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A nexus between air pollution, energy consumption and growth of economy: A comparative study between the USA and China-based on the ARDL bound testing approach

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Abstract: The aim of the study is to investigate and compare the correlation between energy consumption, air pollution and economic growth in China and the USA. Both countries are powerful economic countries in the world, thus we attempt to know whether energy consumption and air pollution vary as the economy develops. The data for the research spanning from 1970 to 2014 was gathered from an indicator of the World Bank. The time span was decided due to the data availability of both countries. To examine the long-run equilibrium relationship, there was performed the ARDL bound test. Results of unit root indicated that all the variables were integrated of order one. In the case of the ARDL bound test, the values of F-statistics exceeded the upper bound value, which means they are statistically significant. The estimation results substantiated the positive coefficient of energy consumption at the 1% significance level in China, implying that air pollution can increase as the energy consumption rises in China. However, the empirical results of the USA were exactly on the contrary. The outcomes of the CUSUM and CUSUMSQ tests revealed that all coefficients in both the short- and long-run models were stable. Based on the above analysis, the study suggests that China should adopt innovation and environmentally friendly modern technologies. Specifically, China ought to inspire and motivate energy saving and low-carbon research innovations, energy saving industries, green investment and carbon sequester technologies as well as public environmental awareness creations to mitigate environmental deterioration and climate change.

Keywords: carbon emission, development of China and USA, environmental pollution, resource saving

Global warming is a serious threat all over the world. Contributors to global warming are primarily the greenhouse gasses, including carbon dioxide, nitroxide, solid fuels and methane. More and more serious environmental problems lead scholars and researchers to measure the global warming and its effect on the economy of the nations. Also, debates over reducing polluting gas emissions such as the greenhouse gasses (GHGs), to alleviate environmental issues and implement policies to develop global economy under healthy and safe environment are on the increase (Ozgan 2013). Furthermore, the mitigation of the carbon emission has been an essential part of the national and international environmental policies agenda (Hamit-Haggar 2012).

Although the economy in China and the USA has been booming for more than three decades, both countries are facing serious environmental problems. Currently, China is the fastest economic developing country and the USA is the second in the world (He and Richard 2010). Meanwhile, in the midst of the economic boom, these two countries consumed much energy and oil (World Bank 2015). Ultimately, the mode that economic development was attained through the high energy consumption has led to the environment deterioration and plighted the lake of

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resources. Therefore, China and the USA are facing more and more pressure to reduce gas emissions for the healthy environment. China exceeded the united emission standard in 2006 and became the world's largest CO_2 emitter because of the coal consumption per capita. Both countries have the big level of resources and a growing, but relatively tiny renewable energy sectors, and both of them have an ambition to mitigate the environmental pollution and boost the economic development. Scientists concluded that the gross emission of pollutant gasses around the world would reach the peak around 2016 and then decline to stop at the critical 2 degree Celsius temperature increase at the end of the century. Although of the global CO_2 emission, 28% comes from China, 16% from America, 11% from the EU, 6% from India and the remaining 39% from other countries, the population scale of China is four times larger than the USA, which denotes that the CO_2 emission per capita in the USA is higher than in China. China developed rapidly and also consumed large amounts of the renewable and non-renewable energy, which contributed to a high carbon emission affecting human health and environmental resources. Therefore, China faces a dilemma of development and emission reduction. Exploring the nexus between economic growth, environment pollution and consumption of energy constitutes a vital part of both countries' environmental energy policies.

The nexus between the consumption of energy, environmental pollution and growth of economy has been investigated intensively by academic researchers and practitioners for a long time. The first strand mainly focuses on the nexus between the energy use and output. There are two theoretical points that have been put forward in the literature. The first view states that a country's economic growth is closely connected to energy consumption because higher energy consumption is required to sustain the rapidly developing economy. This was proved by Wolde-Rufael (2004), Lee and Chang (2005), Ang (2007), Ho and Siu (2007), Narayan and Smyth (2008), Bowden and Payne (2009), Chang (2010). In this view, conservative policies linked to energy consumption pose impediments to the economy. The second point postulates that the economic growth of a country can be neutral to the energy consumption, which indicates that the country can adopt an energy conservation policy in order to reduce the environmental pollution. This was proved by Lee (2006), Jobert and Karanfil (2007), Halicioglu (2009) and Payne (2009) in the USA.

