Threshold Effect of Institutional Quality and the Validity of Environmental Kuznets Curve

Tajul Ariffin Masron[a]
Yogeeswari Subramaniam[b]
Universiti Sains Malaysia

Abstract: Using a threshold estimation technique, this study examines the validity of environmental Kuznets curve (EKC) under different institutional quality regimes. A combined set of 99 developed and developing countries over the period from 2008 to 2016 has been chosen to confirm the issue in hand. Adopting panel threshold regression technique by Hansen (1999), the paper finds evidence substantiating the presence of single threshold effect. In general, we find that EKC hypothesis does not hold in the full sample analysis, in which high income fails to bring environmental degradation down. Only in the case of a segregated sample of developed countries, we find that the impact of high income (or income square) on environmental degradation is negative and significant after a certain level of '*high*' institutional quality has been attained. On the contrary, EKC is found to be invalid, and high income fails to be converted fully to environment-protecting activities in developing countries. Therefore, the effectiveness of income in mitigating environmental issues seems to be dampened by the poor institutional quality in developing countries.

Keywords: Environmental degradation, environmental Kuznets curve (EKC) hypothesis, institutional quality, threshold model
JEL classification: I38, O13, Q58

1. Introduction

In the past decade, president of the World Bank, James D. Wolfensohn has declared corruption, which is one of the important elements in institutional quality (IQ) and also known as a "cancer", poses an enormous obstacle to economic and social development and comparatively has a greater effect on both developed and developing countries (Berdiev, Kim, & Chang, 2013).[1] Based on the report of Transparency International, the score for corruption perception is measured at below 50 in about 120 countries,

[a] School of Management, Universiti Sains Malaysia, 11800 Minden, Penang, Malaysia. Email: tams@usm.my
[b] School of Management, Universiti Sains Malaysia, 11800 Minden, Penang, Malaysia. Email: yogees.wari@yahoo.com.my (Corresponding author)

[1] To our understanding and after deep consideration on various elements representing institutional quality, such as government effectiveness, rule of law, regulatory quality and corruption (as outlined by the World Bank under *Worldwide Governance Indicators* database); although they could be defined differently, corruption is a good reflection of low government effectiveness, unclear rule of law as well as poor regulatory quality. Hence, the discussion in the introduction section is focusing on corruption as the only case that can be easily understood and also able to conserve space.

Article Info: Received 26 August 2019; Revised 25 February 2020; Accepted 16 April 2020
https://doi.org/10.22452/MJES.vol57no1.5

at the scale 0 for highly corrupted countries to 100 for less corrupted ones (Rose-Ackerman & Palifka, 2016). According to the report, corruption is not only prevalent in developing countries but even in developed countries. In this context, corruption has been identified as the main culprit that undermines growth and economic development (Del Monte & Papagni, 2001; Mauro, 1998; Ugur, 2014; Ugur & Dasgupta, 2011). Theoretically, it follows "*sand in the wheels*" hypothesis which postulates that corruption impedes growth and development because it entails resource misallocation and raises transaction costs (Aidt, 2009). This postulates that high levels of corruption tend to reduce the effectiveness of industrial policies and encourage businesses to operate in the unofficial sector to avoid tax and costly regulatory laws (Ampratwum, 2008). In turn, it tends to depress private and public investment by reducing its profitability and certainty (Ampratwum, 2008).

However, corruption also causes serious environmental degradation (Robbins, 2000). It is generally believed that corruption leads to the loss of natural resources, ecosystem and biodiversity, contributing to negative effects on the environment and the environment-dependent communities. Corruption affects environment degradation by embezzlement of funds allocated for environmental protection programme to private pockets (Winbourne, 2002). In addition, bribery in environmental inspections and the permitted system further exacerbates natural resource depletion, environmental pollution and the trafficking of wildlife and other natural resources (Dillon et al., 2006). Bribery assists over-extraction of natural resources, poaching of rhinos, elephants for ivory and tigers for their skin and bones and also illegal logging of timber in tropical forest reserves (Pellegrini & Gerlagh, 2006; Welsch, 2004). Moreover, under the joint implementation (JI) scheme of the United Nations Framework Convention on Climate Change (UNFCCC) around 600 million tons of carbon was wrongly emitted, which was hit by serious corruption allegations involving organised crime in Russia and Ukraine (Zhang, Jin, Chevallier, & Shen, 2016). Hence, there can be a point of irreversible environmental damages or risks if the countries are poor in governance,[2] and suffers due to the high level of corruption.

Table 1 clearly indicates the top ten ranked nations perceived to be the least corrupted and most corrupted countries in year 2016. Somalia, South Sudan, North Korea and Syria are perceived to be the most corrupted countries in the world. There is a widely accepted view that for the past ten years, Somalia has retained the undesirable heading as world's 'most corrupted' with a score of 10 on the corruption perception index. Fourth from the bottom is Syria, a war-torn country which is presently seeing a massive outflow of refugees (Banta, 2008). Although Germany and Canada are classified among the top 10 cleanest countries in the world in terms of corruption index, the scores that merely surpass 80 indicate that corruption is somehow taking place and could be serious in the eyes of developed countries. Hence, Table 1 clearly indicates that corruption is not an exclusive feature of developing countries but also in every country in the world although it is generally low in developed countries. Moreover, it is generally believed that those with high corruption tend to score badly in terms of

[2] Governance and institutional quality could have distinct meanings, but in this study, we treat both as similar. They are used interchangeably.

Table 1. The best and worst countries for corruption in 2016

Rank	Country	Less corrupted				Rank	Country	Most corrupted			
		CPI	GE	RL	RQ			CPI	GE	RL	RQ
1	New Zealand	90	98	99	99	166	Venezuela	17	9	2	0
2	Denmark	90	99	92	98	167	Guinea-Bissau	16	4	9	7
3	Finland	89	96	97	99	168	Afghanistan	15	10	7	6
4	Sweden	88	95	97	100	169	Libya	14	1	0	2
5	Switzerland	86	na	na	na	170	Sudan	14	6	5	9
6	Norway	85	99	93	100	171	Yemen	14	2	5	3
7	Singapore	84	100	100	96	172	Syria	13	2	4	1
8	Netherlands	83	97	99	97	173	North Korea	12	4	0	3
9	Canada	82	95	94	97	174	South Sudan	11	na	na	na
10	Germany	81	94	96	92	175	Somalia	10	0	1	0

Note: Rank refers to rank for corruption perception index (CPI) and the CPI column refers to the score. Meanwhile, GE, RL and RQ refer to the ranking of each country, and not the score of the index while na denotes not available.

Sources: CPI is from Transparency International (2016) while government effectiveness (GE), rule of law (RL) and regulatory quality (RQ) are from World Bank (2017b).

other institutional elements such as government effectiveness (GE), rule of law (RL) and regulatory quality (RQ), as shown in Table 1. None of the most corrupted countries are capable to be above 10th place in the ranking for GE, RL and RQ.

Although the corruption indices in Germany, Canada and Netherlands are far better than Somalia, South Sudan and North Korea, the relatively low corruption indices may still open the door widely for pollution to occur by persons or firms in the countries. Comparing Figure 1 and Figure 2, the most corrupted countries within both groups share the same point, which is the largest polluter in each group. Coincidentally, the second and third worse countries in both groups are also ranked as the second and third most polluted countries in each group. On this basis, no country in the world is pollution-free although some are less corrupted than others. Transparency International (2016) states that people are often faced with bribery and extort situations in lower-scale countries and are reliant on basic services which are undermined by the misappropriation of funds while seeking redress of authorities in charge. Although it seems less evident in the everyday lives of citizens in higher-ranking nations, closed-door deals, illicit finance and patchy law enforcement exacerbate many forms of corruption at home and abroad (Transparency International, 2016).

In view of the above, there is a growing consensus that institutional quality (IQ) can have a strong effect on environmental outcomes and actions. According to Bhattarai and Hammig (2004) and Rodrik, Subramanian and Trebbi (2004), regardless of developed or developing countries, better IQ contributes to good environmental outcomes by being a solution to maintain the collective action, and solve environmental problems and unsustainable use of natural resources. For instance, in South Africa, the new Air Quality Act (2004) which replaced the ineffective Atmospheric Pollution Prevention Act (1965) provides more comprehensive decision-making and management for air pollution. Thereafter, South Africa is not only conducive to a good environmental quality; it also reduces the burden of health impact associated with polluted ambient air (Kotze, 2006).

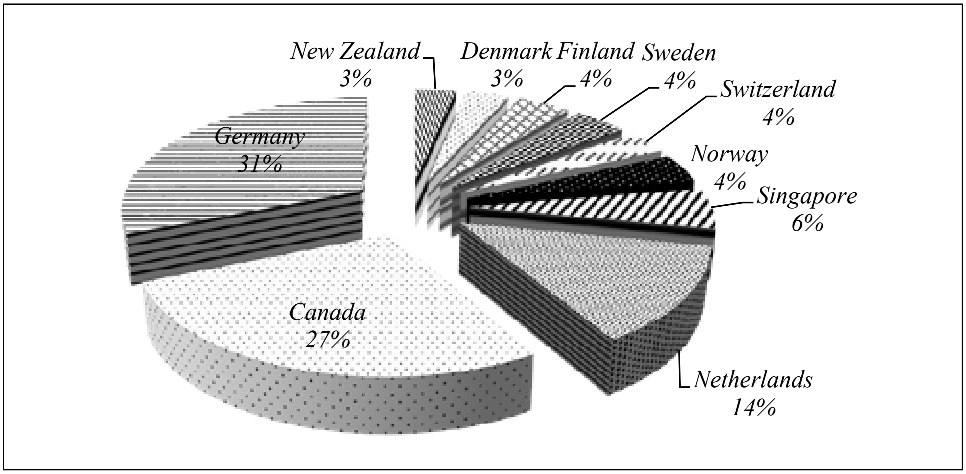

Figure 1. CO_2 emissions per capita (in the perceived as less corrupted countries)
Source: World Bank (2017a).

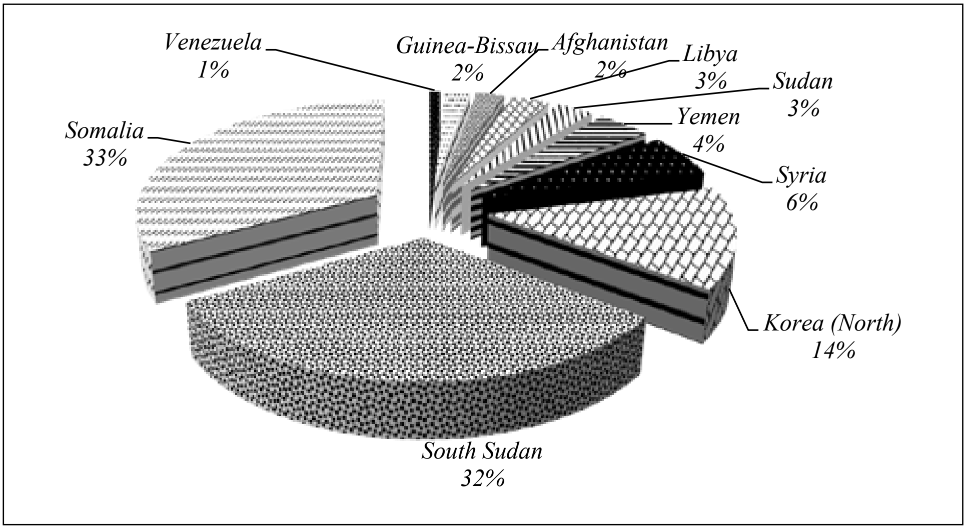

Figure 2. CO_2 emissions per capita (in the perceived as most corrupted countries)
Source: World Bank (2017a).

