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RESEARCH ARTICLE

Economic growth, financial development, and trade in nexuses of CO_2 emissions for Southeast Asia

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Abstract

In energy economics literature, we found few studies on the association between environmental quality energy consumption and financial development. The current study is an attempt to contribute in literature by examining the link between carbon dioxide (CO_2) emissions, financial development, energy consumption, and economic growth, in South East Asian economies for the period 1980–2017 using annual time series data. For empirical analysis, Bound tests for cointegration and error correction approach are used. The estimated results confirm that financial development has positive impact on environmental quality. On the other hand, in the long run, the rise in energy consumption economic growth and trade openness is unfavorable for environment quality. Our results confirm *U*-shaped relationship between economic growth and environmental quality that is a proof of environmental Kuznets curve (EKC). Additionally, the government needs to design different modes of energy consumption to solve the problem of environmental degradation. Moreover, the major conclusion extends new insight for authority to make a comprehensive trade and financial policies to improve environmental quality.

Keywords Economic growth · Financial development · Carbon dioxide

Introduction

Currently, issue of global warming is highly discussed as it is evenly important for all developing and developed countries of the world because of its negative impact on environment. In literature, we found that ozone layer exhaustion is linked with carbon dioxide (CO_2) emissions and it is the major cause of global warming (Alam et al. 2012). Presently, financial sector performance is related to other main energy-consuming economic sectors which influences environmental quality despite the sectoral and overall economic growth. Many emerging and developed economies are doing widespread efforts to deal with the problem of high CO_2 emissions (Ayeche et al. 2016). A key strategy of global struggle is to decrease the dangerous effects of worldwide environmental change and to reduce worldwide CO_2 emissions (Tamazian and Rao 2010).

It is a fact that human has dependence on environment to fulfill their basic needs; they use natural resources and reduce the quality of environment. Different economic activities like transport, manufacturing, and consumption change the position of natural resources, putting pressure to environment leading to environmental degradation (Georgescu-Roegen 1971; Daly 1977; Tariq and Ab Rahim 2016). Moreover, financial sector plays an indispensable role in allocating funds and organizing savings to productive activities (Shahbaz et al. 2013). Financial development takes place when financial intermediary markets and instruments work hand in hand to reduce the cost of enforcement transaction and information. In addition, it has also a major role in speeding up the process of economic development as well-organized and developed financial markets can attract FDI and stimulate the process of economic growth (Frankel and Romer 1999). Therefore, financial development may be another source that affects the environmental performance either in good or worse performance rather than only depends on its income level alone (Zhang 2010).

In the past few decades, air pollution is one of the major problems that is faced by the Association of Southeast Asian

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Nations. The issue has frequently dominated the agenda of ASEAN member states as one of their top priorities in addressing environmental issues in Southeast Asia since the 1980s (Yohanes et al. 2015). In Southeast Asia, the primary source of haze in the region is the fires associated with deforestation, especially of peat forest. Hence, Indonesia's annual peat fires and forest are a manmade crisis, with upsetting health impacts for Indonesia and its Southeast Asian neighbors as well as the global climate (Lin et al., 2014).

In early 1980s, South East Asia has started financial reforms. From 1970s, ASEAN remained the fastest growing regions in the world; the growth rate of gross domestic product was more than 6.6% between the 1970s and 1995 as compared with 3% growth rate in case of other developing countries. In 1994–1995, the growth was 8 to 10% in case of Malaysia, Singapore, and Thailand. Table 1 shows major financial indicators of Southeast Asian economies in 2017.

Energy consumption shows the trends of standard of living of a country. Higher energy demand especially renewable energy demand means economic. We find this evidence (see Table 2) in case of Indonesia, Malaysia, Singapore, and Thailand. Energy consumption was lower in case of Philippines and Vietnam in 2010, 2014, and 2014 respectively. More economic growth means more energy consumption. More economic growth and more energy consumption imply more pollution, more CO_2 emissions, and more nitrous oxide emissions. The average annual CO_2 emissions per capita has been estimated at 1.82 metric tons in Indonesia, 8.03 metric tons in Malaysia, 10.31 metric tons in Singapore, 4.62 metric tons in Thailand, 1.06 metric tons in the Philippines, and 1.80 metric tons in Vietnam in the year 2014.

Limited researches have discussed the relationship between financial development, energy consumption, and pollution in different countries. These studies found different findings; some came up with positive relationships between pollution and energy consumption, for example, Sadorsky (2010, 2011) in the case of Central and Eastern Europe; Zhang (2011) in the case of China; Tang and Tan (2014) and Islam et al. (2013) in the case of Malaysia; and Coban and Topcu (2013) in the case of European Union (EU). Several studies indicate negative relationship between pollution and energy consumption i-e Tamazian and Rao (2010) studies for accross transition nations, Jalil and Feridun (2011) studied for Indonesia and Shahbaz et al. (2013) in case of China. Some found no relationship between CO_2 emission and financial development, like Ozturk and Acaravci (2013) and Ali et al. (2015).

This research investigates the impact of financial development on CO_2 emission in South East Asian economies. We specify our model as CO_2 emission is a function of economic growth, energy consumption, financial development, and trade openness. We can see contribution of the study in different aspects. First, we cannot find literature on financial development and environmental variables in case of South East Asian economies. Second, ARDL bound testing approach and structural break unit root tests are first time used to test the relationship financial development, energy consumption, and emission in six South East Asian economies.

The rest of it is organized as follows. The "Financial development energy consumption and CO_2 emission" section reviews the related studies; the "Model and methodology" section explains the lays out the empirical models, econometric methodology, and data. The "Empirical analysis and results" section offers discussion of the empirical findings. Last, the "Conclusion and policy implications" section concludes and proposes policy recommendations.

Financial development energy consumption and CO_2 emission

CO_2 emissions and economic growth

To begin, Taskin and Zaim (2000) explored the relationship among environmental quality CO_2 emission and GDP using data from 1975 to 1990 for 52 countries. The inverted *U*-shaped hypothesis has been proved. Lo et al. (2005) examined the linkage between CO_2 emissions and growth based on environmental impact using the data from 1987 to 1996. The main findings of the study were that there is a gap between productivity growth trend with and without CO_2 emissions.

Wolde-Rufael (2006) examined the long run and causal links between electricity consumption and GDP for 17

Table 1 Major financial indicators of Southeast Asian economies in 2017

Indicator	Indonesia	Malaysia	Singapore	Thailand	Philippines	Vietnam
Domestic credit provided by financial sector (% of GDP)	47.936	145.256	129.551	167.353	63.492	140.062
Domestic credit to private sector (% of GDP)	39.386	123.907	127.427	145.630	44.717	123.815
Deposit interest rate (%)	7.166	3.028	0.190	1.300	1.596	4.800
Lending interest rate (%)	11.888	4.544	5.350	4.468	5.642	6.960
Commercial bank branches (per 100,000 adults)	17.387	11.485	8.984	12.376	8.873	3.873
Official exchange rate (LCU per US$, period average)	13308.327	4.148	1.382	35.296	47.492	21935.001

Table 2 Trends in GDP, energy consumption, and CO_2 emissions in East Asian economies (1980–2014)