As an outcome of rapid growth in the environmental consequences over the last two decades, researchers and scientists have put great emphasis on investigating the correlation between environment pollution and national economy. The nexus between environment degradation and economic development is listed as an important topic for discussion beneath the environmental Kuznets curve (EKC). The EKC derives from the Kuznets curve, used for testing the income inequality projected by Kuznets (Jha 1996). The EKC package indicated the U-shape association among environmental pollution and income growth. The previous research recommended that the use of alternative energy has positive effects on the economy, while the impacts of alternative energy on the economy are inconsistent (Prakash and Bhat 2009; Zhang and Cheng 2009; Chang 2010; Menyah and Wolde-Rufael 2010; AlFarra and Abu-Hijleh 2012; El Fadel et al. 2013; Lee 2013; Sbia et al. 2014). Jalil and Mahmud (2009) and Wang et al. (2011) did research on China and viewed CO_2 as the environmental pollutant, and the conclusion of these studies is that the climate warming occurs owing to the greenhouse gases emissions. From the literature above, we can easily know that researchers regarded the emission of the greenhouse gas as the single factor of the pollutant emission and did not imitate the scale of toxin in the environment. In this paper, we used different comprehensive indexes for the representation of environmental degradation and air pollution, which are different from the previous studies. The index simultaneously considers the methane emission, nitroxide emission, the emission from solid fuel consumption, the emission from gaseous fuel consumption and the greenhouse gas emission. Those factors can directly reflect the scale of the environment and air pollution. The inclusive index was calculated from the secondary data of key factors of environmental pollution in the USA and China.

LITERATURE REVIEW

There are three major observed research strands with regard to the aforementioned themes of the previous research related with economy and environment. The primary strand focuses on the environmental pollution and its nexus with economic outputs, and is analysing the strength of the EKC (Figure 1) approach. The first related research of EKC is attributed to Grossman and Krueger (1991).

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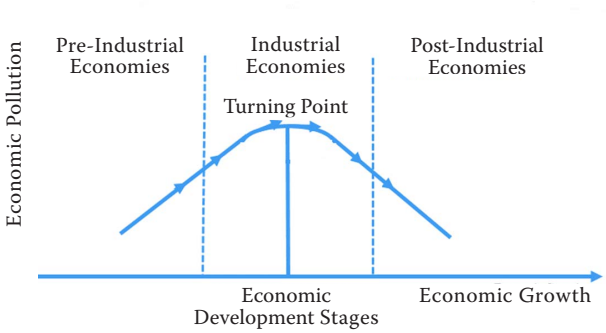

Figure 1. Environmental Kuznets Curve (EKC), Growth-Pollution relation

Source: Panayotou (1993)

Following was the EKC hypothesis tested by many other scholars. These researchers, Selden and Song (1994), Holtz-Eakin and Selden (1995), Friedl and Getzner (2003), Dinda (2004), Stern (2004), Galeotti et al. (2009) and He and Richard (2010),were endowed with a wide range of literature on the EKC approach. The second strand is fixed on the research of economic development and its nexus with energy. Most of the previous studies applied the bivariate model, which was criticized because of the omitted bias and failing variables to obtain unanimous results – Akarca and Long (1980), Erol and Eden (1987), Bentzen and Engsted (1993) and Yang (2000). Therefore, afterwards more and more researchers studied the nexus between the energy consumption, carbon emission and economic growth by employing the multivariate analysing methods – Stern (2000), Altinay and Karagol (2004), Oh and Lee (2004), Al-Iriani (2006), Narayan and Smyth (2008), Apergis and Payne (2009), Soytas and Sari (2009) and Gurgul and Lach (2012), providing an extensive literature body for the energy and growth. Considering the nexus between the growth environment and the nexus between the energy growth by the bivariate research has an obvious shortcoming that bias variables are omitted – Saboori and Soleymani (2011). In addition, Soytas and Sari (2009) found the nexus in a single framework were seminal research, therefore, the third strand of research emerged. Studies belonging to the third strand are divided into two sub-groups. One group utilized the time series data and focused on one single country. The other applied the panel data model and paid attention to many different countries. This paper is in the former group, using time series data and focusing on comparing two large economic countries – China and the USA. The results of a different research are diverse due to the difference in the time span, variables, destination and analytical approaches applied. A detailed literature review of the third strand is outlined below.

A panel data study usually considered the panel unit root and co-integration – Pedroni (1999) and Levin et al. (2002). Therefore, these tests did not take the cross-sectional dependence into account. Farhani and Ben Rejeb (2012) did research on the MENA countries; Lean and Smyth (2010) studied 5 Asian countries; Narayan and Narayan (2010) studied 43 developing countries. Pao and Tsai (2011) worked on the BRIC countries and Wang et al. (2011) conduct their research on 28 provinces of China. According to the literature classification and analysis, there are few studies on the carbon emission, energy consumption and economic growth. The earlier performance of unit root and the co-integration hypothesis for examining the EKC approach and the variables nexus of the 36 developing countries in the world was studied with the time span from 1980 to 2005. Results connoted that both the short- and long-run relationship existed and found a unidirectional causality from GDP to CO2. Hamit-Haggar (2012) set heterogeneity as dependence by applying the panel co-integration and the unit root developed by Westerlund (2005) and Pesaran (2007).

Ozturk (2010) explored the nexus between economic growth and environmental pollution, and he conversed the inverted U-shape correlation between environmental pollution and economic development through analysing the validity of EKC hypothesis. Nonetheless, some other related research represents different conclusions. Jalil and Mahmud (2009) provided empirical evidence of the validity of EKC. Holtz-Eakin and Selden (1995) found a monotonic rising curve. Friedl and Getzner (2003) illustrated the N-shaped curve in the study. In addition, Agras and Chapman (1999), Richmond and Kaufmann (2006) drew the conclusion that there was no causal relationship between economic development and environmental pollution. The research on the nexus between the pollutant emission, economic growth and energy consumption was done in a replication skeleton. These studies considering analytical work for the causal correlation between key variables by adding the literature on EKC were done by these researchers Richmond and Kaufmann (2006), Ang (2007), Soytas and Sari (2009), Acaravci and Ozturk (2010), Apergis and Payne (2010), Ozturk (2010), Wang et al. (2011, 2016).

