{3i} \Delta E_{t-i} + \sum_{i=1}^{j} c_{3i} \Delta Y_{t-i} + \Phi_3 ECM_{t-1} + \varepsilon_{3t} \tag{6}$$

where ECM_{t-1} is the normalize cointegration equation. There are two sources of causation, i.e. through the ECM, if $\Phi_i \neq 0$, or through the lagged dynamic terms. The ECM term represents the long-run equilibrium, relationship whereas the coefficients on lagged difference term show the short-run dynamics. The coefficient of ECM term indicates the speed of adjustment or an error mechanism that drives the variables back to long-run equilibrium. Regarding two sources of causation, there are three different causality tests, short-run Granger non-causality test, long-run non causality test and joint non-causality test. The interpretation is as follows. For example, in Eq. (4), E_t Granger cause C_t in the short-run if the null hypothesis Ho: (all $b_{1i} = 0$) is statistically rejected. For the long-run

causality, E_t Granger causes C_t if the null Ho: ($\Phi_1 = 0$) is statistically rejected. For the strong causality result, E_t Granger caused C_t if the null Ho: (all $b_{1i} = \Phi_1 = 0$) is statistically rejected. Similarly, Y_t Granger cause C_t in the short-run if the null hypothesis Ho: (all $c_{1i} = 0$) is statistically rejected. For the long-run causality, Y_t Granger causes C_t if the null Ho: ($\Phi_1 = 0$) is statistically rejected. For the strong causality result, Y_t Granger caused C_t if the null Ho: (all $c_{1i} = \Phi_1 = 0$) is statistically rejected. The interpretation of Eqs. (5) and (6) can be done following the same notion.

3. Results

The unit root test shown in Table 1 yields good results. All variables: real GDP, energy consumption and CO_2 emission are non-stationary in their levels but become stationary after taking the first difference. Hence it can be concluded that all series are integrated at order one or I(1) at 1% level of significance.

Table 1. Unit root tests.

ADF		
Variable	Level	1st difference
C_t	−1.905	−5.390*
E_t	−2.048	−5.987*
Y_t	−3.080	−4.890*

*Indicates 1% critical value.

The results from the Johansen cointegration tests are shown in Table 2. Both the results of trace tests and maximum eigenvalue tests unanimously point to the same conclusion that there in one cointegrated relationship, at the 5% level of significance.

Table 2. Johansen cointegration results.

Hypothesized no. of cointegrating vectors	Eigenvalue	Trace statistic	Maximum eigenvalue
None*	0.418	33.043	21.642
At most 1	0.241	11.401	11.014
At most 2	0.010	0.387	0.387

*Denote rejection of null hypothesis at 5% significance.

Table 3 presents the cointegrating vector, the speed of adjustment coefficient and *ECM* equation. It can be evident that both E_t and Y_t are positively related to C_t in the long-run. The long-run elasticity of C_t with respect to E_t and Y_t are found to be 1.21 and 0.40 respectively. The loading factor, which measures the speed of adjustment back to the long-run equilibrium level has correct sign (negative). The speed of adjustment at 0.02 implies that CO_2 emission can adjust towards its long-run level with about 2 percent of the adjustment taking place within the first year.

Table 3. Cointegrating vector.

Cointegrated equation:	Φ
$C_t = 0.67 + 1.21E_t + 0.40Y_t$	−0.02
(6.986***) (3.323***)	(−0.151)

Notes : The normalized variable is C_t, figures in parentheses denote t-statistics of cofficients E_t and Y_t.
***Indicate 1% level of significance, respectively.

The results in Table 4 show, to some extent, evidence of causal relationship among CO_2 emissions, energy consumption and economic growth. There is a relationship (bi-directional causality) between energy consumption and CO_2 emissions. Energy consumption cause CO_2 emission (in the short run), implying that an increase of energy consumption could lead to an increase of CO_2 emission, and vice versa (in the long-run). Furthermore, the results show one way or uni-directional causality running from GDP to energy consumption (particular in the long-run), which implies that the increase of economic outputs or activities, could lead to an increase of energy consumption. However, there is no evidence of causality running from energy consumption (or CO_2 emissions) to GDP. The results support the "*conservation hypothesis*" [5,6,12] that refer to uni-directional causality running from economic

Table 4. Causality results.

Dependent variables	Short term F-statistics			Long term t-statistics	Short term & Long term F-statistics		
	$\sum\Delta C_{t-i}$	$\sum\Delta E_{t-i}$	$\sum\Delta Y_{t-i}$	ECM_{t-1}	$\sum\Delta C_{t-i}$ & ECM_{t-1}	$\sum\Delta E_{t-i}$ & ECM_{t-1}	$\sum\Delta Y_{t-i}$ & ECM_{t-1}
ΔC_t	–	1.729*	0.306	−0.151	–	1.495	0.103
		(0.092)	(0.761)	(0.881)		(0.238)	(0.903)
ΔE_t	−1.159	–	0.464	−2.009**	2.291[a]	–	2.021[b]
	(0.254)		(0.645)	(0.052)	(0.115)		(0.146)
ΔY_t	0.000	0.398	–	−0.407	0.083	0.171	–
	(0.999)	(0.693)		(0.686)	(0.920)	(0.843)	

Note: p-values are giving in parentheses.

