International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2019, 9(3), 135-143.

The Impact of Renewable Energy Consumption on Carbon Dioxide Emissions: Empirical Evidence from Developing Countries in Asia

Azilah Hasnisah, A. A. Azlina*, Che Mohd Imran Che Taib

Universiti Malaysia Terengganu, Malaysia. *Email: aqlina@umt.edu.my

Received: 03 January 2019 **Accepted:** 12 March 2019 **DOI:** https://doi.org/10.32479/ijeep.7535

ABSTRACT

This empirical study examines the relationship between environmental quality, economic development, renewable and non-renewable energy (RE) consumption in 13 developing countries in Asia. We use panel data in the period from 1980 to 2014 and panel cointegration, fully modified ordinary least squares (OLS) and dynamics OLS estimators are employed to test for cointegration in the long-run. The study confirms the existence of the inverted U-shape Environmental Kuznets Curve hypothesis in 13 Asia countries for both estimators with the increment of GDP per capita and conventional energy consumption decreasing the environmental quality. However, the empirical finding suggests that RE consumption is insignificant in contributing to less pollution regarding CO_2 emissions. This study concludes that to comprehend better the potential factors affecting the CO_2 emissions, the sampled countries can design a strategic plan to mitigate the rate of global warming and climate change, while at the same time stimulating economic development and promoting energy from eco-friendly resources.

Keywords: Carbon Dioxide, Renewable Energy, Environmental Kuznets Curve
JEL Classifications: Q20, Q30, Q56

1. INTRODUCTION

The linkages between environmental quality and economic development have been discussed thoroughly. In particular, developing countries in Asia (i.e., Bangladesh, China, India, Iran, Iraq, Indonesia, Malaysia, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka and Thailand) have recorded excellent economic development in the most recent three decades as illustrated in Table 1. However, this impressive performance has also led to environmental issues such as increasing the level of CO_2 emissions. The release of CO_2 emissions is one of the contributors to the greenhouse effect which is largely due to human activities such as burning fossil fuels (FOSS) and deforestation (NASA 2018). As in Figure 1, among the selected 13 Asian countries, in 2014, Iran was the largest emitter of CO_2 emissions with 8.28 metric tonnes per capita followed by Malaysia and China. In the same year, Iran was also the largest country in Asia that consumed energy from FOSS based with 98.98%, closely followed by Iraq (97.27%), Malaysia (96.63%) and China (87.48%). In addition, Nepal was the largest country in Asia that uses energy from renewable sources with 84.37%, followed by Myanmar (66.13%) and Sri Lanka (57.59%) as in Figure 1.

Nevertheless, excellent economic performance requires a lot of energy. The high demand, dependency and consumption of energy from conventional sources mainly generated from natural gas, oil and coal have contributed to environmental problems such as increased level of CO_2 emissions which lead to climate change. Apart from that, the empirical evidence remains scarce in the case of Asian countries. In a recent study by Apergis and Ozturk (2015) which incorporating only CO_2 emissions and gross domestic product in their study found the existence of

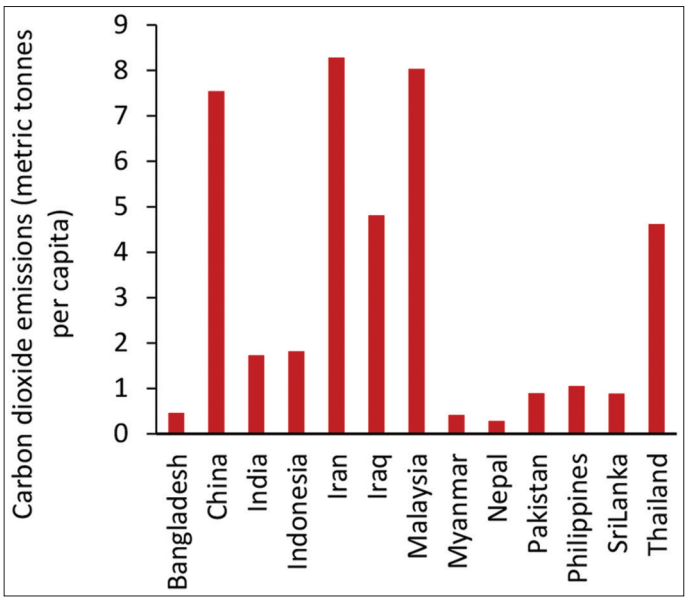
This Journal is licensed under a Creative Commons Attribution 4.0 International License

Table 1: GDP per capita (constant 2010 US$) of 13 selected developing countries in Asia between 1980 and 2014

GDP per capita	1980	2014	GDP per capita	1980	2014
Bangladesh	351.38	922.16	Myanmar	211.37	1266.12
China	347.89	6108.24	Nepal	283.05	675.74
India	389.93	1646.78	Pakistan	556.31	1111.19
Indonesia	1230.84	3692.94	Philippines	1687.29	2505.82
Iran	4684.52	6161.10	Sri Lanka	909.32	3506.73
Iraq	3345.99	5203.44	Thailand	1403.68	5589.69
Malaysia	3317.31	10398.23			

Source: World development indicator

Figure 1: CO_2 emissions (metric tonnes per capita) in 2014



Source: World Bank (2018)

the Environmental Kuznets Curve (EKC) hypothesis 14 Asian countries. The existence of the EKC hypothesis indicates that decreasing environmental quality due to pollution is an inevitable consequence at the beginning of economic improvement, but as income grows, the environmental quality improves over time.

As of July 2018, Bangladesh, China, India, Indonesia, Malaysia, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka and Thailand have ratified the Paris Agreement which committed to reducing pollution to mitigate climate change by keeping a global temperature rise below 2 degrees Celsius (UNFCC 2018). In order to reach this goal, every party involved in developed and developing countries should be ready to take action in terms of financial support, capacity and advanced innovation to achieve their national objectives.