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Wang et al. (2011) confirmed the relationship between the three-panel co-integration and the panel vector error correction model by investigating 28 provinces of China from 1995 to 2007. They found a bi-directional casualty between the CO2 emission and energy consumption as well as between the energy consumption and economic growth. The researcher also found that both the long run and short-run existed.

A number of previous studies has explored the nexus between energy consumption, pollutant emission and economic growth. However, in this empirical research differentiated models were applied in different countries. The results of previous studies reached inconclusive and sometimes controversial conclusions concerning the exact nature and direction of the relationship between environmental pollution, energy consumption, and economic growth. The main differences identified were the types of analysis, the time period examined, the econometric approaches and the variables included in the estimations, level of economic growth in different countries and method of estimation. This research focused on the quantitative nexus between air pollution, energy consumption and economic growth in the USA and China using the ARDL bound test approach. No researcher or scholar before ever did this kind of research. Therefore, we take this topic into our account using different variables and time period, selecting China and the USA because both countries are large economic countries in the world. China's population is three times more than that of the USA, additionally, the energy consumption in China is higher, but the GHS emission level is higher in the USA. Therefore, we attempt to know what is the difference in the nexus between the environmental pollution, energy consumption and economic growth between the Chinese and American policies.

METHODOLOGY

This research was conducted based on the ARDL model to quantify the nexus between air pollution, energy consumption and economic growth in the USA and China. The data was collected from the indicators of the World Bank, with the time span selected from 1970 to 2013 due to the availability of both countries. The multivariate framework includes the real GDP (LnGDP) in constant 2000 U.S. dollars, energy consumption (LnEC) in kilogram of oil equivalent and pollutant gas emissions referring to air pollution (LnAP) in kiloton. Following is the EKC hypothesis equation proposed by Ang (2007) and also processed by other scholars and researchers – Lean and Smyth (2010).

$$LnAP_t = a_o + a_1 LnGDP_t + a_2 (LnGDP_t)^2 + a_3 LnEC + \nu_t \quad (1)$$

where LnAP represents the natural log of air pollution; LnGDP and $(LnGDP)^2$ respectively represent the natural logs of the real GDP and its square term; t stands for the time period and the error term is denoted by ν_t. a_3 is expected to be positive in that the growth of energy consumption is likely to aggravate air pollution. The EKC hypothesis indicates that a_1 is positive but a_2 is negative. However, the studies employed the same approach without including $(LnGDP)^2$ is probably inappropriate. Provided that the EKC hypothesis is not supported in the study or by the co-integration relationship between the selected variables in Equation 1, it is hard to ascertain, then including LnEC is not desirable. Hence, to justify whether including LnEC is desirable or not and test the validity of the EKC hypothesis in our study, Equation 2 is applied:

$$\mathrm{Ln}AP_t = \beta_o + \beta_1 LnGDP_t + (LnGDP_t)^2 + \nu_1 \quad (2)$$

Not those same equations will be used for both countries. If the LnGDP is undesirable for China or the USA, which means the co-integration shows complicated relationship, then $(LnGDP)^2$ will not be included as desirable.

At present, many researchers and scholars have developed and employed the co-integration hypothesis, similarly the outstanding approach by Engle and Granger (1987), the utmost probability technique by Johansen and Juselius (1990) and the recent generated approach, the Autoregressive distributed Lag (ARDL) by Pesaran et al. (2001). The ARDL for the co-integration analysis has a number of attractive features over alternatives. Pesaran et al. (1999) displayed a number of advantages of the ARDL bound testing approach of co-integration. The primary plus point of ARDL is that it is not necessary to order the integrated variables.

Halicioglu (2009), Ghosh (2010) and Iwata et al. (2010) have investigated the co-integration nexus of CO_2 and economic growth including other additional variables by statistical approaches of the single state. This research followed the same analytical approach to for examining the long and short run causal nexus between the CO_2 emission, economic growth and consumption of energy, the ARDL approach is as follows:

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$$\Delta Ln(AP) = \beta_o + \sum_{k=1}^{n}\beta_{1k}\Delta\ln(AP)_{t-k} + \sum_{k=2}^{n}\beta_{2k}\Delta\ln GDP_{t-k} + \sum_{k=1}^{n}\beta_{3k}\Delta(\ln GDP_{t-k})^2 + \sum_{k=1}^{n}\beta_{4k}\Delta\ln EC_{t-k} + \delta_1 Ln(AP)_{t-1} + \delta_2 LnGDP_{t-1} + \delta_3 LnGDP_{t-k}^2 + \delta_4 LnEC_{t-k} + \nu_t \quad (3)$$