Year	Indonesia	Malaysia	Singapore	Thailand	Philippines	Vietnam
GDP per capita (current US$)						
1980	491.438	1774.736	516.293	682.773	684.654	230.874
1990	585.001	2440.592	2489.785	1508.286	715.311	94.880
2000	780.092	4045.170	6995.101	2007.565	1038.911	388.271
2010	3113.481	9071.357	24936.831	5075.302	2129.499	1310.370
2014	3491.596	11183.729	21795.697	5953.794	2842.938	2012.046
Energy use (kg of oil equivalent per capita)						
1980	377.679	861.984	2125.967	464.321	472.915	264.690
1990	543.705	1210.397	3782.720	741.283	463.443	261.929
2000	735.821	2108.601	4634.726	1148.151	512.748	357.923
2010	874.581	2610.310	5006.621	1753.343	431.010	665.878
2014	883.911	2967.541	5121.804	1969.634	476.245	654.963
CO_2 emissions (metric tons per capita)						
1980	0.643	2.029	13.022	0.847	0.781	0.309
1990	0.824	3.137	14.602	1.605	0.674	0.314
2000	1.245	5.423	12.167	2.879	0.940	0.668
2010	1.768	7.772	10.960	4.195	0.905	1.613
2014	1.819	8.033	10.306	4.622	1.055	1.804
Nitrous oxide emissions (thousand metric tons of CO_2 equivalent)						
1980	78035.680	12123.356	623.277	1173.550	7733.694	7438.884
1990	100555.010	13982.116	903.504	1765.413	9882.366	11614.026
2000	94932.850	13821.691	6635.085	2355.663	12364.970	19746.070
2010	91312.670	15010.045	1871.138	2880.873	12511.786	33817.900
2014	93138.923	15310.246	1908.561	3014.423	12762.022	34494.258

African countries from 1971 to 2001. Both the approaches by Pesaran et al. (2001) and Toda and Yamamoto (1995) are used. Main findings of the study were there existing long-run relationship between real GDP per capita and electricity consumption per capita in case of 9 countries; on the other hand, for 12 countries, Granger's causality exists. Zou and Chau (2006) explored the relationship between oil consumption and economic growth in China and found that economic growth Granger causes oil consumption. Azomahou et al. (2006) examined the association between CO_2 emissions and GDP growth for 100 countries for the period 1960 to 1996. Their findings revealed positive slope between CO_2 emissions and GDP growth.

Some of the literature is specially related to oil-exporting countries particularly study of Mehrara (2007). The study investigated the relationship between GDP and energy use covering period from 1971 to 2002 in a panel of eleven high oil-exporting countries. Panel unit root cointegration and Granger's causality test are used to investigate causality between the economic series. The main findings of this study showed robust unidirectional relationship running from a GDP to energy use with no feedback effect. Halicioglu (2008) examined the linkages among GDP CO_2 emissions, foreign trade, and energy use in the case of Turkey by using the time series data from 1960 to 2005. The main finding of the study was that there was no evidence of an EKC. Tanzania an African country has been explored by Apergis and Payne (2010) and examined the relationship between coal consumption and economic growth in the case of OECD countries using panel data from 1980 to 2005, and they used dynamic error correction model to find bidirectional causality.

Sharma (2011) examined the environmental Kuznets curve for 69 countries using panel data during the period from 1985 to 2005. Main variables included are CO_2 emission urbanization, GDP, and energy use. The main findings of the research were GDP, and urbanization was the main determinants.

Lee and Brahmasrene (2013) studied the linkages between economic growth, tourism, CO_2 emissions, and foreign direct investment (FDI) from 1988 to 2009. The main findings of the study showed that CO_2, emissions tourism, and FDI were the main determinants of economic growth.

Antonakakis et al. (2017) analyzed the relationship between output energy and environment from 1971 to 2011. The findings of the study were economic growth and energy use had a bidirectional relationship. Bekhet et al. (2017) studied the relationship among CO_2 emissions, financial development, CO_2 emissions, energy use, and economic growth between 1980 and 2011. The main findings of this research showed GDP growth was the main determinant of growth and financial development was a source of energy emissions.

Economic growth energy consumption and CO_2 emission

Different studies had tested the relationship between CO_2 emissions energy consumption and economic growth using time series data. Halicioglu (2008) explored the linkages between trade, energy use, and GDP in the case of Turkey using time series data from 1960 to 2005. The outcome of the study was that there was no evidence of EKC hypothesis. Soytas et al. (2007) explored the linkages between energy use, CO_2 emissions, gross fixed capital, labor, and GDP for the USA from 1960 to 2004. The study had mainly concerned with nexus between growth and emission by considering the association between real output and CO_2 emission.

The main conclusions of this study were GDP does not Granger causes CO_2 emissions. Furthermore, the case of Canada was studied by Ghali and El-Sakka (2004), who examined the association between energy use and output growth using time series data from 1961 to 1997. A neoclassical set had been used where capital, labor, and energy were used as separate variables. For the long-run relationship, Johansen (1992) cointegration was used and for the short-run relationship, vector error correction model was used. The findings of the research showed bidirectional causality between energy use and output growth. Ang (2007) worked for France and the research examined the association between energy use pollutant emissions and output for time series data from 1960 to 2000. The study had applied unit root tests, ARDL bound test cointegration ECM-based causality techniques for analysis. The results showed both the existence of the short-run and long-run relationships. That was because economic growth affected energy consumption and pollution. In other words, more energy meant more CO_2 emissions, and in the long-run, output and CO_2 emissions had a quadratic relationship.

Moreover, in the short run, there was a unidirectional causality running from energy use to economic growth. Tsani (2010) investigated the causal link between energy use and economic growth for using time series data from 1960 to 2006. For checking the existence of causal nexus, energy consumption is divided into aggregated and disaggregated levels. For estimation, unit root and Toda-Yamamoto approach were used. The results revealed unidirectional link running from energy use to GDP at aggregated levels and bidirectional causal was evident concerning residential energy consumption and the industrial the at disaggregated levels.

Jayanthakumaran et al. (2012) used ARDL methodology to make a comparative analysis of energy consumption, CO_2 emissions, GDP, and trade for China and India using time series data from 1971 to 2007. China and India were interesting cases as both are transitional and largest growing economies. The findings proved EKC hypothesis for both countries. In case of China, 1% increase in per capita income led to 1.62% increase in CO_2 emissions by 1.62%. On the other hand, for India, the long-run elasticities of GDP and GDP squared were 7.85% and − 0.66%. Moreover, in the short run, there was the negative relationship between CO_2 and trade.

CO_2 emission economic growth and financial development

The current empirical literature related to environmental pollution and financial developments is limited, with positive as well as with negative results on financial development (Halkos and Sepetis 2007; He and Wang 2012; Omri et al. 2015). Frankel and Romer (1999) argued that developing countries will be concerned toward adopting cleaner energy technologies throughout and that is important to reduce the environmental degradation. Additionally, due to financial development, companies obtain capital and by using environmentally friendly techniques decrease financial costs. This evidence is also revealed in the work of Yuxiang and Chen (2010), who believe to increase technological progress financial development policies is a critical issue and it can reduce CO_2 emissions and increase domestic production.

On the same ground, Cole and Elliot (2005) investigated the relationship between environmental degradations and financial development. They claimed that various financial tools, for example, leasing, loans, treasury bonds, factoring, and derivatives allow firms to attain economies of scale, thus decreasing CO_2 emissions and the use of resources.

In the work of Tamazian et al. (2009) explored the relationship between the environmental quality and financial development using panel data from 1992 to 2004 in BRIC countries. They argued that increasing financial and economic development decreases the environmental degradation. Thus, government should adopt various policies related to trade and financial openness to increase FDI and thus can decrease CO_2 emissions in BRIC countries. On the same lines, Tamazian and Rao (2010) studied financial development has major role in environmental degradation in transitional economies. Particularly, higher the level of FDI lowers CO_2 emissions, although financial liberalization should carry institutional framework with strong base.