In line with that, one of the targets in the Sustainable Development Goals (SDGs) is to provide affordable and clean energy by enhancing and promoting the contribution of renewable energy (RE) in the total energy mix, enhance international cooperation for better research on environmentally friendly energy with technologies, innovation and investment by 2030 (SDG, 2018). Enhancing RE consumption in the global energy mix will provide a positive impact on environmental quality. As reported by the Energy Information Administration (2018), increasing contribution of electricity generation from renewable and nuclear sources by 35% has reduced the carbon intensity of the electricity supply in 2016. In addition, the electricity consumption from hydroelectric source shows encouraging improvement mostly in China and India as well as other countries over time (Environmental Impact Assessment, 2018).

Hence, this study examines the linkages among CO_2 emissions, economic growth, renewable and non- RE consumption in 13 Asian countries using Fully Modified Ordinary Least Squares (OLS) (FMOLS) and dynamic OLS (DOLS) from 1980 to 2014. It intends to contribute to the research regarding the EKC hypothesis by providing new evidence based on empirical analysis of electricity consumption from FOSS based on a proxy for non- RE consumption. Other than that, this empirical study also examines the potential of electricity consumption from hydroelectric resources as a proxy for RE consumption in 13 Asian countries.

Given the above background, it is crucial to investigate the role of RE consumption within the EKC framework in Asia, which positively impacts on environmental quality by reducing pollution and enhancing economic performance. This study additionally contributes to the literature by using the panel data technique to explore the linkages between environmental quality, economic performance, renewable and non- RE used in 13 Asian countries. The selected 13 countries are developing countries in Asia. They have high consumption levels of energy especially non-renewable sources and are large emitters of CO_2 compared with other Asian members. Fully modified OLS (FMOLS) and Dynamic OLS (DOLS) approaches are employed to support a better understanding of the relationship between CO_2 emissions, real per capita GDP, electricity consumption from hydroelectric and electricity consumption from FOSS. The study also examines the existence of the EKC hypothesis. The outcomes would have policy implications for the region.

The paper is organised as follows. Section 2 reviews the recent literature, Section 3 details the selected data, model and used methodology, Section 4 and 5 reports the empirical results and discussions based on the analysis. It also concludes the study while offering policy recommendations.

2. LITERATURE REVIEW

Studies of environmental quality and economic performance hypothesised that environmental pollution is an inverted U-shape curved of income per capita. This inverted U-shape curve is widely known as the EKC hypothesis. The EKC hypothesis indicates that

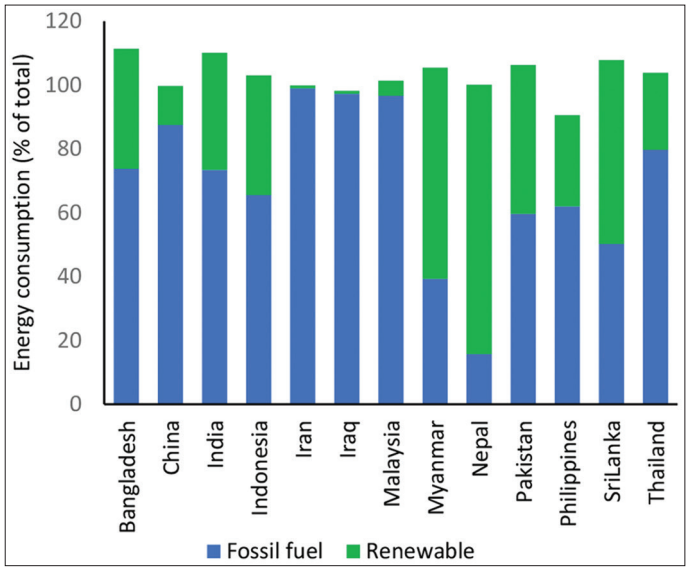
pollution worsens in the early stage of economic growth until it reaches a turning point after which pollution reduces with higher income per capita (Grossman and Krueger 1991). According to Selden and Song (1994), a high level of pollution is inevitable since many technological innovations in various economic sectors is required in the early phase of economic growth.

Along with the rapid economic activities, the abundant demand for energy, especially from conventional resources such as coal, oil and natural gas, also increases every year. A close relationship between energy consumption and per capita income has contributed to the decline in environmental quality. Hence, numerous studies explored the linkages between non- RE consumption, economic growth and environmental quality (Chandran and Tang, 2013; Heidari et al., 2015; Niu et al., 2011; Zhu et al., 2016). Regarding the EKC hypothesis, the empirical studies from Chandran and Tang (2013), Heidari et al. (2015) and Zhu et al. (2016) investigated the existence of this hypothesis in ASEAN-5 and failed to validate its presence in those countries. Summary of selected previous literature on the renewable energy consumption, CO2 emissions, GDP per capita and energy consumption published between 2007 till 2018 as presented in Table 2.

With increasing demand for energy in various industrial sectors, energy production from conventional sources is unable to cope with such high demand. In this regard, the emergence of energy from renewable sources is an alternative to reduce dependency and reliance on traditional sources as well as improving economic performance. Hence, the empirical studies by Bölük and Mert (2014), Dogan and Seker (2016a, 2016b) Irandoust (2016), Jebli et al. (2016), Liu et al. (2017) and Sebri and Ben-Salha (2014) incorporated RE consumption as an additional variable to explore the linkages between non- RE consumption, economic growth and environmental quality. However, only Bölük and Mert (2014), Dogan and Seker (2016a, 2016b), Jebli et al. (2016) and Liu et al. (2017) investigated the presence of the EKC hypothesis. On the contrary, the empirical findings by Bölük and Mert (2014), Jebli et al. (2016) and Liu et al. (2017) found that the EKC hypothesis is invalidated in 16 European Union, 25 OECD and ASEAN-4 countries, respectively. Meanwhile, Dogan and Seker (2016a, 2016b) found that the EKC hypothesis is validated in 15 EU and 40 top RE countries. According to Dogan and Seker (2016a, 2016b), Jebli et al. (2016) and Liu et al. (2017), high consumption from RE improves the environmental quality by reducing CO_2 emissions, and extensive use of energy from conventional sources increases the emissions. Meanwhile, Bölük and Mert (2014) found that energy used from renewable sources contributes to a 50% reduction in emissions compared to energy from conventional sources.