The co-integration equation is as below:

$$\delta_1 AP_{2t-1} - (\delta_1 EC_{t-1} + \delta_3 GDP_{t-1} + \delta_4 GDP_{t-1}^2 + \nu_{2t}) = 0 \quad (4)$$

where β_0 denoted drift component, Δ represent the difference of drivers and ν_t white noise. The terms of β_1, β_2, β_3 and β_4 represents the error correction dynamic while the terms δ_1, δ_2, δ_3 and δ_4 corresponding to the log-run nexus. The ARDL testing approach begins with bound test, we analysed the ARDL directly with the Eviews 9.0 version, and we did not estimate the OLS 1st. The null hypothesis of no co-integration of any long run relationship, *H*0: $\delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$ is tested beside the alternative *H*1: $\delta_1 \neq \delta_2 \neq \delta_3 \neq \delta_4 \neq 0$. The *F*-test was analysed for making sure that in the long term it exists or not among our selected variables. This research was contacted based on the critical value of Pasarana et al. (2001) for the bound *F*-test. In attendance two sets of critical values intended for significance level with time trend and without time trend, one for I(0) and another set is I(1) variables, from that, we can know the lower- bound and upper-bound critical value (LCB and UCB). This provides a band causing all probable classifications of the variables into I(1) and I(0). If the calculated *F*-statistic is higher than the UCB, the null hypothesis of no co-integration is rejected and in case it was lower than LCB, the null hypothesis must be accepted rather than rejected and if it has remained between the LCB and UCB, the results will be called inconclusive. So that the variable of lag order is possibly chosen on the conditions of Schwartz-Bayesian criteria (SBC) and Akaike's information criteria (AIC). The SBC is decided by the lowest possible lag length, although the AIC is prepared to choose the highest lag length. The long-run relationship between variables could be estimated following the assortment of the ARDL model by the AIC or SBC criterion. Once a long-run relationship has been established, the error correction model (ECM) can be estimated. A general ECM is formulated as below:

$$\Delta Ln(AP)_1 = a_0 + \sum_{k=1}^{n}a_{1k}\Delta\ln(AP)_{t-k} + \sum_{k=1}^{n}a_{2k}\Delta LnGDP_{t-k} + \sum_{k=1}^{n}a_{3k}\Delta(\ln GDP_{t-k})^2 + \sum_{k=1}^{n}a_{4k}\Delta LnEC_{t-k} + \theta ECM_{t-1} + \nu_t \quad (5)$$

The error correction term (ECT) identified the speed and adjustment of and shows how the variable returns to long in short period of time and it has statistical significant value with the negative coefficient. To make sure of the fit and goodness of model, the diagnostic and stability test is also conducted. These analysed the tests of casual relation, functional form, normality, and heteroscedasticity. In addition, recommended for the analysing stability of short-run, they can be estimated by the Cumulative sum (CUSUM) and the Cumulative sum of square (CUSUMQ). Therefore, the constancy tests such as the CUSUM and CUSUMQ are conducted in order to check the stability and goodness of the model.

Empirical results

This section provides the results of the empirical analysis including explaining the nexus between air pollution, energy consumption, and economic growth, and defining the difference between the USA and China pollution and economic growth.

Stationary test

The unit root test is basic for the ARDL Bound model regression. On condition that all variables are stationary at the same difference level, we can run the ARDL model. Therefore, the process concerned is to integrate variables, and what is accepted for bound testing is level and 1st difference. This paper followed the unit root ADF test and PP test, respectively, developed by Dickey and Fuller (1979), Phillips and Perron (1988). Both approaches have the unit root for the alternative of stationarty.Table1 shows the results of the unit root test. As we can see from the table, in China, LnGDP, LnEC and LnAP are stationary at the 1st difference level at the 5% significance level, and in the USA, all variables are stationary at the 1st difference at the 1% significance level. The results denoted that variables in both countries were integrated of order one, which implied that the ARDL approach can be employed.

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Table 1. Results of unit root test

Variable	ADF test				PP Test			
	level	Int & Trend	1st diffefence	Int & Trend	level	Int & Trend	1st difference	Int & Trend
China								
LnGDP	2.603	–0.329	–5.687***	–4.192**	2.783	–0.320	–5.744***	–6.574***
$(LnGDP)^2$	0.308	–0.622	–3.418**	–3.336*	1.106	–3.094	–4.355***	–4.450***
LnEC	1.197	–0.850	–4.262***	–4.522***	1.508	–0.497	–4.250***	–4.522**
LnAP	0.534	–1.953	–4.315***	–4.349***	0.260	–1.602	–4.349***	–4.373**
USA								
LnGDP	–1.789	–1.604	–4.735**	–4.730***	–1.861	–1.045	–4.538***	–4.720***
$(LnGDP)^2$	–1.855	–1.565	–4.730***	–4.945***	–1.941	–1.006	–4.470***	–4.740***
LnEC	–1.884	–2.295	–4.946***	–5.017***	–1.884	–1904	–4.910***	–4.843***
LnAP	–1.302	–2.902	–4.447***	–4.340***	–1.343	–1.983	–3.947***	–3.783**

***means the null hypothesis is rejected at the 1% significance level, **denotes the null hypothesis is rejected at the 5% significance level, *at the 10% significance level. These results were attained by using Eviews 9.0 student version.