Currently, a study by Nasreen et al. (2017) analyzed the association between economic growth, CO_2 emissions, energy consumption, and financial stability in South Asian

Table 3 ARDL bounds test results for cointegration

	Estimated equation lncot = *f*(lnGDPt, lnFint, lnEnt, lnTrt)					
	Indonesia	Malaysia	Singapore	Thailand	Philippines	Vietnam
Optimal lag length	(2,0,0,1,2)	(4,4,4,4,2)	(2,1,2,2,2)	(4,0,4,4,1)	(4,2,2,2,0)	(2,1,2,1,2)
F statistics (Wald test)	8.786*	6.930*	10.235*	5.429*	7.257*	9.202*
Significance level						
Significance	I0 bound	I1 bound				
10%	2.45	3.52				
5%	2.86	4.01				
2.50%	3.25	4.49				
1%	3.74	5.06				
R^2	0.753	0.998	0.888	0.999	0.797	1.000
Adjusted R^2	0.695	0.992	0.876	0.998	0.779	0.999
F statistics	5.845 (0.000)	17.16 (0.000)	6.365 (0.006)	9.765 (0.0006)	8.346 (0.0004)	7.236 (0.0003)
Durbin Watson test	1.902	2.351	2.457	2.546	3.658	3.059
Normality test	11.338 (0.543)	0.5124 (0.7744)	4.875 (0.275)	1.3847 (0.500)	2.536 (0.677)	1.247 (0.535)
Ramsey RESET test	1.080 (0.543)	0.263 (0.6236)	2.245 (0.546)	2.375 (0.765)	3.676 (0.254)	0.440 (0.234)
Breusch-Godfrey serial correlation LM test	3.126 (0.205)	1.9353 (0.38)	2.57467 (0.5466)	2.3463 (0.1417)	1.452 (0.745)	3.654 (0.233)
Heteroscedasticity test: Breusch-Pagan-Godfrey	11.566 (0.239)	18.910 (0.6508)	3.54366 (0.4657)	17.2236 (0.4563)	3.566 (0.675)	8.230 (0.766)

*Represent significance at 1% level. Values in parentheses "()" are *P* values

economies using time series data spanning from 1980 to 2012 using cointegration technique. The study concluded that financial stability has a positive impact on environmental quality and supported inverted *U* hypothesis.

Furthermore, Abid (2017) examined the EKC hypothesis using GMM panel data methodology using data from 1990 to 2011 in case of EU, East African Middle East countries. The study used variables such as trade openness, financial development (credit to private sector), and public expenditures. The main conclusion was monotonic positive association between GDP and CO_2 emission and did not find the evidence of EKC hypothesis.

In contrast, some studies found negative impact of financial development on environment. For example, Zhang (2011) argued that financial development creates inefficiency and is a cause of emissions. Shahbaz and Lean (2012) investigated the association between financial development and environmental quality. They claimed that well-organized financial sector attracts FDI as a result of which efficiency of stock market improves and GDP increases, leading to increase in CO_2 emissions. On the other hand, there are number of studies that had neutral relationship between financial development and environmental awareness level (Ozturk and Acaravci 2013).

In their research, Lee et al. (2015) explored the EKC hypothesis for the time period from 1971 to 2007. They used panel data and FMOLS technique and rejected the confirmation of EKC hypothesis for their selected economies. Shahbaz et al. (2016) investigated the impact of financial development on environmental quality using time series quarterly data from 1985 to 2014 for Pakistan. They used different and detailed indices of financial development. They argued that energy inefficient technology led to environmental degradation.

Model and methodology

Stationarity tests

The most commonly used test to check stationarity is the ADF test. The null hypothesis is there is a unit root in time series against the alternative that time series is stationary. The ADF test is based on estimating regression.

$$y_t = \beta^{\cdot} D_{\mathrm{t}} + \varnothing y_{\mathrm{t}-1} + \sum_{j=1}^{p} \psi j \Delta y_{\mathrm{t}-j} + \varepsilon_{\mathrm{t}}$$

where D_t shows vector of deterministic trends; *P* indicates lags used in model; and ε_t is the stochastic error term. It is also based on ARMA structure of the model.

The Phillips-Perron unit root test is different from the ADF test as it deals with serial correlation and heteroscedasticity in the errors. The regression of the Phillips-Perron test is

$$\Delta y_t = \beta^{\cdot} D_t + \pi y_{t-1} + u_t$$

Table 4 Estimated long-run coefficients for the ARDL model (dependent variable: lnCOt)

Country	Variable	GDP	EN	GDP^2	FIN	TR	C
Indonesia	Coefficient	0.145	0.514	− 27.337	− 0.920	− 1.510	− 281.193
	P value	0.072	0.863	0.008	0.038	0.484	0.350
	Coefficient	0.235	1.520		− 0.071	− 0.782	− 6.018
	P value	0.032	0.001		0.002	0.000	0.000
Malaysia	Coefficient	4.804	0.086	− 0.202	− 0.083	0.301	− 25.446
	P value	0.270	0.692	0.015	0.237	0.012	0.177
	Coefficient	0.752	0.411		− 0.047	0.240	− 33.856
	P value	0.000	0.005		0.110	0.000	0.001
Singapore	Coefficient	5.347	0.565	− 0.756	− 0.086	0.047	− 56.870
	P value	0.008	0.005	0.044	0.069	0.047	0.068
	Coefficient	0.679	0.789		− 0.766	0.487	− 20.764
	P value	0.007	0.009		0.058	0.059	0.058
Thailand	Coefficient	16.581	2.083	− 0.333	− 2.324	− 0.472	− 78.577
	P value	0.017	0.012	0.072	0.002	0.004	0.065
	Coefficient	3.877	− 1.775		− 1.414	− 2.049	− 80.346
	P value	0.403	0.585		0.345	0.007	0.005
Philippines	Coefficient	7.868	3.667	− 0.646	− 3.767	0.879	− 5.988
	P value	0.058	0.057	0.068	0.009	0.007	0.099
	Coefficient	2.768	4.737		− 0.544	− 2.049	− 8.875
	P value	0.006	0.054		0.345	0.007	0.088
Vietnam	Coefficient	3.364	2.236	− 4.365	− 0.354	3.456	− 5.143
	P value	0.000	0.235	0.001	0.234	0.032	0.983
	Coefficient	1.506	1.902		0.007	1.557	− 8.940
	P value	0.008	0.000		0.855	0.000	0.000

where U_t is stationary. It is better than the ADF test as PP tests are robust to general form of heteroscedasticity in the error term. And there is no problem of lag selection.

Both ADF and PP tests are based on null hypothesis of unit root in the series while KPSS (Kwiatkowski, Phillips, Schmidt and Shin (1992)) test has null hypothesis of stationary time series. They start their test as

$$y_t = \beta^{\bullet} D_t + \mu_t + u_t$$

$$\mu_t = \mu_{t-1} + \varepsilon_t,\ \varepsilon_t \sim WN(0, \sigma^2)$$

where D is the deterministic trend, U_t is the stationary, and μ_t is the purely random walk. Null hypothesis y_t is stationary and the test is based on Lagrange multiplier (LM) test.

To determine structural break, we apply unit root tests like Dickey-Fuller min-t and intercept Break min-t test in the data set. Null hypothesis in both tests is the variable and has a unit root.