However, weak institutional quality may constrain the outcomes of environmental efforts by escalating environmental degradation, such as trade in endangered species, deforestation and ozone depletion. In response to these statements, weak IQ contributes to the development of environmentally damaging policies and unfair allocation of environmental resources that contribute to environmentally harmful practices. For example, India has a number of environmental policies on Water Act of 1974 and Air Act of 1981 to deal with increasingly hazardous pollution levels (Chen & Lees, 2018). However, these regulations have not been positive in terms of their effectiveness. Thus, if institutions are weak or less effective, then the desire to ignore environmental quality will be higher.

The EKC hypothesis states that as a country enjoys high income level, environmental quality can automatically be protected (or improved as reflected in lower environmental degradation). Based on the experience of several developed countries as depicted in Figure 1 as well as developing countries as shown in Figure 2, EKC hypothesis is unlikely to hold. Although developed countries are becoming high-income countries, their successes are accompanied by growing amounts of emission in the same path to emissions faced by developing countries. In other words, we suspect that the effectiveness of high income in mitigating environmental pollution could have been undermined by poor institutional quality. Simple correlation shows that the biggest polluters are countries such as Germany, Canada and the Netherlands for developed countries (see Figure 1), as well as Somalia, South Sudan and North Korea (see Figure 2) for countries with the lowest corruption index (see Table 1). To further find support, Figure 3 offers a firsthand insight of the issue that EKC relationship may not hold for both developing and developed countries. Therefore, we predict that the validity of EKC is subject to the level of institutional quality.

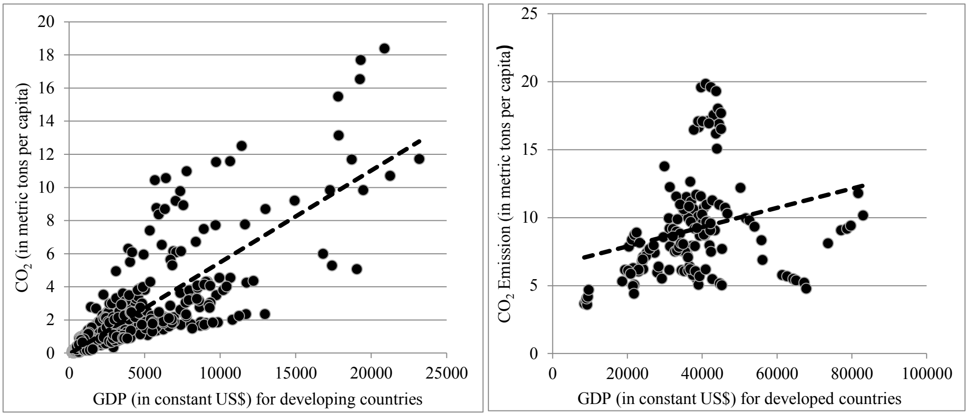

Figure 3. CO_2 emission vs GDP of 50 developing and developed countries
Note: The upward line represents the simple regression line.
Source: World Bank (2017a).

The remainder of the paper is organised as follows. The related literature is briefly reviewed in section 2. The model construction and methodology are outlined in section 3. The empirical results are presented in section 4 and finally, section 5 concludes the study.

2. Literature Review

This section is reserved to demonstrate the research gap as well as the appropriate model to be employed. We start this section by discussing several factors that have been confirmed by past studies as critical to environmental quality.

(a) Renewable Energy and Environmental Pollution

Firstly, the role of renewable energy in environmental pollution has been considered as one of the essential principles in green economics. Renewable energy or also known as a subset of "green power" provides the highest environmental benefit by reducing the emission as opposed to non-renewable energy. A number of studies in this context have found that renewable energy can help reduce environmental pollution and enhance environmental quality (Al-Mulali & Ozturk, 2016; Belaid & Youssef, 2017; Bento & Moutinho, 2016; Bilgili, Kocak, & Bulut, 2016; Dogan & Seker, 2016; Jebli, Youssef, & Ozturk, 2016; Zoundi, 2017). For instance, the adoption of renewable energy sources of solar, wind, geothermal, hydropower and biomass also contribute to improve energy efficiency and also provide sustainable energy services (Elum & Momodu, 2017). Hence, according to the analysis by Elum and Momodu (2017), a transition to renewable energy could reduce emission levels and offer access to sustainable energy to millions of people worldwide. However, Apergis, Payne, Menyah and Wolde-Rufael (2010) and Boluk and Mert (2014) show that increasing renewable energy consumption increases carbon emission for a panel of European Union countries, developed and developing countries. This is largely due to the low price of natural gas which makes renewable energy less attractive compared to natural gas-fuelled generation (Apergis et al., 2010). In addition, it is possible that many countries may not have reached the threshold point of high production of renewable energy to the point where renewable energy can start to mitigate carbon emission level (Apergis et al., 2010).

(b) Foreign Direct Investment and Environmental Pollution

There is also a growing literature that is interested in studying the effect of foreign direct investment (FDI) on environmental pollution, which can be divided into two clusters. The first cluster is related to pollution haven hypothesis (Cole & Elliot, 2005; Lau, Choong, & Eng, 2014; Lee & Lee, 2009; Shahbaz, Nasreen, Ahmed, & Hammoudeh, 2017; Zhang & Zhou, 2016). This hypothesis points out that those multinational firms engaged in highly polluting activities have relocated their production to countries with lower environmental regulation to circumvent the cost of environmental control in their home countries. Countries with high environmental regulations or mainly known as developed countries will lose all the dirty industries and poor developing countries will get them all. On the contrary, the second cluster is related to the pollution halo hypothesis (see Cheung & Lin, 2004; Mielnik & Goldemberg, 2002; Stretesky & Lynch, 2009; Zugravu-Soilita, 2017). One of the explanations to pollution halo hypothesis is that multinational firms will lead to the transference of clean and environmentally friendly technology in the hosting countries. This further implies that increases in FDI inflows are likely to improve R&D techniques and, thereby, induce higher energy efficiency and eventually lead to less environmental pollutions. As a result, it seems that the relationship between FDI and environmental pollutions has appeared to be inconsistent until now, and further analysis, especially at the country level, might be necessary.

(c) Trade and Environmental Pollution

Thirdly, we observe that trade plays an important role in affecting environmental pollution. It is worth noting that an increase in trade can affect environmental pollutions through three independent effects, namely scale, technique and composition (Aklin, 2016; Copeland & Taylor, 1995; Dasgupta, Laplante, Wang, & Wheeler, 2002; Grossman & Krueger, 1995; Halicioglu & Ketenci, 2016; Kellenberg, 2009; Reppelin-Hill, 1999; Shahbaz et al., 2017). In the scale effect, an increase in trade may contribute to higher energy consumption and higher production, where it will lead to a substantial rise in environmental pollutions. The composition effect is based on changes in the structure of the economy (Lau et al., 2014; Rezek & Rogers, 2008). Thus, it can be argued that trade tends to improve environmental quality as the structure of the economy changes from industrialisation to services and information-technology intensive industry (Lau et al., 2014). Lastly, technique effect refers to the technology spillover through trade flows among countries, and the adaptation of environmental-friendly technologies in producing goods that can lead to environmental improvement (Aklin, 2016; Dogan & Seker, 2016; Reppelin-Hill, 1999). More importantly, trade can allow access to new technology which is more environmentally efficient to local production by reducing the use of inputs such as energy, water and other environmentally hazardous substances.

(d) Population Growth and Environmental Pollution

The fourth strand of research focuses on the environmental degradation and population growth. There are a number of studies in this context including studies by Stern (2004) for global, Liddle and Lung (2010) for developed countries, Hossain (2011) for newly industrialised countries, Zhang and Lin (2012) for the United States, Hafeez, Chunhui, Strohmaier, Ahmed and Jie (2018) for One Belt and One Road Initiative (OBORI) countries, Paramati, Alam and Lau (2018) for developed and emerging market economies and a few others. One observation from the related literature states that population growth has an impact on the environmental quality through the consumption of natural resources and production of resources. The consumption of natural resources increases pressure on marginal lands, over-exploitation of soils, soil erosion and flooding. As a result, Hafeez et al. (2018), Hossain (2011), Liddle and Lung (2010), Paramati et al. (2018), and Zhang and Lin (2012) revealed that population growth has been often conjectured to have a negative effect on environmental quality.

(e) Urbanisation and Environmental Pollution

Al-Mulali and Ozturk (2016), Hossain (2011), Liu and Bae (2018), Marquart-Pyatt (2004), Munir and Ameer (2018), Shahbaz et al. (2017) and Zhang and Zhou (2016) examined the effect of urbanisation on environmental quality. In the case of urbanisation, as people migrate from rural areas to urban areas in search of education, better jobs and living standards, they exert pressure on urban environment and resources (Al-Mulali & Ozturk, 2016; Shahbaz et al., 2017). This leads to more degradation. Overall, these empirical evidences seem to be almost similar, suggesting that urbanisation has statistically significant negative effect on environmental degradation.

(f) Economic Growth and Environmental Pollution

Over the past two decades, the literature on economic growth and environmental pollution has been intensively analysed in both developed and developing countries. However, close observation of past studies reveals that most of the past interest is mainly on testing income-environmental degradation nexus. In other words, most of them are interested in examining the existence of EKC in OECD countries (Jebli et al., 2016; Shafiei & Salim, 2014), MENA countries (Omri, Daly, Rault, & Chaibi, 2015), ASEAN countries (Heidari, Katircioğlu, & Saeidpour, 2015; Lean & Smyth, 2010; Saboori, Sulaiman, & Mohd, 2012), low, middle and high-income countries (Roberts & Grimes, 1997) and developing and developed countries (Ehrhardt-Martinez, Crenshaw, & Jenkins, 2003; Sari & Soytas, 2007; Shandra, London, Whooley, & Williamson, 2004; Sharma, 2011). EKC is essentially about environmental pollution level, which rises as a country is at the initial stage of economic development or at low income level. Yet, the empirical evidences still find mixed support for the existence of EKC. Some empirical results demonstrate varied relationships that exist between environmental pollution and economic growth such as linear (Ang, 2007), U-shaped (Begum, Sohag, Abdullah, & Jaafar, 2015), inverted U-shaped (Pao & Tsai, 2011; Roberts & Grimes, 1997; Sabooori et al., 2012; Shandra et al., 2004), N-shaped (Grossman & Krueger, 1995; Shafik, 1994) and monotonic shaped (Holtz-Eakin & Selden, 1995). Therefore, the findings of these studies appear to be contradictory or inconsistent. One potential answer to this inconsistency could be due to the forgotten fact that all countries in the world are suffering from imperfect institutional quality. Accordingly, the contribution of this study is to quantify the effect of income on environmental degradation under different regimes (or level) of IQ. This conjecture requires a flexible modeling strategy that can accommodate different kinds of income and environmental degradation interactions. From this point of view, we hypothesise that the income-environment relationship may be contingent on institutional quality, where increase in income may improve environmental quality after institutional quality exceeds a certain high threshold level.