Co-integration results based on ARDL bound test

We employed the ARDL bound testing approach to examine the co-integration relationship between the selected variables *(air pollution, energy consumption and economic growth).* The results of estimated models are available in Table 2, which shows that in both countries the results exceed the upper bound value (UCB) (according to the table of Pesaran et al. (2001),the values of LCB and UCB are 3.79 and 4.85 respectively).What is more, the values of *F*-statistics are larger than 4.85 at the 1% significance level, therefore, the null hypothesis should be rejected, indicating there is a co-integration relationship between the selected variables. We also can call *H*0: $\delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$ the bound co-integration Equation (4) which can be rewritten as below:

$$\text{(China) Coin Eq} = AP_{2t-1} - (0.795\, EC_t + 0.033\, GDP_t + 1.163\, GDP_t^2 - 1.261) = 0$$

$$\text{(USA) Coin Eq} = AP_{2t-1} - (0.872\, EC_t + 0.273\, GDP_t + 1.209\, GDP_t^2 - 2.437) = 0$$

Table 2. Co-integration results based on the ARDL bound test for both countries

Variables	*F*-Statistics	*P*-Value
China		
F_{AP} (AP|EC, GDP, GDP^2)	7.225	***
Critical Bound Value	I(0) Bound	I(1) Bound
10%	2.37	3.2
5%	2.97	3.63
1%	3.65	4.66
USA		
F_{AP} (AP|EC, GDP, GDP^2)	7.108	***
Critical Bound Value	I(0) Bound	I(1) Bound
10%	2.17	3.19
5%	2.72	3.83
1%	3.88	5.3

*** means null hypothesis is rejected at the 1% significance level

In addition, so as to further investigate the connection between air pollution, energy consumption and economic growth by applying the ARDL method, a proper lag order selection of the equation is prerequisite. Therefore, we employed the ARDL long and the short-run nexus between the constructed variables, the main approach is to estimate the ARDL long-run casual relationship by applying the unrestricted error correlation model. The specification presumes that the disturbances are casually uncorrelated; therefore, it is very essential to select the suitable lagging order. Theo optimum lag order is generally found by observing the values of the Akaike information criterion (AIC), the Schwarz Bayesian Criterion (SBC) and the Hannan-Quinn Information Criterion (HQC).The results of the AIC, SBC and HQC are presented in Figure 2 and Figure 3 and the suitable lag orders of the variables for ARDL model (1, 2, 0 in China & 1, 2, 1 in the USA) were selected for a further analysis. This table was sorted by Author analyzed through Eviews.

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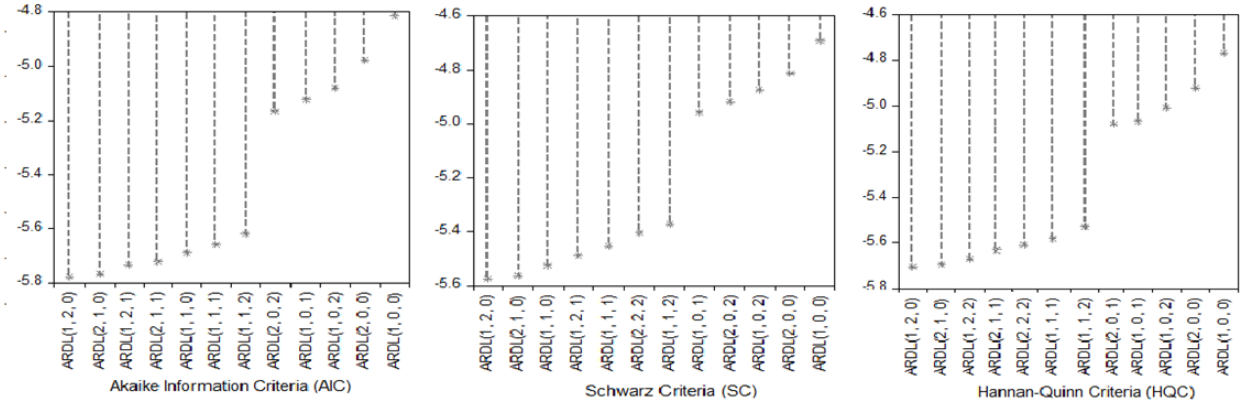

Figure 2. Lag selection criteria for the China by Akaike's information criteria (AIC), Schwartz-Bayesian criteria (SBC) and Hannan-Quinn Information criteria (HQC)