ARDL

To check the long-run relationship among CO_2 emission, energy consumption, and economic growth. For financial development and trade openness, we use autoregressive distributed lag bound testing approach (Pesaran et al. 2001). The following equation shows error correction modeling of CO_2 emission.

$$\begin{aligned}\Delta \mathrm{CO}_t = {} & \alpha_1 + \sum_{j=1}^{p} \beta_{1t}\Delta \mathrm{CO}_{t-i} + \sum_{t=0}^{q1} \eta_{1i}\Delta \mathrm{GDP}_{t-i} \\ & + \sum_{i=0}^{q2} \gamma_{1i}\Delta(\mathrm{GDP}_{t-i})^2 + \sum_{i=0}^{q3} \theta_{1i}\Delta \mathrm{EN}_{t-i} \\ & + \sum_{i=0}^{q4} \pi_{1i}\Delta \mathrm{TR}_{t-i} + \sum_{i=0}^{q5} \varnothing_{1i}\Delta \mathrm{FD}_{t-i} + \delta_1 \ln CO_{t-1} \\ & + \delta_2 \ln \mathrm{GDP}_{t-1} + \delta_3 \ln(\mathrm{GDP}_{t-1})^2 + \delta_4 \ln \mathrm{EN}_{t-1} \\ & + \delta_5 \ln \mathrm{TR}_{t-1} + \delta_6 \ln \mathrm{FD}_{t-1} + \varepsilon_{1t}\end{aligned}$$

The parameters δ_i ,where i = 1, 2, 3, 4, 5, 6, and 7 are the long-run multipliers, whereas the parameters β,η, γ, θ, π, and ϕ are short-run dynamic coefficients of the ARDL model.

Originally, to estimate long-run relationship ARDL bound testing approach has been used. It involves two steps. First of all, appropriate lag length has been made on Schwartz Bayesian criterion (SBC) and model is estimated through the

Table 5 Estimated short-run coefficients for the ARDL model (dependent variable: Δ ln COt)

Variable	Coefficient	*P* value	Coefficient	*P* value	Coefficient	*P* value	Coefficient	*P* value	Coefficient	*P* value	Coefficient	*P* value
Indonesia	Indonesia		Malaysia		Singapore		Thailand		Philippines		Vietnam	
D(CO(-1))	− 0.002	0.988	− 1.067	0.025	1.348	0.347	− 0.045	0.058	1.358	0.000	− 1.095	0.129
D(CO(-2))	− 0.788	0.000	− 0.595	0.061	2.246	0.046	− 0.259	0.035	0.254	0.549	− 0.918	0.175
D(CO(-3))			− 0.917	0.005			− 0.985	0.018	1.265	0.654		
D(CO(-4))			− 1.345	0.003								
D(EN)	0.085	0.821	0.442	0.215	0.569	0.006	0.544	0.003	1.065	0.003	1.237	0.129
D(EN(-1))	0.768	0.038	0.301	0.368	1.347	0.005	1.348	0.236			4.676	0.124
D(EN(-2))	0.910	0.020	− 0.379	0.437							0.762	0.346
D(EN(-3))			0.378	0.279								
D(EN(-4))			1.903	0.004								
D(GDP)	− 0.252	0.780	1.453	0.034	0.747	0.023	1.447	0.001	2.487	0.457	0.633	0.644
D(GDP(-1)			0.659	0.157	0.587	0.236	0.096	0.783	0.577	0.035	− 4.457	0.185
D(GDP(-2)			1.922	0.021	2.465	0.079	0.963	0.110	1.458	0.172	− 2.246	0.254
D(GDP(-3)			1.069	0.067			0.414	0.009	0.638	0.347		
D(FIN)	0.006	0.954	0.587	0.040	0.658	0.046	− 0.077	0.003	1.358	0.457		
D(FIN(-1)			0.170	0.114	1.985	0.235	− 0.348	0.000			− 0.538	0.161
D(FIN(-2)			− 0.020	0.856			0.137	0.107			0.256	0.173
D(FIN(-3)			− 0.600	0.040			− 0.457	0.010				
D(TR)	− 0.373	0.002	0.983	0.028	0.232	0.757	0.091	0.356	2.588	0.006	2.008	0.123
D(TR(-1))	− 0.005	0.973	0.469	0.059	1.876	0.050			0.987	0.001	1.159	0.125
D(TR(-2))	− 0.272	0.038	− 0.675	0.024							1.995	0.136
D(TR(-3))			− 0.215	0.348								
C	0.023	0.386	− 0.062	0.059	1.236	0.001	0.358	0.001	2.847	0.024	1.265	0.000
Et-1	− 0.790	0.000	− 0.565	0.005		0.000	− 0.357	0.007	− 0.876	0.000	− 0.235	0.006
Diagnostic tests												
R^2	0.712		0.927		0.874		0.814		0.697		0.735	
Adj. R^2	0.560		0.734		0.864		0.793		0.685		0.726	
Durbin Watson test	2.022		2.653		2.159		2.235		2.879		2.765	

Table 6 Estimated long-run coefficients (dependent variable: ln YPCt)

Country	Variable	CO	EN	FIN	TR	C
Indonesia	Coefficient	− 0.215	0.152	0.056	− 0.219	3.340
	P value	0.000	0.028	0.005	0.655	0.000
Malaysia	Coefficient	− 1.432	0.615	0.067	0.398	13.463
	P value	0.000	0.043	0.038	0.006	0.007
Singapore	Coefficient	− 0.547	2.466	1.035	0.678	2.623
	P value	0.000	0.055	0.045	0.001	0.066
Thailand	Coefficient	− 1.967	1.347	0.875	0.357	0.264
	P value	0.077	0.035	0.007	0.023	0.007
Philippines	Coefficient	− 0.876	3.267	0.365	0.967	0.547
	P value	0.088	0.438	0.001	0.001	0.153
Vietnam	Coefficient	− 0.168	− 0.824	0.157	− 0.218	− 8.569
	P value	0.433	0.166	0.005	0.061	0.163

OLS method. The approach is based on the joint F statistics or Wald statistics and it tested null hypothesis of no cointegration, i.e., H0: $\delta_i = 0$ against alternative $\delta_i \neq 0$, i = 1, 2, 3, 4, 5, 6, and 7. If calculated value of F statistics is greater than the upper bound critical value, then null hypothesis is rejected and this is the indication of cointegration. The specification of error correction model is given as

$$\Delta \mathrm{CO}_t = \alpha_0 + \sum_{i=1}^{m} \gamma_i \Delta \mathrm{CO}_{t-i} + \sum_{i=0}^{m} \delta_i \Delta \mathrm{GDP}_{t-i} + \sum_{i=0}^{m} \omega_{1i} \Delta (\mathrm{GDP}_{t-i})^2 + \sum_{i=0}^{m} \theta_{1i} \Delta \mathrm{EN}_{t-i} + \sum_{i=0}^{m} \pi_{1i} \Delta \mathrm{TR}_{t-i} + \sum_{i=0}^{m} \varphi_i \Delta \mathrm{FD}_{t-i} + \varnothing \mathrm{EC}_{t-1} + U_t$$

The sign of coefficient of error term is expected to be negative and statistically significant.

Empirical analysis and results

First of all, we have used five different univariate unit roots and stationarity tests to all variables namely the augmented Dickey-Fuller unit root test (ADF), Phillips-Perron (PP) and Kwiatkowski Phillips Schmidt, Shin stationarity test (KPSS), Dickey-Fuller min-t, and Intercept break min-t. The first three tests are common in literature and remaining two are for determining structural break. The results of conventional unit root tests are presented in Tables 8, 9, and 10. Results indicate that the variables $\mathrm{CO_t}$, $\mathrm{FD_t}$, $\mathrm{GDP_t}$, $\mathrm{GDP^2{}_t}$, $\mathrm{EN_t}$, and $\mathrm{TR_t}$ are non-stationary at level except $\mathrm{GDP_t}$, $\mathrm{GDP^2{}_t}$, and $\mathrm{TR_t}$ in the case of Vietnam.