3. Methodology

The empirical model of this paper is derived from the following standard EKC function which can be displayed as follows:[3]

$$\frac{\partial ED_t}{\partial_t} = \alpha(y - y^*)g \tag{1}$$

where Equation (1) is the change of environmental degradation (*ED*) at year (*t*) which is a function of the growth rate (*g*) and the distance of income (*y*) to the turning point (y^*). If *g* and coefficient (α) are positive and negative, respectively, the rate of change of environmental degradation can be either $\frac{\partial ED_t}{\partial_t} > 0$ when $y<y^*$, or $\frac{\partial ED_t}{\partial_t} < 0$ when $y>y^*$. This describes an inverted U-shaped relationship between environmental degradation and income where degradation increases until income level y^* is reached and decreases thereafter. Integrating Equation (1) with respect to time and taking the income measure and the growth rate as a constant, we obtain the following equation:

$$ED_t = \mu + \alpha(y - y^*)gt \tag{2}$$

where μ is a constant of integration. Accordingly, we extend Equation (2) by incorporating the individual-specific effects (μ_i), covariates (Z_{it}), and stochastic error term (ε_{it}). Namely,

$$\begin{aligned} ED_{it} &= \mu_i + \alpha(y_i - y^*)g_i t + \bar{\beta}' Z_{it} + \varepsilon_{it} \\ &= \mu_i + \alpha(y_i g_i t) + \alpha y^*(g_i t) + \bar{\beta}' Z_{it} + \varepsilon_{it} \\ &= \mu_i + \beta_0(y_i g_i t) + \beta_1(g_i t) + \bar{\beta}' Z_{it} + \varepsilon_{it} \end{aligned} \tag{3}$$

Notice that $\alpha=\beta_0$ and $y^*=\beta_1/\beta_0$, where $i=1,2,\ldots,N$ denotes the country and $t=1,2,\ldots,T$ denotes the time period. *ED* is environmental degradation, *y* and *g* are measures of income (*GDP*) and quadratic income (GDP^2), respectively. Hence, we specify the following econometric model and estimate the following in logarithmic form:

$$ED_{it} = \mu_i + \beta_0 GDP_{it} + \beta_1 GDP_{it}^2 + \beta_2 RE_{it} + \varepsilon_{it} \tag{4}$$

[3] Stern (2004) and Leitão (2010).

We take Equation (4) as a baseline specification, where *RE* is renewable energy and β_0, β_1, and β_2 are the coefficients of the relevant variables to be estimated.

To test the hypothesis regarding the influence of institutional quality (*IQ*) on the impact of income in environmental degradation, we extend Equation (4) by applying the panel threshold regression approach suggested by Hansen (1999). The panel threshold regression autoregressive model developed by Hansen (1999) is based on static framework. Thus, the model takes the following form:

$$ED_{it} = \mu_i + \beta_0 GDP_{it} + \beta_1 GDP_{it}^2\, I(IQ_{it} \leq \gamma) + \beta_2 GDP_{it}^2\, I(IQ_{it} > \gamma) + \beta_3 RE_{it} + \varepsilon_{it} \quad (5)$$

where *IQ* is the threshold variable, *I(.)* is the indicator function indicating the regime defined by the threshold variable. The threshold model in Equation (5) can also be rewritten as:

$$ED_{it} = \mu_i + \beta' GDP_{it}^2\,(\gamma) + \varepsilon_{it} \quad (6)$$

γ and GDP^2 is threshold and quadratic income, respectively and $\beta = (\beta 1\ \beta 2\ )'$. As the first step, least square is used to eliminate the individual specific effect. Taking averages of Equation (6) over time (*t*) produces the following equation:

$$\overline{ED_i} = \mu_i + \beta' \overline{GDP_i^2}\,(\gamma) + \overline{\varepsilon_i} \quad (7)$$

where $\overline{ED_i} = T^{-1}\sum_{t=1}^{T} ED_{it}$, $\overline{\varepsilon_i} = T^{-1}\sum_{t=1}^{T} \varepsilon_{it}$ and $\overline{GDP_i^2}(\gamma) = \frac{1}{T}\sum_{t=1}^{T} GDP_{it}^2(\gamma)$

$$= \begin{pmatrix} \frac{1}{T}\sum_{t=1}^{T} GDP_{it}^2 I(IQ_{it} \leq \gamma) \\ \frac{1}{T}\sum_{t=1}^{T} GDP_{it}^2 I(IQ_{it} > \gamma) \end{pmatrix}$$

Taking the difference between Equations (6) and (7) creates:

$$ED^*{}_{it} = \beta' GDP_{it}^{2*}\,(\gamma) + \varepsilon_{it}{}^* \quad (8)$$

where $ED_{it}^* = ED_{it} - \overline{ED_i}$, $GDP_{it}^{2*}(\gamma) = GDP_{it}^2(\gamma) - \overline{GDP_i^2}(\gamma)$, and $\varepsilon_{it}{}^* = \varepsilon_{it} - \overline{\varepsilon_i}$.

Let $ED_i^* = \begin{bmatrix} ED_{i2}^* \\ \vdots \\ ED_{iT}^* \end{bmatrix}$, $GDP_i^{2*}(\gamma) = \begin{bmatrix} GDP_{i2}^{2*}(\gamma)' \\ \vdots \\ GDP_{iT}^{2*}(\gamma)' \end{bmatrix}$, $\varepsilon_i{}^* = \begin{bmatrix} \varepsilon_{i2}{}^* \\ \vdots \\ \varepsilon_{iT}{}^* \end{bmatrix}$

denote the stacked data and errors for an individual with one time period deleted. Then, let *ED**, $GDP^{2*}(\gamma)$ and ε^* denote the data stacked over all individuals, for example

$$GDP^{2*}(\gamma) = \begin{bmatrix} GDP_1^{2*}(\gamma) \\ \vdots \\ GDP_i^{2*}(\gamma) \\ \vdots \\ GDP_n^{2*}(\gamma) \end{bmatrix}$$

Using this notation, Equation (8) is equivalent to

$$ED^* = GDP^{2*}(\gamma)\beta + \varepsilon^* \tag{9}$$

For given γ, the slope of coefficient β can be estimated by ordinary least squares (OLS). The estimated equations are given by:

$$\hat{\beta}(\gamma) = (GDP^{2*}(\gamma)'GDP^{2*}(\gamma))^{-1}GDP^{2*}(\gamma)ED^* \tag{10}$$

The vector of regression residuals is defined as:

$$\widehat{\varepsilon^*}(\gamma) = ED^* - GDP^{2*}(\gamma)\hat{\beta}(\gamma)$$

and the sum of squared error as:

$$\begin{aligned} S_1(\gamma) &= \widehat{\varepsilon^*}(\gamma)'\widehat{\varepsilon^*}(\gamma) \\ &= ED^*(1 - GDP^{2*}(\gamma)'(GDP^{2*}(\gamma)'\,GDP^{2*}(\gamma))^{-1}GDP^{2*}(\gamma)'\,)ED^* \end{aligned} \tag{11}$$

Hansen (1999) recommends estimating γ using least squares in order to minimise the sum of squared errors. Thus, the least squares estimators of γ is:

$$\hat{\gamma} = \underset{\gamma}{argmin}\, S_1(\gamma) \tag{12}$$

Once $\hat{\gamma}$ is obtained, the slope coefficient estimate is $\hat{\beta} = \hat{\beta}(\hat{\gamma})$. The residual is $\widehat{\varepsilon^*} = \widehat{\varepsilon^*}(\hat{\gamma})$ and residual variance is $\hat{\sigma}^2 = \frac{1}{n(T-1)}\widehat{\varepsilon^*}'\widehat{\varepsilon^*} = \frac{1}{n(T-1)}S_1(\hat{\gamma})$.

In the testing procedure, the null hypothesis of no threshold effect or H_0:β_1=β_2 is tested by using the likelihood ratio test:

$$F_1 = (S_0 - S_1(\hat{\gamma}))/\hat{\sigma}^2 \tag{13}$$

where S_0 and $S_1(\hat{\gamma})$ are sum of squared errors for the null hypothesis and alternative hypothesis, respectively. Since the asymptotic distribution of F_1 is non-standard, Hansen (1999) suggests a bootstrap procedure to stimulate the asymptotic distribution of likelihood ratio test. If *p*-value is less than the desired critical value, the null hypothesis of no threshold effect is rejected.

When there is a threshold effect ($\beta_1 \neq \beta_2$) Hansen (1999) has shown that $\hat{\gamma}$ is consistent for γ_0 (true value of γ). The asymptotic distribution of threshold estimate is tested with the null hypothesis of H_0: γ=γ_0, using the likelihood ratio test of:

$$LR_1(\gamma) = (S_1(\gamma) - S_1(\hat{\gamma}))/\hat{\sigma}^2 \tag{14}$$

The asymptotic confidence interval is shown as $c(\beta) = -2\log(1 - \sqrt{1-\beta})$, where for a given asymptotic level β, the null hypothesis of H_0: γ=γ_0 is rejected if $LR_1(\gamma)$ exceeds $c(\beta)$.

For the double threshold, the model is modified as:

$$ED_{it} = \mu_i + \beta_0 GDP_{it} + \beta_1 GDP_{it}^2\, I(IQ_{it} \leq \gamma_1) + \beta_2 GDP_{it}^2\, I(\gamma_1 < IQ_{it} \leq \gamma_2) + \beta_3 GDP_{it}^2\, I(\gamma \ < IQ_{it}) + \beta_4 RE_{it} + \varepsilon_{it} \qquad (15)$$

where the threshold value is $\gamma_1 < \gamma_2$.

While the specification in Equation (4) based on the synthesis of environmental degradation-income literature, several other control variables have also been considered for robustness test. Thus, we add foreign direct investment (Lau et al., 2014; Zhang & Zhou, 2016), population growth (Hossain, 2011; Zhang and Lin, 2012; Hafeez et al., 2018; Paramati et al., 2018), urbanization (Al-Mulali and Ozturk, 2016; Zhang and Zhou, 2016; Munir and Ameer, 2018; Liu and Bae, 2018) and trade (Lau et al., 2014; Rezek & Rogers, 2008) to the baseline specification for robustness check.

3.1 Data

This study employs a panel sample of 99 countries (25 developed countries and 74 developing countries) for the period from 2008-2016. For the measurement of each variable, environmental degradation (ED) is represented by carbon dioxide emission (in metric tons per capita), GDP is represented by per capita real GDP (in constant 2000 US$), FDI is proxied by foreign direct investment as % of GDP, trade (TR) is represented by trade as % of GDP, renewable energy (RE) is proxied by percentage of renewable energy out of total final energy consumption, population (POP) is measured by population growth and urbanisation (URB) is measured by percentage of urban population of the total population. All information is downloaded from the *World Development Indicators* (World Bank, 2017a). Besides that, the present analysis makes use of the four measures of institutional quality (IQ), namely control of corruption (CC), government effectiveness (GE), regulatory quality (RQ), rule of law (RL) and finally, average institutional quality (IQ_{AVG}) as a proxy for aggregate IQ. The IQ_{AVG} is obtained by averaging the four indices.[4] The datasets are collected from the *Worldwide Governance Indicators* (World Bank, 2017b).

4. Empirical Results

Table 2 presents the descriptive statistics of the variables used in our estimation. The summary of the common statistics contains the means, minimum and maximum values of each series before transforming into the logarithmic form. The highest level of

[4] We construct IQ (=IQAVG) based on only four of the most relevant factors to environmental degradation. Voice and accountability (VA) as well as political stability (PS) are not predicted to be directly relevant to environmental issues. In other words, VA and PS may influence environmental quality but most likely to get through government effectiveness, rule of law and regulatory quality. Of course, this argument is still open for debate but this study opts for this option. While all six elements are as suggested by the World Bank (2017b), we also plan to include other potential proxies such as democracy. However, this effort is either hampered by similar argument as the case of VA and PS, or data unavailability for the sample of countries that we want to study. Specifically, data for democracy is not fully available for all countries included in this study. Hence, we leave it for future research.