Source: Analyzed by author using Eviews

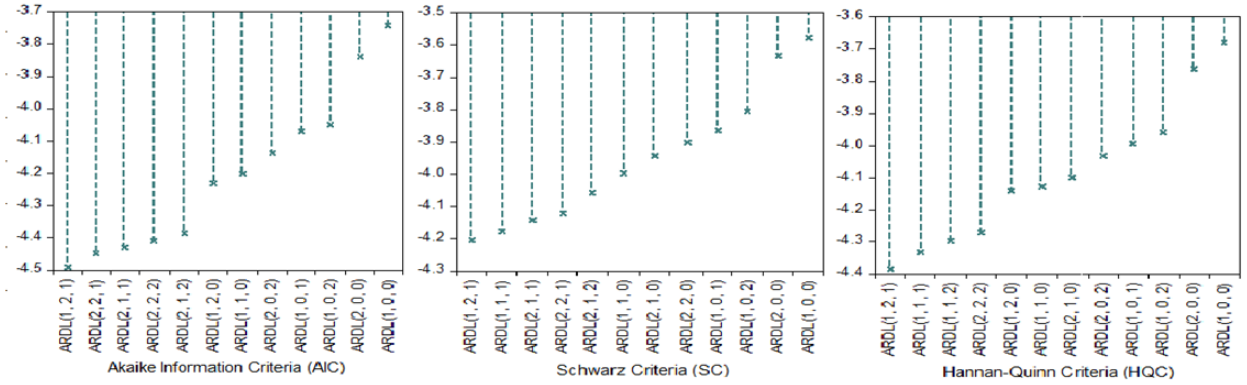

Figure 3. Lag selection criteria for the USA by the Akaike's information criteria (AIC), Schwartz-Bayesian criteria (SBC) and Hannan-Quinn Information criteria (HQC)

Source: Analyzed by author using Eviews

ARDL model

The Lagrange Multiplier (LM) approach tests the casual relationship as well. The results have X2 distribution towards freedom of degree one, which means that the auto regression exists in the residuals of the applied models. Therefore, the misspecification by the Ramsey's RESET test that is similarly dispersed

Table 3. The results of short- and long-run coefficients estimated by the ARDL approach

	China				USA			
	coefficient		*T*-statistics		coefficient		*T*-statistics	
Regressor								
ΔC	−1.261		−1.918***		−2.437		−7.437***	
ΔLnGDP	0.033		0.625		0.273		2.556**	
ΔLnEC	0.795		0.725***		−0.872		−11.183***	
$\Delta(LnGDP)^2$	1.163		7.888***		0.209		3.253**	
ECT(−1)	−0.325		0.863**		−0.318		0.127**	
Dig; test stat								
R-Square	0.998	*F*-Stat	4 325.71	*R*-Square	0.986	*F*-Value	166.78	
Prob *F*-Stat	0.000	D.W	2.103	Prob *F*-Stat	0.000	D.W	1.285	
RESEM	1.574**	LM	0.229	RESEM	1.952**	LM	1.347	
Hetro....	2.175**			Hetro....	2.365**			

***means the null hypothesis is rejected at the 1% significance level, **denotes the null hypothesis is rejected at the 5% significance level. These results were attained by author using Eviews 9.0 student version.

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by the solitary degree of freedom confirms that the applied replication is a proper fit. The replication is also examined by normality test. The results of the short-run coefficients can be seen in Table 3. According to the Table 3, the coefficients of ΔLnEC and ΔLnGDP in China are positive at the 1% significance level. Whereas, compared with China, the coefficient of ΔLnGDP is positive at the 5% significance level, but the coefficient of ΔLnEC is negative at the 1% significance level in the USA. The coefficient of ECT (–1) is properly assigned in both countries at the 5% significant level. The coefficient of the lagged ECT is a more efficient mode to justifying co-integration relationship – Kremers et al. (1992). From Table 3, we discerned the existence of a casual co-integration relationship between variables in the model. We found the coefficients of ECT (–1) for China and the USA are, respectively, –0.325 and –0.318, connoting that the deviation from the long-run equilibrium will be adjusted at the speed of 0.325and 0.318, respectively, in China and the USA.

Under the circumstance that the variables are in natural logarithms, the coefficients can be explained as the elasticity estimates. The coefficient of energy consumption is 0.795 in China, which implies that 1% increase in the energy consumption can increase air pollution by 0.795%. Nevertheless, the coefficient of energy consumption in the USA is negative and