We also apply structural break unit root test like Dickey-Fuller min-t and intercept break min-t test to determine

Table 7 Summary statistics

Variable	CO	EN	FIN	GDP	TR
Indonesia					
Mean	0.150	6.426	3.378	3.267	3.965
Median	0.148	6.520	3.313	3.305	3.960
Maximum	0.940	6.784	4.108	3.533	4.566
Minimum	− 0.442	5.934	2.270	2.977	3.623
Std. Dev.	0.400	0.293	0.455	0.155	0.173
Skewness	0.057	− 0.513	− 0.322	− 0.174	0.952
Kurtosis	1.972	1.752	2.579	1.966	5.505
Malaysia					
Mean	1.512	7.453	4.632	8.749	5.038
Median	1.691	7.546	4.686	8.826	5.053
Maximum	2.084	7.995	5.066	9.352	5.395
Minimum	0.708	6.759	3.910	8.107	4.655
Std. Dev.	0.470	0.407	0.273	0.384	0.239
Skewness	− 0.460	− 0.330	− 0.782	− 0.214	− 0.168
Kurtosis	1.678	1.669	3.218	1.746	1.733
Singapore					
Mean	2.400	8.325	4.542	3.149	5.864
Median	2.483	8.493	4.517	3.168	5.859
Maximum	2.893	8.905	4.864	3.311	6.090
Minimum	1.468	7.594	4.233	2.916	5.687
Std. Dev.	0.301	0.364	0.168	0.124	0.104
Skewness	− 1.107	− 0.728	0.439	− 0.390	0.390
Kurtosis	4.036	2.239	2.235	1.934	2.283
Thailand					
Mean	0.801	6.886	4.557	26.002	4.511
Median	1.039	7.033	4.622	26.102	4.608
Maximum	1.531	7.597	5.115	26.770	4.945
Minimum	− 0.262	6.020	3.709	24.921	3.858
Std. Dev.	0.607	0.507	0.397	0.568	0.376
Skewness	− 0.566	− 0.348	− 0.638	− 0.501	− 0.510
Kurtosis	1.809	1.768	2.357	2.024	1.842
Philippines					
Mean	− 0.240	6.130	3.406	7.475	4.254
Median	− 0.173	6.127	3.467	7.418	4.199
Maximum	0.054	6.240	4.033	7.969	4.684
Minimum	− 0.661	6.026	2.698	7.230	3.827
Std. Dev.	0.182	0.054	0.333	0.203	0.268
Skewness	− 0.727	0.217	− 0.526	0.949	0.123
Kurtosis	2.732	2.296	2.613	2.849	1.757
Vietnam					
Mean	− 0.490	5.884	3.953	6.667	4.595
Median	− 0.541	5.743	4.102	6.660	4.739
Maximum	0.590	6.501	4.873	7.515	5.300
Minimum	− 1.338	5.560	2.614	5.931	2.942
Std. Dev.	0.661	0.341	0.741	0.517	0.608
Skewness	0.329	0.678	− 0.444	0.034	− 1.460
Kurtosis	1.517	1.935	1.742	1.660	4.607

Table 8 ADF test

At level	Indonesia		Malaysia		Singapore		Thailand		Philippines		Vietnam		Thailand		Philippines		Vietnam	
Variables	Intercept	Intercept and trend	Intercept	Intercept and trend	Intercept	Intercept and trend	Intercept	Intercept and trend	Intercept	Intercept and trend	Intercept	Intercept and trend	Intercept	Intercept and trend	Intercept	Intercept and trend	Intercept	Intercept and trend
CO	− 1.083	− 3.159	− 1.259	− 1.574	− 2.161	− 2.585	− 1.274	− 0.484	− 1.083	− 3.159	− 1.259	− 1.574	− 2.161	− 2.585	− 0.431	− 2.258	0.490	− 1.894
EN	− 1.287	− 1.103	− 1.147	− 1.739	− 1.809	− 1.498	− 0.520	− 1.307	− 1.287	− 1.103	− 1.147	− 1.739	− 1.809	− 1.498	− 1.984	− 1.915	1.837	− 1.949
FIN	− 2.543	− 2.374	− 2.817	− 2.367	− 1.223	− 2.229	− 2.231	− 2.265	− 2.543	− 2.374	− 2.817	− 2.367	− 1.223	− 2.229	− 1.770	− 2.542	− 1.748	− 1.072
GDP	− 0.791	− 2.585	− 0.599	− 1.740	− 1.182	− 2.096	− 1.826	− 1.647	− 0.791	− 2.585	− 0.599	− 1.740	− 1.182	− 2.096	2.667	− 0.994	− 0.075	− 4.088
GDP2	− 0.541	− 3.525	− 0.599	− 1.740	− 1.234	− 2.654	− 1.754	− 1.666	− 0.541	− 3.525	− 0.599	− 1.740	− 1.234	− 2.654	2.862	− 0.848	0.453	− 3.299
TR	− 2.508	− 2.518	− 1.640	− 0.165	− 2.197	− 2.388	− 1.138	− 0.914	− 2.508	− 2.518	− 1.640	− 0.165	− 2.197	− 2.388	− 1.221	− 0.746	− 3.907	− 2.733
At first difference																		
CO	− 5.578	− 5.439	− 6.463	− 6.493	− 5.880	− 5.788	− 3.890	− 4.246	− 5.578	− 5.439	− 6.463	− 6.493	− 5.880	− 5.788	− 4.542	− 4.542	− 4.910	− 5.024
EN	− 5.917	− 3.976	− 6.280	− 6.327	− 6.378	− 6.601	− 4.378	− 4.329	− 5.917	− 3.976	− 6.280	− 6.327	− 6.378	− 6.601	− 3.200	− 3.153	− 3.556	− 3.845
FIN	− 4.386	− 4.430	− 5.388	− 4.804	− 6.165	− 6.086	− 3.242	− 3.372	− 4.386	− 4.430	− 5.388	− 4.804	− 6.165	− 6.086	− 3.793	− 3.855	− 3.999	− 4.363
GDP	− 4.457	− 4.400	− 5.079	− 5.008	− 3.765	− 3.804	− 3.205	− 3.571	− 4.457	− 4.400	− 5.079	− 5.008	− 3.765	− 3.804	− 4.548	− 8.572	− 2.584	− 4.161
GDP2	− 3.457	− 3.212	− 5.877	− 5.988	− 3.876	− 3.978	− 3.285	− 3.614	− 3.457	− 3.212	− 5.877	− 5.988	− 3.876	− 3.978	− 5.348	− 8.415	− 4.061	− 3.951
TR	− 8.414	− 8.421	− 3.591	− 3.965	− 5.753	− 5.674	− 5.448	− 5.529	− 8.414	− 8.421	− 3.591	− 3.965	− 5.753	− 5.674	− 4.591	− 4.700	− 5.277	− 4.530

The critical values for intercept and intercept and trend at 5% are − 2.951 and − 3.552 and at 1% are − 3.639 and − 4.262, respectively. ** and * denote significance at 5% and 1% level respectively

structural break in the data set as we have date from 1980 to 2017. Results are presented in Tables 11 and 12.

The results of F statistics are presented in Table 3. For optimal lag selection, Schwartz Baysian criteria has been used. The results of estimated model show that calculated value of F statistics is greater than upper bound value critical F at 1% level of significance in all countries. (According to Pesaran et al. (2001), the values of lower bound and upper bound are 3.74 and 5.06 at 1% significance level respectively). Thus, null hypothesis is rejected indicating cointegration between the variables. So, all the variables (CO_t, FD_t, GDP_t, GDP^2_t, EN_t, and TR_t) in the model are cointegrated.