Several studies examined the presence of the inverted U-shape between environmental pollution and per capita income for individual countries without taking into account RE in their modelling framework (Ang, 2007; Lau et al., 2014). The empirical findings from Ang (2007) and Lau et al. (2014) found that the EKC hypothesis is valid in France and Malaysia. Later on, several studies added RE consumption as another exogenous variable (Azlina et al., 2018; Azlina et al., 2014; Bölük and Mert,

Figure 2: Energy consumption (% of total) in 2014



Source: World Bank (2018)

2015; Sugiawan and Managi 2016; Almulali et al., 2016). The empirical studies by Azlina et al. (2018), Bölük and Mert (2015) and Sugiawan and Managi (2016) provides evidence that the inverted U-shape of the EKC hypothesis is validated and energy production from renewable sources can mitigate pollution by reducing CO_2 emissions in the long-run for the case of Malaysia, Turkey and Indonesia. In contrast, previous study by Azlina et al. (2014) found that the inverted U-shape of the EKC hypothesis is invalid, but energy consumption from renewable sources still provides a positive impact on environmental quality in Malaysia. Meanwhile, Aung et al. (2017) found that EKC hypothesis is failed to validate for CO2 emissions but the existence of inverted U-shaped can be observed for methane (CH4) and nitrous oxide (N2O) in Myanmar.

Apart from that, the literature reveals the presence of bidirectional causality between RE consumption and economic growth in the European Union, OECD, Eurasia and G7 countries (Al-Mulali et al., 2013; Alper and Oguz, 2016; Apergis and Payne, 2010a, 2010b; Chang et al., 2015). According to Al-Mulali et al. (2013), higher income countries are more likely to have bidirectional causality between RE consumption and economic growth in the long-run. The findings also reported that the feedback hypothesis also exists in ASEAN countries, namely Malaysia, Indonesia, Philippines and Thailand. However, Alper and Oguz (2016) failed to confirm the presence of the feedback hypothesis in most new EU member countries (Cyprus, Estonia, Hungary, Poland and Slovenia) due to less energy production from renewable sources. Meanwhile, in the case of ASEAN countries, evidence from Chandran and Tang (2013) reported unidirectional causality running from CO_2 emissions to conventional energy consumption in the short-run for Indonesia and Malaysia and bidirectional causality between CO_2 emissions and energy consumption in the Philippines and Thailand. In another study conducted by Azam et al. (2015) and Wang et al. (2016), the empirical results reveal the existence of unidirectional causality running from conventional energy used to economic growth and CO_2 emissions in Malaysia and ASEAN-8 countries.

Table 2: Summary of selected previous literature on the renewable energy consumption, CO_2 emissions, GDP per capita and conventional energy consumption published between 2007 till 2018

Authors	Study area	Period	Variables	Methodology	Result
Apergis and Ozturk (2015)	14 Asian countries	1990–2011	GDP, CO_2	GMM	EKC is validated
Alper and Oguz (2016)	8 new EU member	1990–2009	RE, GDP, C, L	ARDL	RE has positive impact on GDP
Apergis and Danuletiu (2014)	80 countries	1990–2012	RE, GDP, C, L	Canning and Pedroni long-run causality	RE→GDP in long-run
Irandoust (2016)	4 Nordic countries	1975–2012	RE, GDP, CO_2, TI	VAR	RE→CO_2 (Denmark, Finland) RE↔CO_2 (Sweden, Norway) GDP, TI→RE (all countries) RE≠GDP
Jebli et al. (2016)	25 OECD countries	1980–2010	RE, GDP, CO_2, EC, IM, EX	FMOLS, DOLS	EKC is validated with increases in EC increases CO_2, and increases RE and TR reduces CO_2
Menegaki (2011)	27 European countries	1997–2007	RE, GDP, CO_2, EC	Random effect model	RE≠GDP
Sebri and Ben-Salha (2014)	BRICS countries	1971–2010	RE, GDP, CO_2, TR	ARDL, VECM	RE↔GDP
Shahbaz et al. (2015)	Pakistan	1972Q1–2011Q4	RE, GDP, C, L	ARDL, VECM	RE, C and L have positive impact on GDP RE↔GDP
Chang et al. (2015)	G7 countries	1990–2011	RE, GDP	Granger causality	RE↔GDP (overall panel)
Azam et al. (2015)	ASEAN-5 countries	1980–2012	GDP, EC, C, EX	Granger causality	EC→GDP (Malaysia) C→EC (Thailand, Philippines) EX, C→EC (Singapore)
Chandran and Tang (2013)	ASEAN-5 countries	1971–2008	GDP, CO_2, EC, FDI	VECM	EKC is invalid with GDP and EC significant on CO_2 GDP↔CO_2 (Indonesia, Thailand) GDP→CO_2 (Malaysia)
Liu et al. (2017)	ASEAN-4 countries	1970–2013	RE, GDP, CO_2, EC, AGR	Panel VECM granger causality	EKC is invalid with increasing RE and AGR reduces CO_2, while high EC increases CO_2
Niu et al. (2011)	8 Asian-Pacific countries	1971–2005	GDP, CO_2, EC	Panel VECM granger causality	EC→CO_2 (general) CO_2, EC and energy efficiency lower in developing countries
Wang et al. (2016)	ASEAN-8 countries	1980–2009	CO_2, EC, URB	Panel Granger causality, FMOLS	URB has negative impact on CO_2 URB, EC→CO_2
Zhu et al. (2016)	ASEAN-5 countries	1981–2011	CO_2, GDP, EC, FDI	Panel quantile regression	EKC is invalid with high TR reduces CO_2
Bölük and Mert (2014)	16 EU countries	1990–2008	RE, GDP, CO_2, EC	Panel data (OLS)	EKC is invalid with RE contribute half emissions compared to EC
Dogan and Seker 2016b)	40 top renewable energy countries	1985–2011	RE, GDP, CO_2, EC, TR, FD	FMOLS, DOLS	EKC is validated with high RE, TR and FD reduces CO_2, while high EC increases CO_2
Dogan and Seker (2016a)	15 EU countries	1980–2012	RE, GDP, CO_2, EC, TR	DOLS, Dumitrescu-hurlin non-causality	EKC is validated, with high RE and TR reduces CO_2while EC increases CO_2 RE↔CO_2, GDP, TR→CO_2, CO_2→EC
Dong et al. (2017)	BRICS countries	1985–2016	RE, GDP, CO_2, NG	AMG panel co-integration	EKC is validated, with high RE and NG reduces CO_2
Heidari et al. (2015)	ASEAN-5 countries	1980–2008	GDP, CO_2, EC	PSTR	EKC is validated
Ang (2007)	France	1960–2000	GDP, CO_2, EC	ARDL, VECM	EKC is validated GDP→CO_2, EC
Azlina et al. (2018)	Malaysia	1980–2013	RE, GDP, CO_2, EC, TR	ARDL, VECM	EKC is validated RE↔EC
Azlina et al. (2014)	Malaysia	1975–2011	RE, GDP, CO_2, EC	VECM	EKC is invalid with high RE reduces CO_2 while EC increases CO_2
Lau et al. (2014)	Malaysia	1970–2008	GDP, CO_2, TR, FDI	ARDL, granger causality	EKC is validated with high TR and FDI reduces CO_2
Bölük and Mert (2015)	Turkey	1961–2010	RE, GDP, CO_2	ARDL	EKC is validated with high RE reduces CO_2
Sugiawan and Managi (2016)	Indonesia	1971–2010	RE, GDP, CO_2, EC, TFP	ARDL	EKC is validated with high RE and TFP reduces CO_2while EC increases CO_2
Azam and Khan (2016)	Low, lower middle, upper middle, high income countries	1975–2014	GDP, CO_2, EC, TR, URB	Johansen co-integration	EKC is validated in low and lower middle income countries