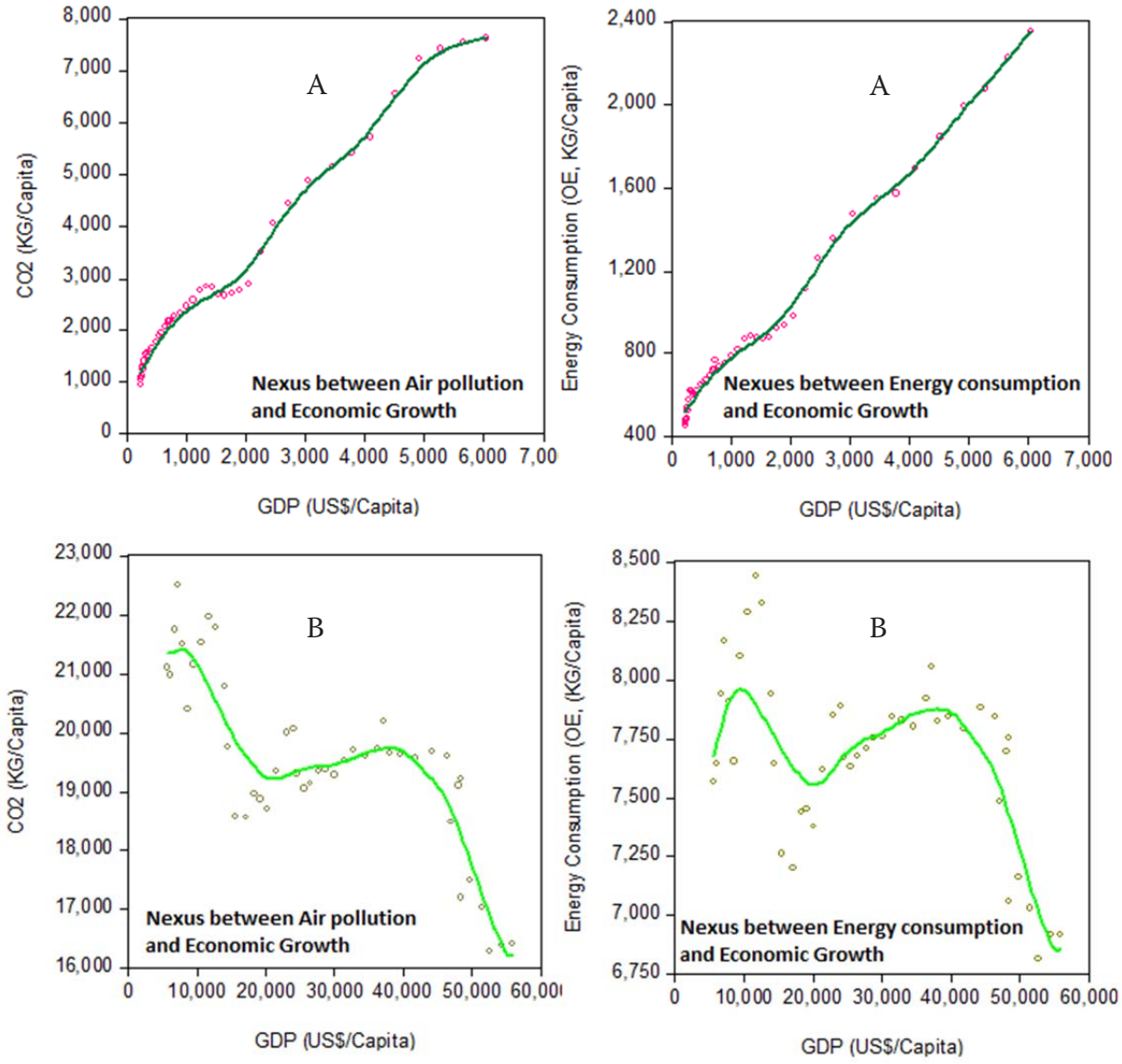

Figure 4. EKC (Environmental Kuznets Curve), the nexus between air pollution and economic growth and the nexus between energy consumption and economic growth of China (A) and the United States of America (B)

Source: Analyzed by author using Eviews

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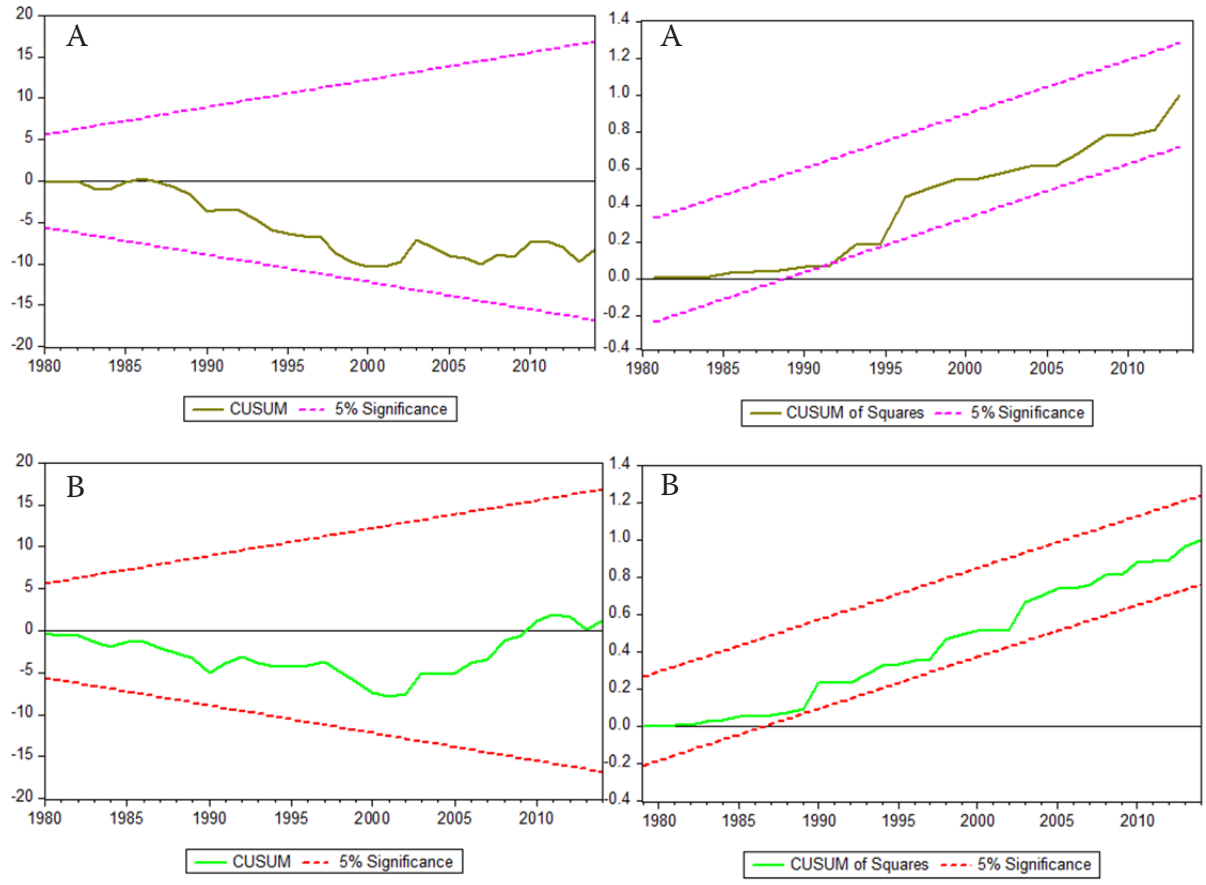