Some diagnostic statistics have also been applied. The diagnostic tests include normality test, Ramsey RESET test, Breusch-Godfrey Serial Correlation LM test, and Breusch-Pagan-Godfrey test. The value of R^2 shows the explanatory power of explanatory variables. Coefficient of determination is between 0.72 and 0.99. The value of adjusted R^2 is between 0.69 and 0.99. According to the normality test (Jarque-Bera (JB) test), the null hypothesis of normally distributed residuals cannot be rejected. The Ramsey RESET test result shows that the calculated χ^2 value is less than the critical value at the 5% level of significance. The Breusch-Godfrey serial correlation LM test suggests that the residuals are not serially correlated. The Breusch-Pagan-Godfrey test (heteroscedasticity test) suggests that the disturbance term in the equation is homoscedastic. Long-run results are given in Table 4. Results show that GDP has positive and significant coefficient in all cases. Our results are similar with Cialani (2007), Lee and Brahmasrene (2013), Bekhet et al. (2017), and Zhang and Da (2015). Energy consumption has positive and significant impact on CO_2 emission in almost all samples of countries. Our results are in line with the finding of Sharma (2011), Jalil and Mahmud (2009), and Ang (2007). GDP^2 has negative sign and statistically significant in all regressions in the long run indicating an evidence of existence of EKC hypothesis as GDP and GDP^2 have positive and negative signs respectively.

Financial development is an important driver for reduction of CO_2 emission. Other studies like Frankel and Romer (1999), Cole and Elliot (2005), Tamazian et al. (2009), and Yuxiang and Chen (2010) confirm this result. Trade openness coefficient has mixed signs. In case of Malaysia, Singapore, the Philippines, and Vietnam coefficient has positive sign and in the case of Indonesia and Thailand, the coefficient has negative sign. Our result of positive impact of trade openness on CO_2 emission is in line with the finding of He and Wang (2011), Jalil and Mahmud (2009), and Shahbaz et al. (2013).

Table 5 shows estimated short-run coefficients for the ARDL model. This is clear from the results that error correction term has negative sign and statistically significant. The

Table 9 Phillips-Perron test

At level	Indonesia		Malaysia		Singapore		Thailand		Philippines		Vietnam	
Variable	Intercept	Intercept and trend	Intercept	Intercept and trend	Intercept	Intercept and trend	Intercept	Intercept and trend	Intercept	Intercept and trend	Intercept	Intercept and trend
CO	− 1.002	− 2.880	− 1.281	− 1.612	− 2.069	− 2.517	− 1.152	− 0.864	− 0.819	− 2.473	0.490	− 1.928
EN	− 1.350	− 1.075	− 1.330	− 1.709	− 1.809	− 1.417	− 0.545	− 1.756	− 2.177	− 2.093	1.406	− 1.909
FIN	− 2.541	− 2.244	− 2.799	− 2.398	− 1.344	− 2.531	− 1.937	− 1.757	− 1.501	− 1.968	− 1.774	− 1.072
GDP	− 0.791	− 2.165	− 1.567	− 2.564	− 1.584	− 1.692	− 2.193	− 1.197	2.667	− 0.826	1.044	− 3.705
GDP2	− 0.791	− 2.165	− 2.765	− 1.346	− 1.452	− 1.746	− 2.064	− 1.176	2.862	− 0.526	1.768	− 4.907
TR	− 2.477	− 2.467	− 1.675	− 2.341	− 2.335	− 2.449	− 1.138	− 1.153	− 1.408	− 0.991	− 3.572	− 3.468
At first difference												
CO	− 6.676	− 6.440	− 6.429	− 6.460	− 7.389	− 7.445	− 3.880	− 4.268	− 4.536	− 4.541	− 4.913	− 5.001
EN	− 5.917	− 6.085	− 6.390	− 6.822	− 6.378	− 6.601	− 4.326	− 4.255	− 7.146	− 7.065	− 3.532	− 3.845
FIN	− 4.384	− 4.407	− 5.379	− 5.480	− 6.164	− 6.087	− 3.242	− 3.372	− 3.759	− 3.825	− 3.998	− 4.936
GDP	− 4.427	− 4.371	− 4.235	− 5.468	− 3.775	− 3.843	− 3.207	− 3.592	− 2.874	− 4.155	− 2.499	− 2.280
GDP2	− 4.427	− 4.371	− 4.835	6.422	− 3.817	− 3.862	− 3.287	− 3.631	− 2.871	− 4.276	− 2.351	− 2.304
TR	− 8.414	− 8.570	− 5.985	− 6.460	− 5.752	− 5.673	− 5.432	− 5.522	− 4.667	− 4.730	− 5.292	− 5.956

The critical values for intercept and intercept and trend at 5% are − 2.951 and − 3.548 and at 1% are − 3.639 and − 4.253, respectively. ** and * denote significance at 5% and 1% level respectively

error correction coefficient value is between − 0.356 and − 0.875 and it implies that when CO_2 is below or above equilibrium level, it is adjusted within the year. It also shows that speed of adjustment toward equilibrium is significant highly. The value of adjusted R^2 is between 0.56 and 0.86 in all models that goodness of fit.

Table 6 shows the results of estimated long-run coefficients for the ARDL model that has per capita GDP as dependent variable. Empirical results show that CO_2 has negative and significant impact on GDP per capita, and in the case of Vietnam, the result is insignificant. These results are confirmed in the studies of Boopen and Vinesh (2011) and Omri (2013). The coefficient of energy consumption is found to be positive and significant in the case of Indonesia, Malaysia, Singapore, and Thailand while in the case of the Philippines and Vietnam, it is

Table 10 Kwiatkowski-Phillips-Schmidt-Shin test

At level	Indonesia		Malaysia		Singapore		Thailand		Philippines		Vietnam	
Variable	Intercept	Intercept and trend	Intercept	Intercept and trend	Intercept	Intercept and trend	Intercept	Intercept and trend	Intercept	Intercept and trend	Intercept	Intercept and trend
CO	0.673	0.082	0.654	0.654	0.437	0.115	0.652	0.184	0.490	0.085	0.641	0.161
EN	0.657	0.184	0.679	0.170	0.502	0.187	0.671	0.149	0.124	0.117	0.618	0.199
FIN	0.189	0.131	0.488	0.167	0.627	0.063	0.527	0.130	0.310	0.067	0.757	0.160
GDP	0.744	0.115	0.734	0.127	0.710	0.132	0.720	0.167	0.593	0.220	0.675	0.096
GDP2	0.744	0.744	0.735	0.111	0.712	0.122	0.722	0.165	0.593	0.221	0.675	0.139
TR	0.187	0.181	0.308	0.183	0.206	0.107	0.661	0.176	0.306	0.171	0.699	0.170
At first difference												
CO	0.203	0.146	0.155	0.068	0.373	0.340	0.232	0.128	0.168	0.112	0.278	0.109
EN	0.247	0.095	0.207	0.097	0.224	0.064	0.109	0.097	0.103	0.099	0.440	0.176
FIN	0.237	0.141	0.247	0.077	0.067	0.067	0.193	0.088	0.114	0.082	0.309	0.067
GDP	0.125	0.098	0.079	0.062	0.186	0.056	0.320	0.067	0.656	0.238	0.245	0.142
GDP2	0.125	0.098	0.065	0.061	0.161	0.056	0.322	0.066	0.675	0.243	0.375	0.141
TR	0.109	0.067	0.423	0.423	0.132	0.127	0.212	0.121	0.215	0.123	0.295	0.484

The critical values for intercept and intercept and trend at 5% are 0.463 and 0.146 and at 1% are 0.739 and 0.216, respectively. ** and * denote significance at 5% and 1% level respectively