ARDL: Auto-regressive distributed lag, DOLS: Dynamic ordinary least squares, EX: Exports, FD: Financial development, FMOLS: Fully modified ordinary least squares, IM: Imports, L: Labour, C: Capital, TI: Technological innovation, FDI: Foreign direct investment, AGR: Agricultural value added, URB: Urbanization, PSTR: Panel smooth transition regression, TFP: Total factor productivity, GMM: Generalized method of moment, NG: Natural gas consumption, AMG: Augmented mean group

The significance of conventional energy used for economic development and environmental quality creates an argument whether consumption from RE is significant in the EKC hypothesis. Thus, the present paper examines the linkages between per capita CO_2 emissions, economic growth, electricity consumption from FOSS and electricity consumption from renewable sources to validate the existence of the EKC curve hypothesis for a panel of 13 Asian countries.

3. METHODOLOGY

3.1 Specification Models

Numerous studies by Ang (2007), Azam and Khan (2016), Chandran and Tang (2013), Heidari et al. (2015), Niu et al. (2011) and Zhu et al. (2016) investigated the environment quality, economic development and energy consumption within the EKC framework with CO_2 emissions as the dependent variable. In addition, the studies Azlina et al. (2014), Bölük and Mert (2014), Dogan and Seker (2016a, 2016b), Dong et al. (2017), Liu et al. (2017) and Sugiawan and Managi (2016) disaggregated energy consumption into renewable energy consumption and non-RE consumption, environment quality and economic development within the EKC framework in which CO_2 emissions are regressed on the real income per capita (GDP), the quadratic real income per capita (GDP^2), RE consumption and non-RE consumption (FOSS).

To investigate the long-run relationships between per capita CO_2 emissions (CO_2), economic growth (GDP) and squared economic growth (GDP^2), the multivariate framework is established following the model from Dogan and Seker (2016a, 2016b) and Jebli et al. (2016). Each selected variable is converted into a natural logarithm. The standard EKC model can be shown as:

$$lnCO_{2it} = \beta_0 + \beta_1 lnGDP_{it} + \beta_2 lnGDP_{it}^2 + \mu_{it} \quad (1)$$

By introducing electricity consumption from FOSS and electricity consumption from renewable sources as another independent variable into the Equation. (1), the modified EKC model is as follows:

$$\ln CO_{2it} = \beta_0 + \beta_1 \ln GDP_{it} + \beta_2 \ln GDP_{it}^2 + \beta_3 \ln FOSS_{it} + \beta_4 \ln RE_{it} + \mu_{it} \quad (2)$$

Where i and t stands for country and the time; while denotes normally distributed error term; β_1,$\beta_2$$\beta_3$ and β_4 are the coefficient estimates on the selected variables, respectively. Equation. (2) employs both GDP and the quadratic of GDP as exogenous variables. Thus, the expected coefficients of $\beta_1 > 0$, and $\beta_2 < 0$ validated the existence of the EKC hypothesis. A threshold of EKC is when per capita income is low risk on the pollution, and the relationship between these two indicators resembles an inverted U-shaped curve. According to Stern (2017), the value of the turning point (τ) of the EKC can be formulated as τ=exp f()($-(0.5\beta_1)/\beta_2$). First, as the economy grows in the early phase of economic development, lots of energy is required to fulfil the energy demand from various sectors and industries. Accordingly, heavy dependence on conventional energy sources from natural gas, oil and coal is inevitable because of its reliability and cheaper compared to RE. As consequences, the level of environmental quality reduced as CO_2 emissions increases which contribute to pollution. The positive impact of environmentally friendly energy on environmental quality can be achieved by promoting its consumption and contribution in the total energy mix.