Table 2. Descriptive statistics

Variable	Unit of measurement	Full sample			Developed countries			Developing countries		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
ED	Metric tons per capita	3.81	0.02	19.85	2.01	0.02	18.40	9.14	3.60	19.85
GDP	Real GDP in USD (in 1000)	13.30	0.19	90.01	37.55	0.84	83.01	37.27	0.93	96.01
RE	% of total energy consumption	38.31	0.01	98.04	16.59	0.44	76.73	45.64	0.01	98.04
TR	% of GDP	82.80	0.16	41.60	77.10	0.16	79.12	69.88	24.49	91.60
FDI	Inward flow % of total world	1.90	0.80	23.34	0.35	0.06	9.04	2.53	0.80	23.34
URB	% of urban population	22.33	12.38	94.61	19.09	12.38	88.26	24.37	11.48	90.35
POP	Annual population growth rate	1.69	0.51	6.69	1.38	0.61	2.79	1.52	0.74	6.94
IQ:										
CC	Scale from -2.5 to 2.5	0.10	-1.67	2.45	0.17	-0.13	0.25	0.18	-0.12	0.40
GE		0.10	-1.78	2.44	0.21	-0.18	0.24	0.20	-0.16	0.40
RQ		0.12	-2.24	1.97	0.23	-0.17	0.32	0.21	-0.16	0.47
RL		0.04	-1.85	1.98	0.17	-0.13	0.23	0.17	-0.12	0.37
IQ_{AVG}		0.09	-1.77	2.12	0.19	-0.15	0.37	0.19	-0.15	0.37

Note: ED, GDP, RE, TR, FDI, URB, POP, CC, GE, RQ, RL, and IQ_{AVG} stand for environmental degradation, income, renewable energy, trade, foreign direct investment, urbanisation, population growth, control of corruption, government effectiveness, regulatory quality, rule of law and average institutional quality, respectively.

Table 3. Correlation analysis

	ED	GDP	RE	TR	FDI	URB	POP	IQ_{AVG}	CC	GE	RQ	RL
ED	1.000											
GDP	0.265	1.000										
RE	-0.218	0.311	1.000									
TR	0.105	-0.082	-0.216	1.000								
FDI	0.514	0.020	-0.323	-0.147	1.000							
URB	-0.125	0.040	-0.198	0.210	0.130	1.000						
POP	-0.158	0.560	0.250	0.600	0.082	0.170	1.000					
IQ_{AVG}	-0.022	-0.150	-0.080	0.307	0.007	0.072	0.260	1.000				
CC	0.046	-0.065	0.060	-0.063	-0.079	0.030	0.014	0.441	1.000			
GE	-0.039	0.201	0.133	-0.036	-0.086	0.043	0.060	-0.497	-0.354	1.000		
RQ	0.021	-0.104	-0.118	-0.022	-0.002	0.023	0.620	0.360	0.619	0.049	1.000	
RL	0.020	-0.045	0.029	0.003	-0.015	0.012	0.019	0.438	0.803	-0.351	0.515	1.000

Note: ED, GDP, RE, TR, FDI, URB, POP, CC, GE, RQ, RL, and IQ_{AVG} stand for environmental degradation, income, renewable energy, trade, foreign direct investment, urbanisation, population growth, control of corruption, government effectiveness, regulatory quality, rule of law and average institutional quality, respectively.

environmental degradation (19.85 metric tons in 2009) is in the United States while the lowest level is in Congo (0.02 metric tons in 2010). Regarding the level of per capita real GDP, Norway has the highest level with USD90008.8 in 2011, whereas Ethiopia has the lowest level with USD194.926 in 2008. Congo has the highest level of consumption of renewable energy (98.041%) in 2013 and the country with the lowest consumption of renewable energy is Saudi Arabia with 0.007% in 2013. Most importantly, from Table 2, we find that the mean of ED recorded the highest for developing countries followed by developed countries at 9.14 and 2.01 metric tons per capita, respectively. This implies that countries in the early stage of growth such as those from the developing countries are generally more polluted.

Table 3 displays the results of correlation matrix of the key variables. As expected, ED has a strong positive correlation with GDP, FDI and TR which weakly supports the existing literature that GDP, FDI and TR are determinants of ED. On the other hand, RE, IQ_{AVG}, GE, URB and POP are negatively related to ED as expected.

Table 4 reports the estimation results of the threshold effects using five institutional quality variables, namely IQAVG, CC, GE, RQ and RL. The statistical significance of the threshold effect is evaluated by F-statistics with bootstrap p-values for the single and double thresholds. Referring to model 1, where institutional quality is measured as the average of IQ (IQ_{AVG}), the point estimate of the single threshold value is 0.173 with F-statistics of 42.63. The F-statistics shows that the single threshold is significant at least at 10% and higher than the critical value of 22.166. On the other hand, the test for a double threshold F_2 is not statistically significant, with a bootstrap p-value of 0.753. Thus, we conclude that there is strong evidence of single threshold in the regression relationships.

Table 4. Tests for threshold effect

	Model 1 $IQ=IQ_{AVG}$	Model 2 IQ=CC	Model 3 IQ=GE	Model 4 IQ=RQ	Model 5 IQ=RL
			Test for Single Threshold		
Threshold 1	0.173	0.142	0.196	0.196	0.148
F_1	42.63	40.23	33.04	22.41	46.69
p-value	0.043**	0.027**	0.060**	0.046**	0.060**
10% Critical value	22.166	22.674	21.801	17.202	24.028
			Test for Double Threshold		
Threshold 2	0.172	0.138	0.189	0.188	0.147
Threshold 1	0.173	0.142	0.196	0.196	0.148
F_2	21.36	20.74	24.60	21.60	23.34
p-value	0.753	0.133	0.110	0.113	0.103
10% Critical value	40.529	22.743	25.415	27.392	24.101

Note: ** denotes significance of at least at 10% critical value. CC, GE, RQ, RL, and IQ_{AVG} stand for control of corruption, government effectiveness, regulatory quality, rule of law and average institutional quality, respectively.

Model 2 presents the results of the repeated analysis, which used CC as an alternative proxy for institutional quality. We find that the test for a single threshold F_1 (40.23) is significant with the bootstrap p-value of 0.027, and the test for a double threshold F_2 (20.74) is insignificant, with a bootstrap p-value of 0.133. The key assumption here is that there is evidence of single threshold effect of CC on GDP^2. Moving on to Models 3 and 4, where the institutional quality proxies are GE and RQ, the estimated threshold values are 0.196 for both proxies. Again, the test statistics of F_1 shows that a single threshold exists for both indicators, with bootstrap p-values of 0.060 and 0.046, respectively. However, the tests for double threshold are insignificant. Model 5 reports the result for the model using another institutional indicator, which is RL. The single threshold of 46.69 is statistically significant at 10% with bootstrap p-value of 0.060. However, the test for double threshold F_2 is insignificant with the bootstrap p-value of 0.103. Thus, we can firmly conclude that there is strong evidence of single threshold in all models. Hence, for the remainder of the analyses, we worked with the single threshold model.

Having established the existence of an institutional quality threshold, the next question will be on how income affects environmental degradation. Table 5 presents the estimated results. In all five models, the coefficients of income and renewable energy are statistically significant and consistent with the theory. The estimated coefficient of income (GDP) is positive and is a significant determinant of environmental degradation at 1%. Interestingly, this finding confirms that income at the early stage contribute to increment in environmental pollution. Renewable energy (RE) is negative and statistically significant in promoting “green power” that provides the highest environmental benefit by reducing the emissions. The adoption of renewable energy sources such biomass, wind, solar, hydropower and geothermal can help reduce the

Table 5. Estimated parameters for single thresholds [DV = ED]

	Model 1 IQ=IQ_{AVG}	Model 2 IQ=CC	Model 3 IQ=GE	Model 4 IQ=RQ	Model 5 IQ=RL
Constant	3.056*** (0.000)	3.460* (0.091)	3.807*** (0.000)	3.659*** (0.000)	3.867*** (0.000)
GDP	0.493*** (0.000)	0.596*** (0.000)	0.578*** (0.000)	0.556*** (0.000)	0.589*** (0.000)
RE	-0.397*** (0.000)	-0.397*** (0.000)	-0.398*** (0.000)	-0.396*** (0.000)	-0.403*** (0.000)
GDP^2 I(λ_1≤IQ)	0.007*** (0.008)	0.006** (0.011)	0.008*** (0.002)	0.007*** (0.004)	0.006** (0.016)
GDP^2 I(λ_2>IQ)	0.005** (0.031)	0.007*** (0.005)	0.006** (0.014)	0.006** (0.010)	0.005** (0.027)

Note: The p-values are reported in parentheses. *, **, and *** denote 10%, 5%, and 1% level of significance, respectively. DV, ED, GDP, RE, CC, GE, RQ, RL, and IQ_{AVG} stand for dependent variable, environmental degradation, income, renewable energy, control of corruption, government effectiveness, regulatory quality, rule of law and average institutional quality, respectively.

growth of carbon intensity and also provide sustainable energy services (Shafiei & Salim, 2014).

Moving on to our main interest, the findings indicate that all five proxies for institutional quality in Model 1 until Model 5 have positive signs and are statistically significant in the first regime, or when IQ is below the threshold point. These estimates are substantially lower than those by Sharma (2011) for developed and developing countries (i.e. 13.189), Pao and Tsai (2011) for BRIC (Brazil, Russia, India and China) and Balsalobre-Lorente, Shahbaz, Roubaud and Farhani (2018) for European countries (i.e. 0.019). For example, the first regime estimates that the coefficient in Model 2 is 0.006 which implies that ED increases by 0.006% with an increase of 1% in GDP^2 for countries that have CC of less than or equals to 0.142%. As for the second regime (or when IQ is above the threshold point), we find that the coefficient estimates of GDP^2 are positive and significant in all models. Our findings of single threshold effect of institutional quality on GDP^2 values show that the two regime coefficients below or above the threshold value are positive and statistically significant at conventional level.

These empirical results suggest a noteworthy point that GDP^2 is ineffective in reducing environmental degradation, or EKC is not valid. This issue explains that lack of enforcement of rules and regulations has significantly aggravated environmental quality, even at the higher level of income which contradicts what EKC predicted. Since in our dataset, 74 out of 99 countries are developing countries, it is conceivable that the increase in income may not be fully capable to mitigate environmental degradation in the absence of strong institutional quality as the case of most developing countries might be dominating the effect. For instance, India has a number of environmental policies, such as the Water Act of 1974 and Air Act of 1981 which deals with the increasingly hazardous pollution levels (Chen & Lees, 2018). However, these regulations are not positive or very effective. The next analysis is to split the sample countries into developing and developed countries.

Although the full sample has been divided, the evidence of single threshold effect of IQ is still similar in both developed and developing countries as shown in Table 6. For developing countries, the F-statistic of 0.179 shows that the single thresholds are statistically significant as it is higher than the critical values for all models. This implies that there is evidence of single threshold effect of IQ on GDP^2 for developing countries. Likewise, for developed countries, the F-statistic also shows that the single threshold is significant since it is higher that the critical values. Therefore, we focus on the single threshold model for the rest of the estimation analysis.