Table 11 Dickey-Fuller min-t. Unit root with break test

At level	Indonesia		Malaysia		Singapore		Thailand		Philippines		Vietnam	
Variable	B.D.	Intercept and trend	B.D.	Intercept and trend	B.D.	Intercept and trend	B.D.	Intercept and trend	B.D.	Intercept and trend	B.D.	Intercept and trend
CO	1990	− 4.639	1985	− 3.790	1987	− 2.766	1997	− 3.303	1989	− 2.569	1994	− 1.357
EN	2003	− 2.096	1994	− 3.656	1985	− 4.833	2008	− 3.876	2007	− 2.875	1999	− 2.248
FIN	2008	− 6.686	2006	− 5.119	1993	− 2.375	1995	− 3.347	2012	− 3.794	2009	− 3.258
GDP	1995	− 5.744	2008	− 3.207	1998	− 3.769	1994	− 3.998	1991	− 3.377	2006	− 2.357
GDP2	1999	− 5.744	1982	− 3.182	2007	− 4.678	1992	− 3.918	2002	− 3.459	2003	− 1.673
TR	2002	− 2.077	1991	− 2.431	1989	− 4.734	2010	− 2.724	1982	− 4.358	1982	− 2.377
At first difference												
CO	2001	− 6.661	2008	− 7.698	2009	− 7.366	1999	− 6.116	1985	− 6.248	1995	− 6.347
EN	2011	− 8.166	2001	− 6.489	1993	− 6.368	2007	− 5.718	2000	− 6.387	2010	− 7.357
FIN	1993	− 10.785	1991	− 6.365	2002	− 6.768	2005	− 5.865	1998	− 6.546	2002	− 7.379
GDP	1984	− 7.246	2006	− 7.144	2007	− 6.368	1991	− 6.673	1988	− 5.727	1991	− 6.379
GDP2	1990	− 7.346	1983	− 6.675	2000	7.357	2010	− 6.347	2004	− 5.772	2011	− 5.937
TR	2003	− 5.631	1982	− 6.348	1999	8.636	2012	− 6.732	1999	− 5.469	1982	− 7.379

B.D. represents break dates. Critical values at 5% and 1% are − 4.860 and − 5.348 respectively. ** and * denote significance at 5% and 1% level respectively

insignificant. The coefficient of financial development is positive and significant in all cases. Trade openness has positive impact on economic growth in the case of Malaysia, Singapore, Thailand, and the Philippines, and has negative impact in the case of Indonesia and Vietnam (Agénor 2004; Liang 2006; Herzer 2013) (Tables 7, 8, 9, 10, 11, and 12).

Conclusion and policy implications

The aim of this study is to investigate the relationship between financial development, GDP growth, environmental degradation, and energy consumption in South East Asian countries using annual time series data from 1980 to 2017. Up until now, in the case of South East Asian economies, we find no

Table 12 Intercept break min-t

At level	Indonesia		Malaysia		Singapore		Thailand		Philippines		Vietnam	
Variable	B D.	Intercept and trend	B D.	Intercept and trend	B D.	Intercept and trend	B D.	Intercept and trend	B D.	Intercept and trend	B D.	Intercept and trend
CO	1993	− 4.636	2006	− 0.889	1997	− 1.872	1987	− 3.303	1992	− 3.266	2002	− 2.436
EN	2010	− 2.096	2013	− 3.656	2001	− 2.268	2000	− 1.156	2009	− 2.348	2011	− 3.835
FIN	1993	− 6.686	2005	− 2.737	1993	− 2.345	2002	− 3.723	2003	− 3.246	2005	− 3.346
GDP	2001	− 4.258	1994	3.470	2012	− 2.246	1988	− 3.254	1983	− 2.278	1995	− 2.993
GDP2	1990	− 3.096	2010	− 5.435	1994	− 3.490	1992	− 2.548	2007	− 3.357	2001	− 3.467
TR	2008	− 2.453	1992	− 0.632	2013	− 1.457	1999	− 2.323	2009	− 3.457	2010	− 1.986
At first difference												
CO	2006	− 5.763	1992	− 7.239	1987	− 7.346	1999	− 6.116	1991	− 6.678	1994	− 6.765
EN	1985	− 6.547	2008	− 5.563	2011	− 5.659	2010	− 5.718	1997	− 5.376	2008	− 6.377
FIN	2005	− 6.464	1993	− 5.592	2006	− 6.376	2007	− 6.596	1992	− 6.677	2004	− 7.359
GDP	1993	− 7.565	2003	− 5.875	1993	− 6.688	1996	− 6.548	1992	− 5.952	1995	− 6.746
GDP2	2011	− 6.342	1990	− 6.570	1990	6.346	2005	− 6.325	2009	− 5.536	1989	− 6.565
TR	1992	− 5.857	2008	− 5.765	1984	− 7.858	2001	− 6.215	1988	− 5.674	2003	− 6.488

B.D. represents break dates. Critical values at 5% and 1% are − 4.643 and − 5.151 respectively. ** and * denote significance at 5% and 1% level respectively study investigating the relationship. The ARDL bound testing approach to cointegration has been used in the analysis. *F* test values show cointegration relationships between energy consumption, CO_2 emissions, economic growth, and trade openness in our sample countries. The signs and significance of variables are according to economic theory. Our findings show negative and significant relationship between financial development and CO_2 emissions in the case of five countries suggesting that over long run, efficient financial sector has dynamic role for reducing CO_2 emissions. Energy consumption, GDP growth, and trade openness are statistically significant in all selected countries, indicating that income growth, energy consumption, and trade openness are main factors in deteriorating environmental quality in selected countries.

Our finding indicate that the signs of estimated long-run coefficients of GDP and squared GDP satisfy the inverted *U*-shaped EKC hypothesis in our selected countries. There are different policy implications derived from this study. First, funds should be issued for productive purpose. Financial reforms should be implemented soundly and there should be a system of punishment to those firms which are source of CO_2 emissions in air and water by imposing restrictions on easy credit. Moreover, a twin purpose energy policies should be implemented that increases energy efficiency on one place and decreases energy consumption for mitigating the negative effects of CO_2 emissions. Trade openness is also main factor affecting environmental pollution. Results show that government needs to adopt policies that reduce environmental pollution by opening the trade sector.

References

Abid M (2017) Does economic, financial and institutional developments matter for environmental quality? A comparative analysis of EU and MEA countries. J Environ Manag 188:183–194

Agénor PR (2004) Does globalization hurt the poor? IEEP 1(1):21–51

Alam MJ, Begum IA, Buysse J, Van Huylenbroeck G (2012) Energy consumption, carbon emissions and economic growth nexus in Bangladesh: cointegration and dynamic causality analysis. Energy Policy 45:217–225

Ali HS, Yusop ZB, Hook LS (2015) Financial development and energy consumption nexus in Nigeria: an application of ARDL bound testing approach. Int J Energy Econ Policy 5(3):816–821

Ang JB (2007) CO_2 emissions, energy consumption, and output in France. Energy Policy 35:4772–4778

Antonakakis N, Chatziantoniou I, Filis G (2017) Energy consumption, CO_2 emissions, and economic growth: an ethical dilemma. Renew Sust Energ Rev 68(Part 1):808–824

Apergis, N., & Payne, J. E. (2010). Coal consumption and economic growth: Evidence from a panel of OECD countries. Energy Policy, 38(3), 10.1007/s11356-019-06624-7 1353-1359

Ayeche MB, Barhoumi M, Hammas MA (2016) Causal linkage between economic growth, financial development, trade openness and CO_2 emissions in European Countries. Am J Environ Eng 6(4):110–122. 3

Azomahou T, Laisney F, Nguyen Van P (2006) Economic development and CO_2 emissions: a nonparametric panel approach. J Public Econ 90:1347–1363

Bekhet HA, Matar A, Yasmin T (2017) CO_2 emissions, energy consumption, economic growth, and financial development in GCC countries: dynamic simultaneous equation models. Renew Sust Energ Rev 70:117–132

Boopen, S., Vinesh, S. (2011). On the relationship between CO_2 emissions and economic growth: the Mauritian experience. University of Mauritius, Mauritius Environment Outlook Report, http://www.csae.ox.ac.uk/conferences/2011-EDiA/papers/776-Seetanah.pdf, (12.03.2019).