Figure 5. Plot of the CUSUM (Cumulative Sum) of Recursive Residuals and CUSUMSQ (Cumulative Sum Squares) of Recursive Residuals of the USA (A) and China (B)

Source: Analyzed by author using Eviews

statistically significant at the 1% significance level, which infers that when the energy consumption accrues, the air pollution will decrease. The coefficient of energy consumption is –0.872 in the USA, denoting that the 1% increase in the energy consumption will decrease air pollution by 0.872 %. Figure 4 displays that the energy consumption and carbon emission have positive correlations with economic growth in China, which connotes that economic growth requires more energy consumption and will to some extent lead to a higher carbon emission. Whereas, in the USA, the curves depicting the correlations between the carbon emission, energy consumption and economic growth are shaped as "N", which is more complicated than China. Note that the line broke is Kernel Fit.

To classify the stability *(goodness of the model)* of the short-and long run coefficients, the cumulative sum (CUSUM) and the cumulative sum of squares (CUSUMSQ) techniques were employed. Graphically, four statistical plots are displayed to test the stability of the coefficients. What is found in common is that in both countries the CUSUM and CUSUMSQ plots fall within two critical lines at the 5% significance level, which means that the null hypothesis of unstable parameters is rejected, namely, the short- and long-run coefficients are stable (Figure 5).

CONCLUSION

The study investigated the nexus between air pollution, energy consumption and economic growth in the USA and China. The ADF and PP test results of selected variables were integrated of order one. Results of the co-integration test connoted that the long-term equilibrium relationship existed among the variables. The estimation of the short-run coefficients showed that, in the case of China, the coefficients of ΔLnEC and ΔLnAP were positive

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at the 1% significant level. In contrast, in the case of the USA, the coefficients of ΔLnEC and ΔLnAP were negative at the 1% significant level. In addition, whether coefficients of C and ΔLnGDP were positive or negative, the coefficients of ECT (–1) in China and the USA were –0.325 and –0.318, respectively, at the 5% significance level, which implies that the deviation from the long-run correlation among variables is proper at about 32% and 31% period. The estimated long-run pollutant factor with the air pollutant factor probably $\beta > 0$ significant at 1% level. In case of the positive coefficient of China, the air pollution increases by almost 0.795% when the energy consumption increases by 1%, however, the coefficient is totally negatively inverted in the USA, significant at the 1% level. It implies that the air pollution can decrease by 0.872% with 1% decrease of the energy consumption. This simply means that in future air pollution may increase in China, but it decreases in the USA. The results of the CUSUM and CUSUMSQ tests indicated that all coefficients in the short and long run models were stable.

The causality from economic growth to air pollution was not found in China, which suggests that China can pursue the pollution reduction regardless of negative effects on the economic growth. This means that a reduction of pollution may be possible without sacrificing economic growth, in that the pollution is not necessarily connected with economic growth. In this sense, China can take some environment – protecting measures to prevent the pollution owing economic growth, like the USA did. It is recommended that the environment sectors should invest more in the innovation for modern environmentally friendly technologies to cope with the pollution and subsequently promote economic growth under the healthy and suitable environment. Furthermore, government should support the green investment and encourage enterprises to increase energy efficiency, avoid energy waste and use cleaner technology in production. Meanwhile, the shares of energy-dependent industries should be reduced. Some incentive-based strategies, such as emission charges and transferable discharge permits, can be applied to encourage the polluters to find more effective ways to reduce emission. China should inspire and motivate energy saving and the low-carbon research innovation, energy saving industries, green investment and carbon sequester technologies as well as the public environmental awareness to mitigate the environmental deterioration and climate change.

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