*Indicate 10% level of significance.

**Indicate 5% level of significance.

[a]Indicates 11.5%.

[b]Indicates 14.6%.

growth to energy consumption. Therefore, policies aiming to reduce energy consumption could be implemented as it could help to reduce the level of CO_2 emission without affecting economic growth.

4. Conclusion

In summary, this paper investigates the relationships between CO_2 emissions, energy consumption and economic growth for ASEAN region based on cointegration and causality approach. The cointegration results show the long run relationship between these variables, indicating that energy consumption and economic activities are related to CO_2 emissions. The causality results to some extent show evidence of the relationships between these variables implying that policies relating to a reduction of energy consumption, through an improvement in energy efficiency, or the investigation of new energy sources, should be taken into consideration as they could reduce the level of CO_2 emissions without affecting the region's economic growth.

Acknowledgment

This work was financially supported by School of Liberal Arts, (grant 2562103) and the Research, Innovation and Partnerships Office (RIPO) both of King Mongkut's University of Technology Thonburi, Bangkok, Thailand.

References

[1] Intergovernmental Panel on Climate Change (IPCC). Global warming of 15 °C. An IPCC Special Report on the impacts of global warming of 15 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. 2018. Retrieved from Geneva Switzerland: http://www.ipcc.ch/report/sr15/.

[2] Stern DI. Economic growth and energy. Encycl Energy 2004;2:35–51.

[3] Chontanawat J, Hunt LC, Pierse R. Does energy consumption cause economic growth?: Evidence from a systematic study of over 100 countries. J Policy Model 2008;30:209–20. http://dx.doi.org/10.1016/j.jpolmod.2006.10.003.

[4] International Energy Agency (IEA). Southeast Asia Energy Outlook 2017, World Energy Outlook Special Report (9789264285576 (PDF)). 2017. Retrieved from Paris: https://www.oecd-ilibrary.org/content/publication/9789264285576-en.

[5] Kraft J, Kraft A. Note and comments: On the relationship between energy and GNP. J Energy Dev 1978;3:401–3.

[6] Payne JE. Survey of the international evidence on the causal relationship between energy consumption and growth. J Econom Stud 2010;37:53–95. http://dx.doi.org/10.1108/01443581011012261.

[7] Ozturk I. A literature survey on energy-growth nexus. Energy Policy 2010;38(1):340–9.

[8] Özokcu S, Özdemir Ö. Economic growth, energy, and environmental Kuznets curve. Renew Sustain Energy Rev 2017;72:639–47. http://dx.doi.org/10.1016/j.rser.2017.01.059.

[9] Chen PY, Chen ST, Hsu CS, Chen CC. Modeling the global relationships among economic growth, energy consumption and CO2 emissions. Renew Sustain Energy Rev 2016;65:420–31. http://dx.doi.org/10.1016/j.rser.2016.06.074.

[10] Ahmad A, Zhao Y, Shahbaz M, Bano S, Zhang Z, Wang S, Liu Y. Carbon emissions, energy consumption and economic growth: An aggregate and disaggregate analysis of the Indian economy. Energy Policy 2016;96:131–43. http://dx.doi.org/10.1016/j.enpol.2016.05.032.

[11] Esso LJ, Keho Y. Energy consumption, economic growth and carbon emissions: Cointegration and causality evidence from selected African countries. Energy 2016;114:492–7. http://dx.doi.org/10.1016/j.energy.2016.08.010.

[12] Wang S, Li Q, Fang C, Zhou C. The relationship between economic growth, energy consumption, and CO2 emissions: Empirical evidence from China. Sci Total Environ 2016;542:360–71. http://dx.doi.org/10.1016/j.scitotenv.2015.10.027.
[13] Alshehry AS, Belloumi M. Energy consumption, carbon dioxide emissions and economic growth: The case of Saudi Arabia. Renew Sustain Energy Rev 2015;41:237–47. http://dx.doi.org/10.1016/j.rser.2014.08.004.
[14] Bastola U, Sapkota P. Relationship among energy consumption, pollution emission and economic growth in nepal. Energy 2015;80:254–62. http://dx.doi.org/10.1016/j.energy.2014.11.068.
[15] Saboori B, Sapri M, Baba M. Economic growth, energy consumption and CO2 emissions in OECD (Organization for Economic Co-operation and Development)'s transport sector: A fully modified bi-directional relationship approach. Energy 2014;66:150–61, http://www.internationaltransportforum.org/.
[16] International Energy Agency (IEA). World Energy Statistics and Balances (Database) from International Energy Agency, Paris, France. 2017.
[17] Engle RF, Granger CW. Cointegration and error correction: Representation, estimation and testing. Econometrica 1987;55:251–76. http://dx.doi.org/10.2307/1913236.
[18] Dickey D, Fuller W. Distribution of the estimators for autoregressive time series with a unit root. J Am Stat Assoc 1979;74:427–31. http://dx.doi.org/10.2307/2286348.
[19] Johansen S, Juselius K. Maximum likelihood estimation and inference on cointegration with applications to the demand for money. Oxford Bull Econom Stat 1990;52:169–210. http://dx.doi.org/10.1111/j.1468-0084.1990.mp52002003.x.