Thus, by applying the panel cointegration approach, this empirical study examines the relationship between environmental quality, economic development, RE and non- RE consumption for a panel of 13 Asian countries during the 1980-2014 period. The empirical analysis is started by examining the stationarity of each variables using common and individual unit root tests. This study applies panel cointegration tests; namely Pedroni cointegration test Pedroni (1999, 2004) and Kao cointegration test Kao (1999) to test the existence of a long-run relationship among variables.

After confirming the presence of cointegration, this study uses the fully modified OLS (FMOLS) and dynamic OLS (DOLS) estimators to show long-run coefficient estimates of the real income per capita, the square of real income per capita, renewable and non- RE consumption for CO_2 emissions. The FMOLS approach and the DOLS estimators have been proposed by Pedroni (2001, 2004) and Kao and Chiang (2000) and Mark and Sul (2003).

This study uses the FMOLS and the DOLS estimators in order to show long-run coefficient estimates of the CO_2 emissions, GDP per capita, squared of GDP per capita, squared of GDP per capita, energy consumption from conventional sources and energy consumption from renewables.

3.2 Data and Variables

CO_2 emissions denoted as CO_2 as a proxy for environmental quality in metric tonnes per capita concerning the independent variables, while independent variables, GDP per capita (constant 2010 US$) as a proxy for low economic growth and squared of GDP per capita as a proxy for high economic growth. FOSS is electricity consumption from FOSS measured in million Kw based as a proxy for energy consumption from conventional sources, and RE is electricity consumption from renewable sources measured in million Kw as proxy for energy consumption from renewable sources. The dataset was obtained from 1980 to 2014. The panel data on CO_2 emissions and GDP per capita are taken from the World Development Indicators (WDI), and the data on FOSS and RE retrieved from the U.S. Energy Information Administration. This study selected 13 countries in Asia based on the availability of data extracted from WDI and Energy Information Administration including Bangladesh, China, India, Iran, Iraq, Indonesia, Malaysia, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka and Thailand. The data used in this study are transformed into the natural logarithm in order to interpret the coefficient estimates as the elasticities of the response variable.

The magnitude of coefficients for EC and RE, β_3 and β_4 are predicted to be positive and negative respectively as shown by Dogan and Seker (2016b). Table 3 reports a summary of descriptive statistics with means, standard deviation, maximum

and minimum of each selected variables before transforming into the logarithm form from 1980-2014.

4 EMPIRICAL RESULTS

4.1 Panel Unit Root Tests

This empirical work uses four different panel unit root tests developed by Levin-Lin-Chu (LLC) Levin et al. (2002), Breitung (2000), Im-Pesaran-Shin (IPS) Im et al. (2003) and Fisher Phillips-Perron (PP) Phillips and Perron (1988) tests to examine the stationarity of each series. As in Table 4, the panel unit root tests can be classified into common and individual unit root. The first group of common unit root consists of the t-statistics of Breitung (2001) and LLC's test by Levin et al. (2002). Next, another group of individual unit root tests includes IPS-W-statistic (Im et al., 2003) and PP-Fisher Chi-square (Phillips and Perron, 1988). The assumption for the null hypothesis is that the series is not stationary with a unit root, while the alternative hypothesis is that the series is stationary with no unit root. All panel unit root tests are estimated with intercept and deterministic trends.

Table 4 of panel unit root tests of LLC, Breitung, IPS and PP reports the results of panel unit root statistics tests at the level and after the first difference. The p-values of variables of CO_2, GDP, GDP^2, FOSS and RE accept the null hypothesis of unit root at level. The four unit root tests reject the null hypothesis of non-stationary at 1% level of significance, after the first difference. In other words, we can conclude that CO_2, GDP, GDP^2, FOSS and RE are all I (1).

4.2 Panel Co-integration Test

First and foremost, this study employs the Pedroni panel cointegration test (Pedroni, 1999) to find a possible cointegration relationship between the analysed variables in Equation (2). According to Pedroni (1999), there are seven tests statistics as shown in Table 5. The results from the Pedroni panel cointegration test indicate that majority of the test statistics provide evidence with the presence of cointegrating relationship between the analysed variables in Equation (2).

The second panel cointegration test is the Kao panel cointegration test (Kao 1999). According to the results in Table 5, the analysed variables in Equation (2) are cointegrated and have long-run relationships since we have enough evidence to reject the null hypothesis of no cointegration in favour of the alternative hypothesis of cointegration at 5% level of significance.

As reported in Table 5, results from Pedroni cointegration tests (Pedroni, 2001, 2004) can be categorised into within-dimension and between-dimension parts. Two out of four panel statistics reject the null hypothesis of no cointegrating relationship among selected variables at the 1% and 5% significance level in the within-dimension part. Meanwhile, for the between-dimension part, two out of three group statistics reject the null hypothesis. Thus, this result indicates a long-run cointegrating relationship between these selected variables in 13 Asian countries. The Kao cointegration test developed by Kao (1999) is applied to confirm the accuracy and reliability of the previous result.