In developed countries, the results reported on the left-hand side of Table 7 reveal that the estimated coefficients of GDP^2 is positive for IQ below the threshold point, but turn out to be negative after the threshold point. In other words, when IQ in the developed countries is lower than or equals to the threshold point (i.e. 1.142 as per Table 6), improvement in income (or GDP^2) will still be unable to reduce environmental degradation. A 1% increase in income will deteriorate environmental quality on average by 0.67%, or 0.45% in the case of high corruption, 1.35% in the case of government ineffectiveness, 0.86% in the case of poor regulatory quality and 0.31% in the case of weak rule of law. However, if the institutional quality is higher than the threshold point of developed countries, improvement in income could protect the environmental quality

Table 6. Tests for threshold effect in the sub-samples

	Developed Countries					Developing Countries				
	Model 1 IQ_{AVG}	Model 2 IQ=CC	Model 3 IQ=GE	Model 4 IQ=RQ	Model 5 IQ=RL	Model 1 IQ_{AVG}	Model 2 IQ=CC	Model 3 IQ=GE	Model 4 IQ=RQ	Model 5 IQ=RL
Test for Single Threshold										
Threshold 1	1.142	1.949	1.523	1.632	1.147	0.179	0.149	1.607	1.247	1.869
F_1	23.41**	20.35**	69.99**	28.41**	58.41**	18.81**	15.74**	13.65**	13.23**	28.68**
p-value	0.043	0.036	0.000	0.020	0.000	0.053	0.056	0.066	0.096	0.026
10% CV	16.590	15.947	14.270	13.856	15.707	13.036	13.707	11.589	12.740	17.548
Test for Double Threshold										
Threshold 2	1.133	1.922	1.512	1.614	1.122	0.178	0.109	1.532	1.209	1.574
Threshold 1	1.142	1.949	1.523	1.632	1.147	0.179	0.149	1.607	1.247	1.869
F_2	4.82	14.46	7.59	9.15	3.27	4.96	8.20	6.44	6.44	11.45
p-value	0.670	0.116	0.583	0.230	0.737	0.803	0.493	0.580	0.580	0.313
10% CV	13.322	15.632	20.583	18.109	15.517	20.625	17.006	14.868	14.868	20.068

Note: ** denotes significance of at least 10% critical value (CV). CC, GE, RQ, RL, and IQ_{AVG} stand for control of corruption, government effectiveness, regulatory quality, rule of law and average institutional quality, respectively.

Table 7. Estimated parameters for single thresholds in the sub-samples [DV = ED]

	Developed Countries					Developing Countries				
	Model 1 IQ_{AVG}	Model 2 IQ=CC	Model 3 IQ=GE	Model 4 IQ=RQ	Model 5 IQ=RL	Model 1 IQ_{AVG}	Model 2 IQ=CC	Model 3 IQ=GE	Model 4 IQ=RQ	Model 5 IQ=RL
Constant	3.92*	1.77*	1.59*	6.02*	1.89*	7.66*	1.49*	0.96*	1.61*	1.34*
	(0.00)	(0.01)	(0.02)	(0.02)	(0.09)	(0.00)	(0.08)	(0.05)	(0.05)	(0.04)
GDP	4.65*	10.93*	11.31*	7.50*	6.61*	0.89*	0.92*	1.04*	0.89*	0.88*
	(0.04)	(0.02)	(0.02)	(0.04)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
RE	-1.04*	-0.13*	-0.14*	- 0.12*	-0.12*	-0.38*	-0.38*	-0.35*	-0.39*	-0.39*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$GDP^2\ I(\lambda_1 \leq IQ)$	0.67*	0.45*	1.35*	0.86*	0.31*	0.09*	0.04*	1.52*	1.09*	1.04*
	(0.03)	(0.04)	(0.00)	(0.08)	(0.00)	(0.02)	(0.03)	(0.08)	(0.01)	(0.03)
$GDP^2\ I(\lambda_2 > IQ)$	-0.69*	-0.59*	-1.38*	-0.87*	-0.92*	0.09*	0.03*	1.48*	1.09*	1.03*
	(0.00)	(0.01)	(0.09)	(0.01)	(0.03)	(0.08)	(0.02)	(0.09)	(0.01)	(0.02)

Note: The p-values are reported in parentheses. * denotes significance of at least 10%. DV, ED, GDP, RE, CC, GE, RQ, RL, and IQ_{AVG} stand for dependent variable, environmental degradation, income, renewable energy, control of corruption, government effectiveness, regulatory quality, rule of law and average institutional quality, respectively.

from deteriorating further. This indicates that even in the case of highly developed countries with relatively among the best IQ level in the world, a mere weakness in IQ level will open the door for environmental destruction. Only those countries with the best IQ or surpass the threshold IQ are capable to fully protect their environment.

For the developing countries case, the results are similar to the full sample case where being the countries with poor IQ level, the door for environmental destruction is even larger as reflected in the positive effect of GDP^2 below the threshold point, which is 0.179 for IQ_{AVG}, 0.149 for CC, 1.607 for GE, 1.247 for RQ and 1.869 for RL (see Table 6). The effect of GDP^2 remains positive although it is slightly less destructive when IQ is better, or above the threshold point. At this stage, we observe that EKC is valid only in the case of developed countries with high institutional quality level. For the rest, namely developed countries with weak institutional quality, and developing countries, regardless of the level of institutional quality, EKC in general does not hold.

For further analysis, we performed a robustness check by incorporating foreign direct investment, trade, urbanisation and population growth in the threshold specification for developed and developing countries. Table 8 shows the results of the F-statistics for the single and double thresholds effect together with their bootstrap p-values. For the case of a single threshold, all five models display strong evidence of a threshold and it is higher than the critical value for both developed and developing countries. However, the tests for double threshold effect are insignificant, which indicates that the threshold effect does not exist. Hence, this confirms the validity of the single threshold.

Table 9 presents the estimated coefficients based on OLS for both developed and developing countries. The result for developed countries shows that GDP has a significantly positive relationship with environmental degradation in the first regime. In the second regime, when IQ is above the threshold point, GDP^2 and environmental degradation have significantly negative relationship. The validity of the EKC is further substantiated in developed countries. On the other hand, for the case of developing countries, both GDP^2 for below and above the threshold point show positive signs. This shows that EKC is invalid and high income fails to be converted fully to environment-protecting activities. Even in the case of developing countries with high IQ, that high IQ may still be considered as low from world perspective and therefore, greatly offers rent-seeking opportunities.

It has been found that FDI has a significant negative impact on environmental degradation which is in line with Cheung and Lin (2004), Mielnik and Goldemberg (2002), Stretesky and Lynch (2009) and Zugravu-Soilita (2017). Accordingly, it indicates the existence of the pollution halo hypothesis that FDI can help to reduce environmental pollution. The inflow of FDI leads to an improvement in environmental quality due to the usage of more efficient production technology. In this case, it is suggested that countries should attract large quantities of FDI projects to promote better environmental quality. Likewise, trade has a significant negative impact on environmental degradation for both developed and developing countries. This finding is similar to those obtained by Rezek and Rogers (2008) for industrialised countries, Lau et al. (2014) for Malaysia and Dogan and Seker (2016) for developed and developing countries. As discussed in the literature review section, this finding may be due to the presence of techniques and composition effects.

Table 8. Tests for threshold effects for extended models in the sub-samples

Developed Countries

	Model 1: IQ=IQ_{AVG}				Model 2: IQ=CC				Model 3: IQ=GE				Model 4: IQ=RQ				Model 5: IQ=RL			
	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)
Test for Single Threshold																				
T1	1.14	1.14	0.16	0.16	1.94	1.94	0.14	0.14	1.52	1.52	0.21	0.21	1.63	1.63	0.19	0.19	1.14	1.14	0.15	0.15
F_1	33.9*	31.3*	32.2*	18.3*	47.3*	48.4*	28.6*	9.2*	69.9*	70.4*	15.2*	20.1*	29.5*	28.9*	25.0*	0.20*	59.1*	59.1*	14.4*	17.2*
p-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.07	0.00	0.03	0.03	0.06	0.03	0.00	0.00	0.04	0.02
10% CV	15.5	15.6	12.5	11.3	14.5	14.9	12.1	8.6	14.6	13.4	13.2	10.1	16.0	17.5	19.4	12.7	14.4	15.8	9.5	12.0
Test for Double Threshold																				
T1	1.13	1.13	0.16	0.16	1.92	1.92	0.14	0.14	1.51	1.50	0.21	0.21	1.60	1.61	0.19	0.19	1.12	1.12	0.15	0.15
T2	1.14	1.14	0.23	0.23	1.94	1.94	0.15	0.15	1.52	1.50	0.22	0.22	1.60	1.63	0.22	0.22	1.14	1.14	1.18	1.18
F_2	10.4	11.7	8.2	7.4	11.7	11.7	6.3	3.5	8.0	8.6	6.9	6.2	9.3	10.0	3.0	7.9	6.9	7.2	1.4	4.8
p-value	0.31	0.26	0.22	0.34	0.19	0.28	0.61	0.81	0.56	0.40	0.48	0.78	0.20	0.31	0.71	0.30	0.58	0.64	0.95	0.58
10% CV	18.3	18.2	10.7	11.4	15.4	17.6	8.7	13.2	19.7	20.8	16.4	24.0	15.0	22.4	11.5	12.6	21.4	25.1	9.1	13.9

Developing countries

	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)
Test for Single Threshold																				
T1	0.17	0.17	0.16	0.16	0.14	0.14	0.13	0.13	1.60	1.60	0.22	0.22	1.24	1.24	0.21	0.21	1.86	1.86	0.17	0.17
F_1	88.9*	86.1*	16.5*	20.9*	42.3*	38.5*	19.6*	20.5*	12.8*	45.3*	22.6*	25.3*	18.5*	19.0*	16.9*	16.9*	21.8*	23.4*	21.2*	26.4*
p-value	0.00	0.00	0.06	0.06	0.00	0.01	0.09	0.08	0.08	0.00	0.03	0.06	0.06	0.05	0.07	0.08	0.02	0.03	0.05	0.00
10% CV	13.6	14.1	13.0	13.0	17.3	17.3	19.3	19.3	11.7	14.7	16.3	18.6	14.2	14.1	15.1	14.1	15.7	16.6	14.1	14.9
Test for Double Threshold																				
T1	0.17	0.17	0.16	0.16	0.10	0.10	0.13	0.13	1.53	1.53	0.22	0.22	1.20	1.20	0.21	0.21	1.57	1.57	0.17	0.17
T2	0.18	0.18	0.20	0.20	0.14	0.14	0.21	0.21	1.60	1.60	0.25	0.25	1.24	1.24	0.31	0.31	1.86	1.86	0.24	0.24
F_2	7.8	6.9	2.8	4.4	9.4	8.7	21.9	9.6	2.6	9.2	8.2	8.2	3.2	4.3	6.2	9.3	6.6	5.8	2.3	3.6
p-value	0.47	0.58	0.91	0.72	0.30	0.48	0.10	0.19	0.96	0.37	0.47	0.37	0.83	0.73	0.60	0.43	0.51	0.68	0.94	0.76
10% CV	14.6	18.7	14.3	14.7	18.3	23.5	24.9	12.8	15.1	21.3	23.1	17.0	18.2	20.8	19.6	19.8	14.4	17.7	13.6	16.5

Note: * denote significance of at least 10%. CC, GE, RQ, RL, and IQ_{AVG} stand for control of corruption, government effectiveness, regulatory quality, rule of law and average institutional quality, respectively. (a) refers to equation with foreign direct investment (FDI) as additional explanatory variable, (b) refers to equation with trade (TR) as additional variable, (c) refers to equation with population (POP) as additional explanatory variable, while (d) refers to equation with urbanisation (URB) as additional variable.