Cialani, C. (2007). Economic growth and environmental quality: An econometric and a decomposition analysis. Management of Environmental Quality: An International Journal, 18(5), 568–577

Coban S, Topcu M (2013) The nexus between financial development and energy consumption in the EU: a dynamic panel data analysis. Energy Econ 39:81–88

Cole MA, Elliot RJR (2005) FDI and the capital intensity of ‘dirty' sectors: a missing piece of the pollution haven puzzle. Rev Dev Econ Lit 42(1):7–71

Daly, H. E. (1977). Steady-state economics. The economics of biophysical equilibrium and moral growth. W.H. Freemann and Company: San Francisco\Frankel. J. & Romer. D. (1999). Does trade cause growth? American Economic Review, 89 (3), 379- 399.

Frankel J, Romer D (1999) Does trade cause growth? Am Econ Rev 89(3):379–399

Georgescu-Roegen N (1971) The entropy law and the economic process. Harvard University Press. Cambridge, MA

Ghali KH, El-Sakka MI (2004) Energy use and output growth in Canada: a multivariate cointegration analysis. Energy Econ 26:225–238

Halicioglu F (2008) The bilateral J-curve: Turkey versus her 13 trading partners. J Asian Econ 19:236–243

Halkos G, Sepetis A (2007) Can capital markets respond to environmental policy of firms? Evidence from Greece. Ecol Econ 63(2/3):578–587

He J, Wang H (2012) Economic structure, development policy and environmental quality: an empirical analysis of environmental Kuznets curves with Chinese municipal data. Ecol Econ 76:49–59

Herzer D (2013) Cross-country heterogeneity and the trade-income relationship. World Dev 44:194–211

Islam F, Shahbaz M, Ahmed AU, Alam MM (2013) Financial development and energy consumption nexus in Malaysia: a multivariate time series analysis. Econ Model 30:435–441

Jalil A, Feridun M (2011) The impact of growth, energy and financial development on the environment in China: a cointegration analysis. Energy Econ 33:284–291

Jalil, A., & Mahmud, S. F. (2009). Environment Kuznets curve for CO2 emissions: a cointegration analysis for China. Energy policy, 37(12), 5167–5172.

Jayanthakumaran K, Verma R, Liu Y (2012) CO2 emissions, energy consumption, trade and income: a comparative analysis of China and India. Energy Policy 42:450–460

Johansen S (1992) Cointegration in partial systems and the efficiency of single-equation analysis. J Econ 52:389–402

Lee JW, Brahmasrene T (2013) Investigating the influence of tourism on economic growth and carbon emissions: evidence from panel analysis of the European Union. Tour Manag 38:69–76

Lee JM, Chen KH, Cho CH (2015) The relationship between CO_2 emissions and financial development: evidence from OECD countries. Singap Econ Rev 60(5):1550117

Lin, N. H., Sayer, A. M., Wang, S. H., Loftus, A. M., Hsiao, T. C., Sheu, G. R., ... & Chantara, S. (2014). Interactions between biomass-burning aerosols and clouds over Southeast Asia: Current status, challenges, and perspectives. Environmental pollution, 195, 292-307

Z. Liang (2006) Threshold estimation on the globalization poverty nexus: evidence from China Research Paper, UNU-WIDER United Nations University (No. 2006/57)

Lo S-F, Sheu H-J, Hu J-L (2005) Taking CO_2 emissions into a country's productivity change: the Asian growth experience. Int J Sustain Dev World Ecol 12:279–290

Mehrara, M., & Oskoui, K. N. (2007). The sources of macroeconomic fluctuations in oil exporting countries: A comparative study. Economic Modelling, 24(3), 365–379

Nasreen S, Anwar S, Ozturk I (2017) Financial stability, energy consumption and environmental quality: evidence from South Asian economies. Renew Sust Energ Rev 67:1105–1122

Omri A (2013) CO_2 emissions, energy consumption and economic growth nexus in MENA countries: evidence from simultaneous equations models. Energy Econ 40:657–664

Omri A, Daly S, Rault CH, Chaibi A (2015) Financial development, environmental quality, trade and economic growth: what causes what in MENA countries. Energy Econ 48:242–252

Ozturk I, Acaravci A (2013) The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. Energy Econ 36(C):262–267

Pesaran MH, Shin Y, Smith RJ (2001) Bounds testing approaches to the analysis of level relationships. J Appl Econ 16:289–326

Sadorsky P (2010) The impact of financial development on energy consumption in emerging economies. Energy Policy 38(5):2528–2535

Sadorsky P (2011) Financial development and energy consumption in Central and Eastern European frontier economies. Energy Policy 39:999–1006

Shahbaz M, Lean HH (2012) Does financial development increase energy consumption? The role of industrialization and urbanization in Tunisia. Energy Policy 40:473–479

Shahbaz. M., Tiwari. A. K., & Nasir. M. (2013) The effects of financial development, economic growth, coal consumption and trade openness on environment performance in South Africa. Retrieved from http://www.researchgate.net/publication/254443091.

Shahbaz M, Shahzad S, Hussain J, Nawaz A, Shaista A (2016) Financial development and environmental quality: the way forward. In: MPRA Paper 74704. University Library of Munich, Germany

Sharma SS (2011) Determinants of carbon dioxide emissions: empirical evidence from 69 countries. Appl Energy 88:376–382

Shin, Y., & Schmidt, P. (1992). The KPSS stationarity test as a unit root test. Economics Letters, 38(4), 387–392

Soytas U, Sari R, Ewing BT (2007) Energy consumption, income, and carbon emissions in the United States. Ecol Econ 62:482–489

Tamazian A, Rao B (2010) Do economic, financial and institutional developments matter for environmental degradation? Evidence from transitional economies. Energy Econ 32(1):137–145

Tamazian A, Chousa J, Vadlamannati KC (2009) Does higher economic and financial development lead to environmental degradation: evidence from BRIC countries. Energy Policy 37(1):246–253

Tang CF, Tan BW (2014) The linkages among energy consumption, economic growth, relative price, foreign direct investment and financial development in Malaysia. Qual Quant 48:781–797

Tariq B, Ab Rahim R (2016) The environmental effects of intra-industry trade in the SAARC region. Int J Bus Soc 17(1):113–130

Taskin F, Zaim O (2000) Searching for a Kuznets curve in environmental efficiency using kernel estimation. Econ Lett 68:217–223

Toda HY, Yamamoto T (1995) Statistical inference in vector autoregressions with possibly integrated processes. J Econ 66: 225–250

Tsani SZ (2010) Energy consumption and economic growth: a causality analysis for Greece. Energy Econ 32:582–590

Wolde-Rufael Y (2006) Electricity consumption and economic growth: a time series experience for 17 African countries. Energy Policy 34: 1106–1114

Yohanes SP, Astriana F, Adiwena.W. (2015) Ensuring the ASEAN Agreement of Transboundary Haze's (AATHP) effectiveness: a case study of Riau province's haze summary. The Habibie Center - ASEAN Studies Program 2(4):1–2

Yuxiang K, Chen Z (2010) Financial development and environmental performance: evidence from China. Environ Dev Econ 16:93–111

Zhang YJ (2010) The impact of financial development on carbon emissions: an empirical analysis in China. Energy Policy 39:2197–2203

Zhang YJ (2011) The impact of financial development on carbon emissions: an empirical analysis in China. Energy Policy 39(4):2197–2203

Zhang, Y. J., & Da, Y. B. (2015). The decomposition of energy-related carbon emission and its decoupling with economic growth in China. Renewable and Sustainable Energy Reviews, 41, 1255–1266

Zou G, Chau K (2006) Short-and long-run effects between oil consumption and economic growth in China. Energy Policy 34:3644–3655