Table 3: Summary of descriptive statistics for each series

Variable	Unit of measurement	Mean	Standard deviation	Minimum	Maximum
CO_2	Metric tonnes per capita	1.8758	2.0479	0.0284	8.2830
GDP	Per capita constant 2010 US$	2230.647	2039.022	190.9119	10398.23
FOSS	Million Kw	37.3311	108.5518	0.0250	923.6300
RE	Million Kw	12.1814	39.3258	0.0530	415.0570

Table 4: Panel unit root tests

Variables	Levels				1st diff.			
	Common unit root		Individual unit root		Common unit root		Individual unit root	
	LLC	Breitung	IPS	PP	LLC	Breitung	IPS	PP
CO_2	−0.0112	0.4446	−0.1289	28.4697	−6.0320***	−3.7566***	−8.2963***	534.725***
GDP	−1.1480	3.1186	0.7920	15.9335	−7.4969***	−7.1933***	−8.3948***	287.127***
GDP^2	−0.6391	3.1128	2.0139	13.0426	−7.2895***	−6.6663***	−8.2410***	221.423***
FOSS	−0.1241	0.2816	−1.2245	25.8391	−2.7839***	−2.1876***	−6.2549***	158.052***
RE	0.2471	−1.7336**	06781	35.6593	−6.1007***	−5.8214***	−6.1410***	183.304***

*, **, *** indicates significant at 0.10, 0.05 and 0.01 level

Table 5: Results from Pedroni cointegration test

Statistic		Weighted statistic	Statistic		Statistic	
Pedroni					Kao	
Alternative hypothesis: Common AR coefs. (within-dimension)			Alternative hypothesis: Individual AR coefs. (between-dimension)		ADF	−2.200**
Panel v-statistic	−0.4752	−1.3229	Group rho-statistic	2.0459		
Panel rho-statistic	−0.2501	0.7128	Group PP-statistic	−3.2104***		
Panel PP-statistic	−3.5092***	−2.8625***	Group ADF-statistic	−2.3043**		
Panel ADF-statistic	−2.1334**	−1.8634**				

*, **, *** indicates significant at 0.10, 0.05 and 0.01 level

Table 6: FMOLS and DOLS long-run estimates

FMOLS long-run estimates			DOLS long-run estimates		
Variables	Coefficients	Prob.	Variables	Coefficients	Prob.
GDP	1.0049***	0.0000	GDP	1.3764***	0.0019
GDP^2	−0.0376***	0.0003	GDP_2	−0.0475*	0.0956
FOSS	0.3871***	0.0000	FOSS	0.3649***	0.0000
RE	−0.0124	0.2138	RE	−0.0393	0.2705

*, **, *** indicates significant at 0.10, 0.05 and 0.01 level

4.3 Long-run Estimates

The FMOLS and the DOLS approaches are effective in eliminating the endogeneity problems and serial correlation. Results from panel both estimators Table 6 indicate that GDP is highly positive and statistically significant on carbon dioxide emissions. Meanwhile, GDP^2 is negatively statistically significant at the 1% level in explaining carbon dioxide emissions. Thus, the connection between environmental quality and economic performance resembles an inverted U-shaped curve and thus validates the EKC hypothesis in 13 Asian countries. These empirical findings align with previous studies by Apergis and Ozturk (2015) and Heidari et al. (2015) that found that the EKC hypothesis is validated in 14 Asian and ASEAN-5 countries. In contradict, findings from Bölük and Mert (2014), Chandran and Tang (2013) and Liu et al. (2017) found that EKC hypothesis is invalid in 16 European Union, ASEAN-5 and ASEAN-4 countries. The implication of this findings indicates that carbon emissions increases in the early phase of economic development, but when it reaches a turning point or threshold value, the emissions reduces without jeopardising the economic growth. In relation to that, Tamazian et al. (2009) found that environmental pollution declines during high levels of economic and financial development in BRIC countries.

As expected, FOSS is positively statistically significant in explaining carbon dioxide emissions for FMOLS and DOLS estimators. Therefore, a 1% increase in energy consumption from electricity consumption from FOSS contributes to carbon dioxide emissions by 38.7% and 36.4% in the long-run for 13 Asian countries. Our result is similar to those of Dogan and Seker (2016a, 2016b) and Liu et al. (2017) for the European Union, top RE and ASEAN-4 countries. Economic development requires extensive consumption of energy, but its impact on environmental quality is inevitable. With the high demand for energy, the level of pollution also increases due to most energy supply coming from non-renewable sources. Energy from conventional sources is favourable due to its reliability and is cheaper compared to RE.

The result from FMOLS and DOLS long-run estimates indicates that RE is insignificant in explaining environmental quality. The empirical finding is contradicted with the studies by Dogan and Seker (2016b), Dong et al. (2017) and Liu et al. (2017) in top RE, BRICS and ASEAN-4 countries, respectively. This indicates that consumption of energy from renewable sources is insufficient in reducing the impact of climate change in selected 13 Asian countries. Meanwhile, high dependency on energy from FOSS compared to RE in the total energy mix is dominant. According to a report from the Energy Information Administration (2018) issued in September 2017, energy consumption by OECD countries exceeds the non-OECD countries by 2015. Nevertheless, by 2030, non-OECD countries are expected to utilise energy beyond OECD countries due to excellent and promising economic development. Additionally, world energy consumption from petroleum and other liquids resources is expected to continue to grow until 2040. However, RE consumption is predicted to grow rapidly between 2015 and 2040 and reduce consumption and dependency on consumption from coal sources. Serious actions taken by promoting RE consumption to contribute as much as possible to the total energy mix and reduce dependency on energy from FOSS will be beneficial for the quality of the environment in the future.

5. CONCLUSION

This study investigates the linkages of environmental quality, economic development, renewable and non-RE consumption in selected 13 developing countries in Asia from 1980 to 2014. Previously, empirical evidence concerning the relationship between environmental quality, economic development and energy consumption did not include energy from renewable sources in Asia countries. Hence, this study contributes to the literature by examining the relationship between carbon dioxide emissions, economic growth, hydroelectricity consumption and electricity consumption from FOSS within the EKC framework. This study used the panel unit root cointegration, fully modified (OLS) and dynamic (OLS) approach to analyse the linkages between carbon dioxide emissions and its determinants in Asia countries.