Table 9. Extended model for single thresholds – sub-samples [DV = ED]

	Model 1: $IQ=IQ_{AVG}$				Model 2: IQ=CC				Model 3: IQ=GE				Model 4: IQ=RQ				Model 5: IQ=RL			
	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)
Developed Countries																				
Constant	1.40*	1.48*	14.40*	17.60*	1.27*	1.28*	17.30*	17.00*	1.49*	1.45*	6.75*	8.60*	1.10*	1.25*	17.90*	20.10*	1.69*	1.77*	16.40*	20.10*
	(0.02)	(0.01)	(0.00)	(0.01)	(0.05)	(0.05)	(0.05)	(0.00)	(0.00)	(0.00)	(0.07)	(0.02)	(0.03)	(0.08)	(0.00)	(0.00)	(0.04)	(0.01)	(0.00)	(0.00)
GDP	9.30*	9.94*	0.08*	0.02*	8.44*	8.50*	0.07*	0.01*	10.00*	9.83*	0.03*	0.06*	7.09*	8.29*	0.04*	0.01*	7.19*	11.90*	0.04*	0.01*
	(0.03)	(0.02)	(0.05)	(0.02)	(0.07)	(0.07)	(0.01)	(0.04)	(0.01)	(0.01)	(0.07)	(0.02)	(0.05)	(0.09)	(0.09)	(0.00)	(0.05)	(0.01)	(0.03)	(0.00)
RE	-0.10*	-0.15*	-0.15*	-0.91*	-0.11*	-0.11*	-0.18*	-0.43*	-0.13*	-0.13*	-0.16*	-0.10*	-0.12*	-0.11*	-0.13*	0.80*	-0.11*	-0.11*	-0.19*	-0.10*
	(0.00)	(0.00)	(0.00)	(0.03)	(0.00)	(0.00)	(0.00)	(0.09)	(0.00)	(0.00)	(0.00)	(0.04)	(0.00)	(0.00)	(0.00)	(0.09)	(0.00)	(0.00)	(0.00)	(0.09)
FDI	-0.02*	–	–	–	-0.02*	–	–	–	-0.02*	–	–	–	-0.02*	–	–	–	-0.01*	–	–	–
	(0.03)	–	–	–	(0.04)	–	–	–	(0.03)	–	–	–	(0.02)	–	–	–	(0.06)	–	–	–
TR	–	-0.05*	–	–	–	-0.04*	–	–	–	-0.12*	–	–	–	-0.02*	–	–	–	-0.05*	–	–
	–	(0.06)	–	–	–	(0.04)	–	–	–	(0.07)	–	–	–	(0.08)	–	–	–	(0.09)	–	–
POP	–	–	0.77*	–	–	–	0.48*	–	–	–	0.58*	–	–	–	0.77*	–	–	–	0.83*	–
	–	–	(0.00)	–	–	–	(0.00)	–	–	–	(0.00)	–	–	–	(0.00)	–	–	–	(0.06)	–
URB	–	–	–	0.84*	–	–	–	0.72*	–	–	–	0.73*	–	–	–	0.89*	–	–	–	0.92*
	–	–	–	(0.00)	–	–	–	(0.00)	–	–	–	(0.00)	–	–	–	(0.00)	–	–	–	(0.00)
GDP^2	0.22*	0.06*	1.18*	6.71*	0.51*	0.85*	6.46*	9.37*	1.47*	1.35*	1.20*	9.09*	0.69*	0.66*	1.80*	2.80*	0.41*	0.49*	1.61*	0.31*
$I(\lambda_1 \leq IQ)$	(0.02)	(0.03)	(0.03)	(0.02)	(0.05)	(0.06)	(0.00)	(0.00)	(0.00)	(0.00)	(0.04)	(0.06)	(0.03)	(0.07)	(0.00)	(0.00)	(0.08)	(0.01)	(0.04)	(0.01)
GDP^2	-0.27*	-0.07*	-3.45*	-9.36*	0.52*	0.86*	-9.23*	-1.20*	-1.49*	-1.39*	-1.10*	-1.10*	-0.83*	-0.66*	-1.70*	-2.60*	-0.48*	-0.50*	-2.90*	-3.12*
$I(\lambda_2 > IQ)$	(0.02)	(0.03)	(0.00)	(0.00)	(0.09)	(0.06)	(0.00)	(0.00)	(0.00)	(0.00)	(0.09)	(0.00)	(0.04)	(0.07)	(0.00)	(0.00)	(0.09)	(0.01)	(0.00)	(0.01)
Developing Countries																				
Constant	3.89*	4.98*	1.16*	1.49*	1.98*	1.86*	1.33*	0.38*	3.43*	5.74*	2.03*	1.27*	5.76*	8.15*	1.95*	0.44*	4.56*	3.91*	1.22*	0.63*
	(0.02)	(0.04)	(0.00)	(0.08)	(0.04)	(0.09)	(0.00)	(0.09)	(0.00)	(0.05)	(0.00)	(0.00)	(0.03)	(0.00)	(0.03)	(0.09)	(0.08)	(0.04)	(0.00)	(0.02)
GDP	0.92*	0.82*	0.27*	0.32*	0.65*	0.41*	0.28*	0.19*	0.72*	0.71*	0.02*	0.03*	0.70*	0.66*	0.02*	0.31*	0.63*	0.73*	0.02*	0.05*
	(0.00)	(0.00)	(0.08)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Table 9. Continued

	Model 1: IQ=IQ_{AVG}				Model 2: IQ=CC				Model 3: IQ=GE				Model 4: IQ=RQ				Model 5: IQ=RL			
	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)
RE	-0.38*	-0.36*	-0.02*	-0.06*	-0.86*	-0.86*	-0.02*	-0.86*	-0.90*	-0.92*	-0.02*	-0.21*	-0.43*	-0.94*	-0.02*	-0.31*	-0.97*	-1.40*	-0.02*	-0.23*
	(0.00)	(0.00)	(0.00)	(0.06)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.05)	(0.00)	(0.00)	(0.00)	(0.00)
FDI	-0.03*	–	–	–	-0.01*	–	–	–	-0.27*	–	–	–	-0.02*	–	–	–	-0.04*	–	–	–
	(0.05)	–	–	–	(0.04)	–	–	–	(0.01)	–	–	–	(0.09)	–	–	–	(0.09)	–	–	–
TR	–	-0.07*	–	–	–	-0.03*	–	–	–	0.01*	–	–	–	-0.01*	–	–	–	0.08*	–	–
	–	(0.03)	–	–	–	(0.07)	–	–	–	(0.09)	–	–	–	(0.03)	–	–	–	(0.09)	–	–
POP	–	–	0.25*	–	–	–	0.22*	–	–	–	0.25*	–	–	–	0.28*	–	–	–	0.27*	–
	–	–	(0.05)	–	–	–	(0.07)	–	–	–	(0.05)	–	–	–	(0.02)	–	–	–	(0.04)	–
URB	–	–	–	0.17*	–	–	–	0.15*	–	–	–	0.15*	–	–	–	0.62*	–	–	–	0.12*
	–	–	–	(0.07)	–	–	–	(0.02)	–	–	–	(0.02)	–	–	–	(0.09)	–	–	–	(0.06)
GDP^2	0.09*	0.01*	3.07*	1.37*	0.04*	0.05*	1.16*	0.39*	0.16*	0.72*	1.07*	2.34*	0.20*	0.62*	1.65*	0.01*	0.22*	0.56*	0.96*	0.63*
$I(\lambda_1 \leq IQ)$	(0.03)	(0.00)	(0.08)	(0.02)	(0.00)	(0.00)	(0.00)	(0.05)	(0.00)	(0.00)	(0.08)	(0.08)	(0.00)	(0.00)	(0.06)	(0.00)	(0.00)	(0.00)	(0.07)	(0.08)
GDP^2	0.09*	0.03*	7.80*	1.71*	0.04*	0.06*	5.22*	2.47*	0.19*	0.80*	3.14*	4.55*	0.21*	0.81*	2.80*	0.73*	0.27*	0.66*	1.54*	0.91*
$I(\lambda_2 > IQ)$	(0.04)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.04)	(0.00)	(0.00)	(0.04)	(0.00)	(0.00)	(0.00)	(0.03)	(0.00)	(0.00)	(0.00)	(0.02)	(0.05)

Note: The p-values are reported in parentheses. * denotes significance of at least 10%. DV, ED, GDP, RE, CC, GE, RQ, RL, and IQ_{AVG} stand for dependent variable, environmental degradation, income, renewable energy, control of corruption, government effectiveness, regulatory quality, rule of law and average institutional quality, respectively. (a) refers to equation with foreign direct investment (FDI) as additional explanatory variable, (b) refers to equation with trade (TR) as additional variable, (c) refers to equation with population (POP) as additional explanatory variable, while (d) refers to equation with urbanisation (URB) as additional variable.

Besides that, this study finds that population growth increases environmental degradation in both developed and developing countries. This finding suggests that population growth may lead to use of greater amounts of resources to assist their basic necessities and livelihoods. As a result, it will generate a negative impact on the environment by offering various types of destruction on it (such as climate change, biodiversity loss and pollution). Our estimates are close to the ones reported by Hafeez et al. (2018), Hossain (2011), Liddle and Lung (2010), Paramati et al. (2018) and Zhang and Lin (2012).

Based on the analysis, urbanisation has been found to have a positive significant impact on environmental degradation, which implies that as urbanisation increases, the destruction level in developing and developed countries also rises, simultaneously. Although higher levels of industrialisation in urban areas create jobs and encourage modernisation, it will also increase emission. Our finding is consistent with the findings from researchers such as Al-Mulali and Ozturk (2016), Liu and Bae (2018), Munir and Ameer (2018) and Zhang and Zhou (2016).

Finally, we also examine the threshold model by incorporating all control variables in the model at once. Generally, the effect of income on environmental degradation is maintained. To conserve space, the results are displayed in Appendix A. To conclude, it can be said that EKC is only valid in the case of developed countries with good institutional qualities only.

5. Conclusion

The effectiveness of income in reducing environmental degradation remains as an unresolved issue as described by mixed results of past studies. Expecting the potential poor institutional quality as the conditional factor, applying data from 99 countries covering through 2008-2016, this study examines the existence of threshold effect of institutional quality on income-environment nexus, or to be precise, the EKC hypothesis. First of all, the empirical results indicate that there is a significant single institutional threshold in the environmental degradation-income nexus. Secondly, we also observe that in the presence of imperfect institutional quality, income seems to be ineffective to promote quality environment as the effects of higher income (represented by GDP^2) are no longer negative in both regimes. Thirdly, since income is likely ineffective to reduce environmental degradation in the presence of imperfect institutional quality, better institutional quality tends to help maintain the environmental quality. In summary, this study tends to invalidate the existence of EKC in the presence of imperfect institutional quality with exception to the case of developed countries with high quality of institution.

In terms of policy implication, policy makers should give equal attention to the efforts on promoting economic growth and improving institutional quality. This is because weak formal institutional qualities will prevent high income to effectively protect environmental degradation, mainly in developing countries and also in some developed countries. Accordingly, as countries strive towards higher economic growth, governments should develop stronger institutions such as improving government efficiency, transparency and enhancing the rule of law in order to assure the large amount of allocation (due to high income) for environmental protecting efforts to be fruitful. For instance, setting up more effective anti-corruption agencies to enforce the rule and prosecute corrupted people by imposing stricter environmental laws and enforcement in order to strengthen environmental qualities (Law, Kutan, & Naseem, 2018; Olayungbo & Adediran, 2017).