The main empirical findings suggest that the EKC hypothesis (inverted U-shaped) is validated in both FMOLS and DOLS estimators in the long-run. The positive relationship between the release of carbon dioxide and GDP per capita postulates that environmental quality is decreasing in the early stage of economic development. However, as income grows with advanced technology and innovation as well as better understanding and awareness, the level of pollution decreases over time. From empirical findings, increased energy consumption from conventional sources has resulted in an increment in the level of pollution as expected. The extensive consumption of energy from conventional sources such as FOSS has negatively impacted on environmental quality by increasing the level of carbon emissions. Unfortunately, consumption from RE which is environmentally friendly is insignificant in explaining carbon dioxide emissions in Asian countries. This may happen because the share of energy consumption from renewable sources is relatively low and thus insufficient contribution in total energy supply for countries like Iran, Iraq, Malaysia and China failed to have a beneficial effect on environmental quality. Although this empirical study has failed to prove that RE is capable of contributing positively to the environment in 13 Asia's developing countries, it is undeniable that the energy efficiency of this resource is more environmentally friendly and has minimal risk compared to conventional resources.

Last but not least, the findings are critical to enable the Asia countries to design and structure suitable policies regarding RE including enhancing its consumption and reducing heavy reliance on non-renewable sources without risking economic development.

In line with the aim of the parties ratified in the Paris Agreement to mitigate climate change and to support the SDGs, future studies can investigate the importance of technology and innovation in RE development to enhance and promote the consumption of this alternative energy in the total primary energy supply.

6. ACKNOWLEDGEMENTS

This paper was initially presented at the 6th International Association for Energy Economics (IAEE) Conference: Energy Exploitation and Cooperation in Asia, 2–4 November 2018, Wuhan China. Travel grant support from the OPEC Fund for International Development/IAEE Support Fund for Students from Developing Countries is also gratefully acknowledged.

REFERENCES

Al-Mulali, U., Fereidouni, H.G., Lee, J.Y., Sab, C.N.B. (2013), Examining the bi-directional long run relationship between renewable energy consumption and GDP growth. Renewable and Sustainable Energy Reviews, 22, 209-222.

Al-Mulali, U., Ozturk, I., Solarin, S.A. (2016), Investigating the environmental Kuznets curve hypothesis in seven regions: The role of renewable energy. Ecological Indicators, 67, 267-282.

Alper, A., Oguz, O. (2016), The role of renewable energy consumption in economic growth: Evidence from asymmetric causality. Renewable and Sustainable Energy Reviews, 60, 953-959.

Ang, J.B. (2007), CO_2 emissions, energy consumption, and output in France. Energy Policy, 35(10), 4772-4778.

Apergis, N., Danuletiu, D.C. (2014), Renewable energy and economic growth : Evidence from the sign of panel long-run causality. International Journal of Energy Economics and Policy, 4(4), 578-587.

Apergis, N., Ozturk, I. (2015), Testing environmental Kuznets curve hypothesis in Asian countries. Ecological Indicators, 52, 16-22.

Apergis, N., Payne, J.E. (2010a), Renewable energy consumption and economic growth: Evidence from a panel of OECD countries. Energy Policy, 38(1), 656-660.

Apergis, N., Payne, J.E. (2010b), Renewable energy consumption and growth in Eurasia. Energy Economics, 32(6), 1392-1397.

Aung, T.S., Saboori, B., Rasoulinezhad, E. (2017), Economic growth and environmental pollution in Myanmar : An analysis of environmental Kuznets curve. Environmental Science and Pollution Research, 24(25), 20487-20501.

Azam, M., Khan, A.Q. (2016), Testing the environmental Kuznets Curve hypothesis: A comparative empirical study for low, lower middle, upper middle and high income countries. Renewable and Sustainable Energy Reviews, 63, 556-567.

Azam, M., Khan, A.Q., Bakhtyar, B., Emirullah, C. (2015), The causal relationship between energy consumption and economic growth in the ASEAN-5 countries. Renewable and Sustainable Energy Reviews, 47, 732-745.

Azlina, A.A., Azilah, H., Mahirah, K., Izyan, N.W. (2018), The role of renewable energy consumption within the environmental Kuznets Curve (EKC) framework in Malaysia. In: Abdul-Rahim, editor. Environmental Impacts and Conservation Evaluation. Malaysia: Universiti Putra Malaysia Press. p5-32.

Azlina, A.A., Law, S.H., Mustapha, N.H.N. (2014), Dynamic linkages among transport energy consumption, income and CO_2 emission in Malaysia. Energy Policy, 73, 598-606.

Bölük, G., Mert, M. (2014), Fossil and renewable energy consumption, GHGs (greenhouse gases) and economic growth: Evidence from a panel of EU (European Union) countries. Energy, 74(C), 439-446.

Bölük, G., Mert, M. (2015), The renewable energy, growth and environmental Kuznets curve in Turkey : An ARDL approach. Renewable and Sustainable Energy Reviews, 52, 587-595.

Breitung, J. (2001), The local power of some unit root tests for panel data. In: Nonstationary Panels, Panel Cointegration, and Dynamic Panels. London: Emerald Group Publishing Limited. p161-178.

Chandran, V., Tang, C. (2013), The impacts of transport energy consumption, foreign direct investment and income on CO_2 emissions in ASEAN-5 economies. Renewable and Sustainable Energy Reviews, 24, 445-453.

Chang, T., Gupta, R., Inglesi-Lotz, R., Simo-Kengne, B., Smithers, D., Trembling, A. (2015), Renewable energy and growth: Evidence from heterogeneous panel of G7 countries using Granger causality. Renewable and Sustainable Energy Reviews, 52, 1405-1412.

Dogan, E., Seker, F. (2016a), Determinants of CO_2 emissions in the European Union: The role of renewable and non-renewable energy. Renewable Energy, 94, 429-439.

Dogan, E., Seker, F. (2016b), The influence of real output, renewable and non-renewable energy, trade and financial development on carbon emissions in the top renewable energy countries. Renewable and Sustainable Energy Reviews, 60, 1074-1085.

Dong, K., Sun, R., Hochman, G. (2017), Do natural gas and renewable energy consumption lead to less CO_2 emission? Empirical evidence from a panel of BRICS countries. Energy, 141, 1466-1478.

Environmental Impact Assessment. (2018), U.S. Energy Information Administration. Available from: http://www.eia.gov/beta/international. [Last accessed on 2018 Oct 22].

Grossman, G.M., Krueger, A.B. (1991), Environmental Impacts of a North American Free Trade Agreement. Cambridge: National Bureau of Economic Research Working Paper Series, No. 3914(3914). p1-57.

Heidari, H., Katircioğlu, S.T., Saeidpour, L. (2015), Economic growth, CO_2 emissions, and energy consumption in the five ASEAN countries. International Journal of Electrical Power and Energy Systems, 64, 785-791.

Im, K.S., Pesaran, M.H., Shin, Y. (2003), Testing for unit roots in heterogeneous panels. Journal of Econometrics, 115(1), 53-74.

Irandoust, M. (2016), The renewable energy-growth nexus with carbon emissions and technological innovation: Evidence from the Nordic countries. Ecological Indicators, 69, 118-125.

Jebli, M.B., Youssef, S.B., Ozturk, I. (2016), Testing environmental Kuznets curve hypothesis: The role of renewable and non-renewable energy consumption and trade in OECD countries. Ecological Indicators, 60(1), 824-831.

Kao, C. (1999), Spurious regression and residual-based tests for cointegration in panel data. Journal of Econometrics, 90(1), 1-44.

Kao, C., Chiang, M. (2000), On the inference of a cointegrating regression in panel data. Advances in Econometrics, 15(1), 179-222.

Lau, L.S., Choong, C.K., Eng, Y.K. (2014), Investigation of the environmental Kuznets curve for carbon emissions in Malaysia: Do foreign direct investment and trade matter? Energy Policy, 68, 490-497.

Levin, A., Lin, C.F., Chu, C.S.J. (2002), Unit root tests in panel data: Asymptotic and finite-sample properties. Journal of Econometrics, 108(1), 1-24.

Liu, X., Zhang, S., Bae, J. (2017), The impact of renewable energy and agriculture on carbon dioxide emissions : Investigating the environmental Kuznets curve in four selected ASEAN countries. Journal of Cleaner Production, 164, 1239-1247.

Mark, N.C., Sul, D. (2003), Cointegration Vector Estimation by Panel DOLS and Long-run Money Demand. Journal Recommendation Serives, 65(5), 655-680.

Menegaki, A.N. (2011), Growth and renewable energy in Europe: A random effect model with evidence for neutrality hypothesis.

Energy Economics, 33(2), 257-263.
NASA. (2018), NASA Global Climate Change. Available from: https://www.climate.nasa.gov/causes. [Last accessed on 2018 Dec 25].
Niu, S., Ding, Y., Niu, Y., Li, Y., Luo, G. (2011), Economic growth, energy conservation and emissions reduction: A comparative analysis based on panel data for 8 Asian-Pacific countries. Energy Policy, 39(4), 2121-2131.
Pedroni, P. (1999), Critical values for cointegration tests in heterogeneous panels with multiple regressors. Oxford Bulletin of Economics and Statistics, 61(S1), 653-670.
Pedroni, P. (2001), Purchasing power parity tests in cointegrated panels. Review of Economics and Statistics, 83(4), 727-731.
Pedroni, P. (2004), Panel cointegration: Asymptotic and finite sample properties of pooled time series tests with an application to the ppp hypothesis. Econometric Theory, 20(3), 597-625.
Phillips, P.C.B., Perron, P. (1988), Testing for a unit root in time series regression. Biometrika, 75(2), 335-346.
SDG. (2018), United Nations Sustainable Development Goals. Available from: http://www.un.org/sustainabledevelopment. [Last accessed on 2018 Oct 22].
Sebri, M., Ben-Salha, O. (2014), On the causal dynamics between economic growth, renewable energy consumption, CO_2 emissions and trade openness: Fresh evidence from BRICS countries. Renewable and Sustainable Energy Reviews, 39, 14-23.
Selden, T.M., Song, D. (1994), Environmental quality and development: Is there a Kuznets Curve for air pollution emissions? Journal of Environmental Economics and Management, 27(2), 147-162.
Shahbaz, M., Loganathan, N., Zeshan, M., Zaman, K. (2015), Does renewable energy consumption add in economic growth? An application of auto-regressive distributed lag model in Pakistan. Renewable and Sustainable Energy Reviews, 44, 576-585.
Stern, D.I. (2017), The environmental Kuznets curve after 25 years. Journal of Bioeconomics, 19(1), 7-28.
Sugiawan, Y., Managi, S. (2016), The environmental Kuznets curve in Indonesia: Exploring the potential of renewable energy. Energy Policy, 98, 187-198.
Tamazian, A., Chousa, J.P., Vadlamannati, K.C. (2009), Does higher economic and financial development lead to environmental degradation: Evidence from BRIC countries. Energy Policy, 37(1), 246-253.
UNFCC. (2018), United Nations Framework Convention on Climate Change. Available from: https://www.unfccc.int/topics/mitigation/the-big-picture/introduction-to-mitigation. [Last accessed on 2018 Aug 09].
Wang, Y., Chen, L., Kubota, J. (2016), The relationship between urbanization, energy use and carbon emissions: Evidence from a panel of Association of Southeast Asian Nations (ASEAN) countries. Journal of Cleaner Production, 112, 1368-1374.
Zhu, H., Duan, L., Guo, Y., Yu, K. (2016), The effects of FDI, economic growth and energy consumption on carbon emissions in ASEAN-5: Evidence from panel quantile regression. Economic Modelling, 58, 237-248.