Concerning foreign direct investment and trade, both signal a negative effect and are likely to support the effort of host countries in preserving environmental quality. More pro-environment FDI should be encouraged to inflow and pro-environment quality trading goods must be targeted. Thereby, governing bodies need to eliminate or minimise any legal and non-legal obstacles that discourage multinational corporations from coming. Nevertheless, policies on flows of goods should be made more stringent to ensure only goods that are compatible with the environment should be allowed. Moreover, governments should design and implement effective policies to promote investment in renewable technologies and energy conservation (e.g. stability of energy price, affordability and reliability) to promote more demand for renewable energy and eventually, improve the quality of the environment. Such government policies will encourage a high capacity for renewable energy investment, reduce obstacles (e.g. lack of cost, regulation and issues) and opportunities (e.g. energy security and new technology use) to the growth of renewable energy use. Enhancement of basic education and formulation of appropriate policy for long term urban planning help to increase environmental awareness, skills to promote environmental quality, construction of new '*green*' residential parks and necessary infrastructure to minimise the adverse environmental impact of population growth or urbanisation.

Despite these important findings, there is a possibility of having a different threshold effect of institutional quality on the income-environment nexus in each developing and developed nation. Thus, future researchers need to broaden the analysis to include time series data such as for individual developing countries. This is because most of the developing countries are assumed to be similar to each other, but in reality, these countries may have their own unique policies and socio-economic characteristics. As a result, proper planning to spur sustainable environmental management and good environmental quality can be proposed strategically by evaluating these economies individually.

References

Aidt, T.S. (2009). Corruption, institutions, and economic development. *Oxford Review of Economic Policy, 25*(2), 271-291. https://doi.org/10.1093/oxrep/grp012

Aklin, M. (2016). Re-exploring the trade and environment nexus through the diffusion of pollution. *Environmental and Resource Economics, 64*(4), 663-682. https://doi.org/10.1007/s10640-015-9893-1

Al-Mulali, U., & Ozturk, I. (2016). The investigation of environmental Kuznets curve hypothesis in the advanced economies: The role of energy prices. *Renewable and Sustainable Energy Reviews, 54*(February), 1622-1631. https://doi.org/10.1016/j.rser.2015.10.131

Ampratwum, E.F. (2008). The fight against corruption and its implications for development in developing and transition economies. *Journal of Money Laundering Control, 11*(1), 76-87. https://doi.org/10.1108/13685200810844514

Ang, J.B. (2007). CO_2 emissions, energy consumption, and output in France. *Energy Policy, 35*(10), 4772-4778. https://doi.org/10.1016/j.enpol.2007.03.032

Apergis, N., Payne, J.E., Menyah, K., & Wolde-Rufael, Y. (2010). On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth. *Ecological Economics, 69*(11), 2255-2260. https://doi.org/10.1016/j.ecolecon.2010.06.014

Balsalobre-Lorente, D., Shahbaz, M., Roubaud, D., & Farhani, S. (2018). How economic growth, renewable electricity and natural resources contribute to CO_2 emissions? *Energy Policy, 113*(February), 356-367. https://doi.org/10.1016/j.enpol.2017.10.050

Banta, B.R. (2008). Just war theory and the 2003 Iraq war forced displacement. *Journal of Refugee Studies, 21*(3), 261-284. https://doi.org/10.1093/jrs/fen027

Begum, R.A., Sohag, K., Abdullah, S.M.S., & Jaafar, M. (2015). CO_2 emissions, energy consumption, economic and population growth in Malaysia. *Renewable and Sustainable Energy Reviews, 41*(January), 594-601. https://doi.org/10.1016/j.rser.2014.07.205

Belaid, F., & Youssef, M. (2017). Environmental degradation, renewable and non-renewable electricity consumption, and economic growth: Assessing the evidence from Algeria. *Energy Policy, 102*(March), 277-287. https://doi.org/10.1016/j.enpol.2016.12.012

Bento, J.P.C., & Moutinho, V. (2016). CO_2 emissions, non-renewable and renewable electricity production, economic growth, and international trade in Italy. *Renewable and Sustainable Energy Reviews, 55*(March), 142-155. https://doi.org/10.1016/j.rser.2015.10.151

Berdiev, A.N., Kim, Y., & Chang, C.-P. (2013). Remittances and corruption. *Economics Letters, 118*(1), 182-185. https://doi.org/10.1016/j.econlet.2012.10.008

Bhattarai, M., & Hammig, M. (2004). Governance, economic policy, and the environmental Kuznets curve for natural tropical forests. *Environment and Development Economics, 9*(3), 367-382. https://doi.org/10.1017/S1355770X03001293.

Bilgili, F., Kocak, E., & Bulut, U. (2016). The dynamic impact of renewable energy consumption on CO_2 emissions: A revisited environmental Kuznets curve approach. *Renewable and Sustainable Energy Reviews, 54*(February), 838-845. https://doi.org/10.1016/j.rser.2015.10.080.

Boluk, G., & Mert, M. (2014). Fossil & renewable energy consumption, GHGs (greenhouse gases) and economic growth: Evidence from a panel of EU (European Union) countries. *Energy, 74*(September), 439-446. https://doi.org/10.1016/j.energy.2014.07.008

Chen, G.C., & Lees, C. (2018). The new, green, urbanization in China: Between authoritarian environmentalism and decentralization. *Chinese Political Science Review, 3*(2), 212-231. https://doi.org/10.1007/s41111-018-0095-1

Cheung, K.Y., & Lin, P. (2004). Spillover effects of FDI on innovation in China: Evidence from the provincial data. *China Economic Review, 15*(1), 25-44. https://doi.org/10.1016/S1043-951X(03)00027-0

Cole, M.A., & Elliott, R.J. (2005). FDI and the capital intensity of "dirty" sectors: a missing piece of the pollution haven puzzle. *Review of Development Economics, 9*(4), 530-548. https://doi.org/10.1111/j.1467-9361.2005.00292.x

Copeland, B.R., & Taylor, M.S. (1995). Trade and the environment: A partial synthesis. *American Journal of Agricultural Economics, 77*(3), 765-771. https://doi.org/10.2307/1243249

Dasgupta, S., Laplante, B., Wang, H., & Wheeler, D. (2002). Confronting the environmental Kuznets curve. *Journal of Economic Perspectives, 16*(1), 147-168. https://doi.org/10.1257/0895330027157

Del Monte, A., & Papagni, E. (2001). Public expenditure, corruption, and economic growth: The case of Italy. *European Journal of Political Economy, 17*(1), 1-16. https://doi.org/10.1016/S0176-2680(00)00025-2

Dillon, J., Ekmekji, K., Feighery, A., Garrett, R., Gray, M., Johnson, T., … Reilly, K. (2006). *Corruption & the environment*. In a project for Transparency International, Environmental Science and Policy Workshop, Columbia University, School of International & Public Affairs.

Dogan, E., & Seker, F. (2016). 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*(July), 1074-1085. https://doi.org/10.1016/j.rser.2016.02.006

Ehrhardt-Martinez, K., Crenshaw, E.M., & Jenkins, J.C. (2003). Deforestation and the environmental Kuznets curve: A cross-national investigation of intervening mechanisms. *Social Science Quarterly, 83*(1), 226-243. https://doi.org/10.1111/1540-6237.00080

Elum, Z.A., & Momodu, A.S. (2017). Climate change mitigation and renewable energy for sustainable development in Nigeria: A discourse approach. *Renewable and Sustainable Energy Reviews, 76*(September), 72-80. https://doi.org/10.1016/j.rser.2017.03.040

Grossman, G.M., & Krueger, A.B. (1995). Economic growth and the environment. *The Quarterly Journal of Economics, 110*(2), 353-377. https://doi.org/10.2307/2118443

Hafeez, M., Chunhui, Y., Strohmaier, D., Ahmed, M., & Jie, L. (2018). Does finance affect environmental degradation: Evidence from One Belt and One Road Initiative region? *Environmental Science and Pollution Research, 25*(10), 9579-9592. https://doi.org/10.1007/s11356-018-1317-7

Halicioglu, F., & Ketenci, N. (2016). The impact of international trade on environmental quality: The case of transition countries. *Energy, 109*(August), 1130-1138. https://doi.org/10.1016/j.energy.2016.05.013

Hansen, B.E. (1999). Threshold effects in non-dynamic panels: Estimation, testing, and inference. *Journal of Econometrics 93*(2), 345-368. https://doi.org/10.1016/S0304-4076(99)00025-1

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 & Energy Systems, 64*(January), 785-791. https://doi.org/10.1016/j.ijepes.2014.07.081

Holtz-Eakin, D., & Selden, T.M. (1995). Stoking the fires? CO_2 emissions and economic growth. *Journal of Public Economics, 57*(1), 85-101. https://doi.org/10.1016/0047-2727(94)01449-X

Hossain, M.S. (2011). Panel estimation for CO_2 emissions, energy consumption, economic growth, trade openness and urbanization of newly industrialized countries. *Energy Policy, 39*(11), 6991-6999. https://doi.org/10.1016/j.enpol.2011.07.042

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*(January), 824-831. https://doi.org/10.1016/j.ecolind.2015.08.031

Kellenberg, D.K. (2009). An empirical investigation of the pollution haven effect with strategic environment and trade policy. *Journal of International Economics, 78*(2), 242-255. https://doi.org/10.1016/j.jinteco.2009.04.004

Kotze, L.J. (2006). Improving unsustainable environmental governance in South Africa: The case for holistic governance. *Potchefstroom Electronic Law Journal/Potchefstroomse Elektroniese Regsblad, 9*(1), 1-44. https://doi.org/10.4314/pelj.v9i1.43452.

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*(May), 490-497. https://doi.org/10.1016/j.enpol.2014.01.002

Law, S.H., Kutan, A.M., & Naseem, N.A.M. (2018). The role of institutions in finance curse: Evidence from international data. *Journal of Comparative Economics, 46*(1), 174-191. https://doi.org/10.1016/j.jce.2017.04.001

Lean, H.H., & Smyth, R. (2010). CO_2 emissions, electricity consumption and output in ASEAN. *Applied Energy, 87*(6), 1858-1864. https://doi.org/10.1016/j.apenergy.2010.02.003

Lee, C.C., & Lee, J.-D. (2009). Income and CO_2 emissions: Evidence from panel unit root and cointegration tests. *Energy Policy 37*(2), 413-423. https://doi.org/10.1016/j.enpol.2008.09.053

Leitão, N. (2010). Does trade help to explain tourism demand? The case of Portugal. *Theoretical and Applied Economics, 3*(3), 63-74.

Liddle, B., & Lung, S. (2010). Age-structure, urbanization, and climate change in developed countries: Revisiting STIRPAT for disaggregated population and consumption-related environmental impacts. *Population and Environment, 31*(5), 317-343. https://doi.org/10.1007/s11111-010-0101-5

Liu, X., & Bae, J. (2018). Urbanization and industrialization impact of CO_2 emissions in China. *Journal of Cleaner Production, 172*(January), 178-186. https://doi.org/10.1016/j.jclepro.2017.10.156

Marquart-Pyatt, S. (2004). A cross-national investigation of deforestation, debt, state fiscal capacity, and the environmental Kuznets Curve. *International Journal of Sociology, 34*(1), 33-51. https://doi.org/10.1080/00207659.2004.11043128

Mauro, P. (1998). Corruption and the composition of government expenditure. *Journal of Public Economics, 69*(2), 263-279. https://doi.org/10.1016/S0047-2727(98)00025-5

Mielnik, O., & Goldemberg, J. (2002). Foreign direct investment and decoupling between energy and gross domestic product in developing countries. *Energy Policy, 30*(2), 87-89. https://doi.org/10.1016/S0301-4215(01)00080-5

Munir, K., & Ameer, A. (2018). Effect of economic growth, trade openness, urbanization, and technology on environment of Asian emerging economies. *Management of Environmental Quality: An International Journal, 29*(3), 1123-1134. https://doi.org/10.1108/MEQ-05-2018-0087

Olayungbo, D.O., & Adediran, K.A. (2017). Effects of Oil Revenue and Institutional Quality on Economic Growth with an ARDL Approach. *Energy and Policy Research, 4*(1), 44-54. https://doi.org/10.1080/23815639.2017.1307146

Omri, A., Daly, S., Rault, C., & Chaibi, A. (2015). Financial development, environmental quality, trade and economic growth: What causes what in MENA countries? *Energy Economics, 48*(March), 242-252. https://doi.org/10.1016/j.eneco.2015.01.008

Pao, H.T. & Tsai, C.M. (2011). Multivariate granger causality between CO_2 emissions, energy consumption, FDI (foreign direct investment) and GDP (gross domestic product): Evidence from a panel of BRIC (Brazil, Russian Federation, India, and China) countries. *Energy, 36*(1), 685-693. https://doi.org/10.1016/j.energy.2010.09.041

Paramati, S.R., Alam, M.S., & Lau, C.K.M. (2018). The effect of tourism investment on tourism development and CO_2 emissions: Empirical evidence from the EU nations. *Journal of Sustainable Tourism, 26*(9), 1587-1607. https://doi.org/10.1080/09669582.2018.1489398

Pellegrini, L., & Gerlagh, R. (2006). Corruption, democracy, and environmental policy: An empirical contribution to the debate. *The Journal of Environment & Development, 15*(3), 332-354. https://doi.org/10.1177/1070496506290960

Reppelin-Hill, V. (1999). Trade and environment: An empirical analysis of the technology effect in the steel industry. *Journal of Environmental Economics and Management, 38*(3), 283-301. https://doi.org/10.1006/jeem.1999.1085

Rezek, J.P., & Rogers, K. (2008). Decomposing the CO_2-income tradeoff: An output distance function approach. *Environment and Development Economics, 13*(4), 457-473. https://doi.org/10.1017/S1355770X08004385

Robbins, P. (2000). The rotten institution: Corruption in natural resource management. *Political Geography, 19*(4), 423-443. https://doi.org/10.1016/S0962-6298(99)00087-6

Roberts, J.T., & Grimes, P.E. (1997). Carbon intensity and economic development 1962–1991: A brief exploration of the environmental Kuznets curve. *World Development, 25*(2), 191-198. https://doi.org/10.1016/S0305-750X(96)00104-0

Rodrik, D., Subramanian, A., & Trebbi, F. (2004). Institutions rule: The primacy of institutions over geography and integration in economic development. *Journal of Economic Growth, 9*(2), 131-165. https://doi.org/10.1023/B:JOEG.0000031425.72248.85

Rose-Ackerman, S., & Palifka, B.J. (2016). *Corruption and government: Causes, consequences, and reform*. Cambridge, UK: Cambridge University Press.

Saboori, B., Sulaiman, J., & Mohd, S. (2012). Economic growth and CO_2 emissions in Malaysia: A cointegration analysis of the environmental Kuznets curve. *Energy Policy 51*(December), 184-191. https://doi.org/10.1016/j.enpol.2012.08.065

Sari, R., & Soytas, U. (2007). The growth of income and energy consumption in six developing countries. *Energy Policy, 35*(2), 889-898. https://doi.org/10.1016/j.enpol.2006.01.021

Shafiei, S., & Salim, R.A. (2014). Non-renewable and renewable energy consumption and CO_2 emissions in OECD countries: A comparative analysis. *Energy Policy, 66*(March), 547-556. https://doi.org/10.1016/j.enpol.2013.10.064

Shafik, N. (1994). Economic development and environmental quality: An econometric analysis. *Oxford Economic Papers, 46*(S1), 757-773. https://doi.org/10.1093/oep/46.Supplement_1.757

Shahbaz, M., Nasreen, S., Ahmed, K., & Hammoudeh, S. (2017). Trade openness–carbon emissions nexus: The importance of turning points of trade openness for country panels. *Energy Economics, 61*(January), 221-232. https://doi.org/10.1016/j.eneco.2016.11.008

Shandra, J.M., London, B., Whooley, O.P., & Williamson, J.B. (2004). International nongovernmental organizations and carbon dioxide emissions in the developing world: A quantitative, cross-national analysis. *Sociological Inquiry, 74*(4), 520-545. https://doi.org/10.1111/j.1475-682X.2004.00103.x

Sharma, S.S. (2011). Determinants of carbon dioxide emissions: Empirical evidence from 69 countries. *Applied Energy, 88*(1), 376-382. https://doi.org/10.1016/j.apenergy.2010.07.022

Stern, D.I. (2004). The rise and fall of the environmental Kuznets curve. *World Development, 32*(8), 1419-1439. https://doi.org/10.1016/j.worlddev.2004.03.004

Stretesky, P.B., & Lynch, M.J. (2009). A cross-national study of the association between per capita carbon dioxide emissions and exports to the United States. *Social Science Research, 38*(1), 239-250. https://doi.org/10.1016/j.ssresearch.2008.08.004

Transparency International. (2016). *Corruption perception index 2016*. Retrieved from https://www.transparency.org/news/feature/corruption_perceptions_index_2016

Ugur, M. (2014). Corruption's direct effects on per-capita income growth: A meta-analysis. *Journal of Economic Surveys, 28*(3), 472-490. https://doi.org/10.1111/joes.12035

Ugur, M., & Dasgupta, N. (2011). *Evidence on the economic growth impacts of corruption in low-income countries and beyond: A systematic review*. London: EPPI-Centre, SSRU. Institute of Education, University of London.

Welsch, H. (2004). Corruption, growth, and the environment: A cross-country analysis. *Environment and Development Economics 9*(5), 663-693. https://doi.org/10.1017/S1355770X04001500

Winbourne, S. (2002). *Corruption and the environment*. Washington, DC: USAID and Management Systems International.

World Bank. (2017a). *World development indicators*. Retrieved from http://data.worldbank.org/indicator

World Bank. (2017b). *Worldwide governance indicators*. Retrieved from http://data.worldbank.org/data-catalog/worldwide-governance-indicators

Zhang, C., & Lin, Y. (2012). Panel estimation for urbanization, energy consumption and CO_2 emissions: A regional analysis in China. *Energy Policy, 49*(October), 488-498. https://doi.org/10.1016/j.enpol.2012.06.048

Zhang, C., & Zhou, X. (2016). Does foreign direct investment lead to lower CO2 emissions? Evidence from a regional analysis in China. *Renewable and Sustainable Energy Reviews, 58*(May), 943-951. https://doi.org/10.1016/j.rser.2015.12.226

Zhang, Y.-J., Jin, Y.-L., Chevallier, J., & Shen, B. (2016). The effect of corruption on carbon dioxide emissions in APEC countries: A panel quantile regression analysis. *Technological Forecasting and Social Change, 112*(November), 220-227. https://doi.org/10.1016/j.techfore.2016.05.027
Zoundi, Z. (2017). CO2 emissions, renewable energy and the environmental Kuznets curve, a panel cointegration approach. *Renewable and Sustainable Energy Reviews, 72*(May), 1067-1075. https://doi.org/10.1016/j.rser.2016.10.018
Zugravu-Soilita, N. (2017). How does foreign direct investment affect pollution? Toward a better understanding of the direct and conditional effects. *Environmental and Resource Economics, 66*(2), 293-338. https://doi.org/10.1007/s10640-015-9950-9

Appendix A

Table A1. Tests for threshold effect in sub-samples

	Developed Countries					Developing Countries				
	Model 1 IQ_{AVG}	Model 2 IQ_{CC}	Model 3 IQ_{GE}	Model 4 IQ_{RQ}	Model 5 IQ_{RL}	Model 1 IQ_{AVG}	Model 2 IQ_{CC}	Model 3 IQ_{GE}	Model 4 IQ_{RQ}	Model 5 IQ_{RL}
Test for Single Threshold										
Threshold 1	0.173	0.145	0.219	0.199	0.155	0.156	0.131	0.187	0.205	0.154
F_1	13.55**	32.60**	19.46**	28.52**	23.57**	21.41**	16.64**	74.19**	21.72**	92.22**
p-value	0.096	0.000	0.000	0.000	0.041	0.050	0.070	0.000	0.050	0.000
10% CV	11.620	12.721	11.535	16.579	10.480	14.515	15.224	16.093	14.467	16.032
Test for Double Threshold										
Threshold 2	0.173	0.145	0.219	0.199	0.155	0.156	0.131	0.187	0.205	0.154
Threshold 1	0.251	0.150	0.239	0.226	0.234	0.164	0.214	0.228	0.219	0.175
F_2	4.56	9.82	6.61	7.51	1.47	3.86	5.75	9.61	9.18	2.22
p-value	0.540	0.113	0.823	0.300	0.936	0.850	0.586	0.680	0.270	0.926
10% CV	12.185	10.553	27.080	12.100	8.184	15.845	15.069	41.129	15.198	13.905

Note: ** denotes significance at least at 10%.

Table A2. Estimated parameters for single thresholds in sub-samples [DV = ED]

	Developed Countries					Developing Countries				
	Model 1 IQ_{AVG}	Model 2 IQ_{CC}	Model 3 IQ_{GE}	Model 4 IQ_{RQ}	Model 5 IQ_{RL}	Model 1 IQ_{AVG}	Model 2 IQ_{CC}	Model 3 IQ_{GE}	Model 4 IQ_{RQ}	Model 5 IQ_{RL}
Constant	13.88*	17.18*	5.23*	15.13*	15.99*	1.67*	1.68*	2.73*	1.17*	1.70*
	(0.00)	(0.00)	(0.07)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.02)	(0.00)
GDP	0.01*	0.09*	0.02*	0.05*	0.05*	0.03*	0.03*	0.02*	0.08*	0.02*
	(0.01)	(0.07)	(0.06)	(0.02)	(0.08)	(0.00)	(0.00)	(0.00)	(0.00)	(0.04)
RE	-0.15*	-0.18*	-0.16*	-0.13*	-0.18*	-0.02*	-0.02*	-0.02*	-0.02*	-0.01*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
FDI	-0.09*	0.09*	-0.08*	-0.08*	-0.08*	0.22*	-0.18*	-0.15*	-0.23*	-0.23*
	(0.004)	(0.03)	(0.07)	(0.07)	(0.06)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
TR	-0.02*	0.01	-0.01*	0.01	-0.06*	0.03*	-0.04*	-0.29*	-0.27	-0.02*
	(0.01)	(0.11)	(0.08)	(0.11)	(0.04)	(0.00)	(0.09)	(0.00)	(0.13)	(0.00)
POP	0.61*	0.44*	0.48*	0.67*	0.81*	0.21*	0.27*	0.14	0.23*	0.17
	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.09)	(0.03)	(0.23)	(0.06)	(0.10)
URB	0.15*	0.50*	0.73*	0.65*	0.65*	0.73*	0.26*	0.11*	0.15	0.32*
	(0.03)	(0.00)	(0.00)	(0.00)	(0.03)	(0.04)	(0.02)	(0.03)	(1.08)	(0.00)
GDP^2 $I(\lambda_1 \leq IQ)$	1.69*	18.84*	14.02*	16.28*	19.00*	2.14*	3.70*	3.29*	2.64*	0.61*
	(0.07)	(0.00)	(0.09)	(0.00)	(0.03)	(0.06)	(0.00)	(0.06)	(0.02)	(0.09)
GDP^2 $I(\lambda_2 > IQ)$	-4.53*	-22.24*	-16.23*	-18.76*	-27.25*	8.06*	4.26*	4.26*	3.76*	0.45*
	(0.04)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.02)	(0.03)	(0.00)

Note: The p-values are reported in parentheses. * denotes significance at least at 10% level.