Manzoor **AHMAD** • Han **HENGYI** • Zia Ur **RAHMAN**
Shehzad **KHAN** • Zia Ullah **KHAN** • Zeeshan **KHAN**

CARBON EMISSIONS, ENERGY USE, GROSS DOMESTIC PRODUCT AND TOTAL POPULATION IN CHINA

Manzoor **Ahmad,** PhD student – *Nanjing University*
Han **Hengyi,** MS student – *Nanjing University*
Zia Ur **Rahman,** PhD student – *Xiamen University*
Zia Ullah **Khan,** PhD student – *Southwestern University of Finance and Economics*
Shehzad **Khan,** PhD – *Abdul Wali Khan University Mardan*
Zeeshan **Khan,** PhD student – *Tsinghua University*

Correspondence address:
School of Economics
Department of Industrial Economics
Anzhong Building, Business School
Nanjing University, Gulou Campus
22 Hankou Road, Nanjing, Jiangsu 210093, China
email: manzoorahmad94@163.com

ABSTRACT: The current study explores the impact of energy consumption, total population, gross domestic product on carbon emissions by utilizing time series data of 1971-2013 for China. Earlier studies concentrated on testing the present form of an environmental Kuznets curve not taking total population in a model. Specifically, this study focuses on analyzing the long run existence of environmental Kuznets curve. The methodology of auto regressive distributed lag model is utilized. The quadratic linkage between national income and emissions of carbon have been detected, confirming the presence of long run linkage between quadratic national income and emissions of carbon. Granger causality test divulge one-way causality between gross domestic product and carbon emissions. The empirical findings also reveal that the energy use and national income are important factors of carbon emanations in the long run. Total population has an insignificant positive influence on emissions of carbon. It is suggested that government should focus to extract that substitute sources of energy which is more environmental friendly.

KEY WORDS: energy consumption, carbon emissions, GDP, granger causality, ARDL, EKC

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Introduction

In the early 1980s, the Chinese's government decided to introduce new reforms to establish market economy which brings a greater economic and industrial revolution in China. Today China is the fastest growing economy in the globe. The main reason behind China rapid economic growth is attributed to its huge expansion of the industrial sector. Conversely, economic growth based on industrial expansion may certainly cause to environmental worsen. Meanwhile, China is one of the substantial emitter of carbon dioxide in the world (Environmental Assessment Agency, 2015). Its average carbon emissions are around 6.70 metric tons per capita during 2009-2013 (World Development Report 2016). China's 13th Five-Year plans place many plans and strategies for reducing carbon emission.

Concerns regarding the contrary impacts of environmental variables on economic growth were in conflict with assertions that expansion in gross domestic product would advantage the environment, the creed and belief about environmental quality as a luxury good. Furthermore, masses are ready to pay progressively on this good, wealthy they will (De Bruyn, 2012). Grossman and Krueger (1991) scrutinized nexus between income and environmental quality, discovered an upside-down U-shaped association between gross domestic product and production of a specific contaminant. Panayotou (1993) inferred the association identifying as EKC, later the same relationship was drawn by the famous Economists Simon Kuznets (Kuznets, 1955). Thus, the basic idea behind EKC hypothesis is an upside-down U-shaped relation between variables on environmental contamination and income per capita. It further implies that an expansion in national income will invalidate the environmental influence of the initial phases of economic advancement in long run. The current study, originally, Environmental Kuznet Curve relationships for carbon emissions by including population factor for China, use data from 1971-2013, has been investigated.

This article is divided into five parts. Part two describes the previous studies on EKC. In part three, an analytical framework, empirical model and data used have been discussed. Part four connects the study with empirical results. Conclusions have been drawn in part five.

Literature review

Even though the model of the EKC is a newly established phenomenon, though, a vast literature is available for utilization of the phenomenon (Kuznets, 1955). These studies use variable(s) relating to environmental degradation as responding variable while gross domestic product as the explanatory variable(s) and give different outputs.

A number of studies, lying on the same issue, have been investigated by several researchers after (Grossman, Krueger, 1995) and (Selden, Song, 1995) asserted the expansions and contractions in gross domestic product and the level of environmental degradation develops an inverted U-shaped relationship. Many authors have been tested EKC hypothesis by taking different factors of environmental degradation, for example, municipal waste, carbon emissions, and deforestation. Conversely, the most frequently used variable as a proxy of environmental degradation was sulfur dioxide. In contrast, a U-shaped function for carbon emanation has been described (Heil, Selden, 2001; De Bruyn et al., 1998; Moomaw, Unruh, 1997; Holtz-Eakin, Selden, 1995) by using panel data. Other research also computed findings on the association between gross domestic product and carbon emanations for different nations by using new methods (Kanjilal, Ghosh, 2013; Galeotti et al., 2006; Vollebergh, Kemfert, 2005; Cole, 2005; Martínez-Zarzoso, Bengochea-Morancho, 2004; Dinda, 2004; Stern, 2004).

The another most important factor which plays very significant role in the determinant of carbon emission is energy consumption. There are a lot of studies existed, in passing, after the study conducted by Kraft and Kraft (1978). For instance, (Narayan et al., 2008; Narayan, Singh, 2007; Wolde-Rufael, 2006; Yang, 2000; Masih, Masih, 1996) examine nexus between use of energy and economic growth by employing a variety of procedures for group of counties. Hence, it more appropriate, if take growth of income and use of energy at once in a single multivariate model. Therefore, the current study is utilizing these two linkages, GDP-environment linkage and GDP-environment linkage, in a one model. This method allows the scholar to carry out the rationality of both linkages in a similar structure. For instance, (Halicioglu, 2009; Ang, 2007) introduced this pooled of framework.

In addition to this, the majority of the prevailing literature on the same subject has utilized pooled data for sets of countries in order to develop a linkage between average income per capita and environmental degradation. Contrariwise, time series data apply to only one nation may lead a good general background to examine the linkage. It also allows investigating the cause of strategies about environmental protection, energy policy and other elements during the time (Stern et al., 1996)1996.

There are few studies which use population as a factor of carbon emission. The linkage between population growth and carbon emission has bees discusses in more detail by (Cramer, 1996) and (Shi, 2003). Zhang and Tan (2016) examine the linkage between population factors and carbon emission by taking China as a case study. The findings indicate that population are important factor which bring variations in emission of carbon.

A clear logical for choosing China for our study is that it enacts a noteworthy role in the world energy market. Besides to this, among developing countries, China is important transitional economies that sustain the top figure economic growth, most populated country and the largest contributor of the carbon dioxide emission along with utmost user of energy.

Model specification and econometric methodology

The long-run association between release of carbon dioxide, gross domestic product, use of energy and total population for China is tested by applying the following linear logarithmic quadric form:

$$CE_t = \alpha_0 + \alpha_1 EU_t + \alpha_2 GDP_t + \alpha_3 GDP_t^2 + \alpha_4 TP_t + \varepsilon_t \qquad (1)$$

Where: CE_t represents carbon emission per capita, α_0 represent constant, α_1 is coefficient of EU_t, EU_t denotes energy use per capita equivalent to kg of oil, α_2 represents the respective coefficient of GDP_t, GDP_t signify Gross domestic product in current US \$, α_4 signify respective coefficient of GDP_t^2, GDP_t^2 shows square of gross domestic product, α_5 shows respective coefficient of TP_t, TP_t is total population and ε_t represents error term.

The ARDL depiction of carbon dioxide emissions, energy consumptions, GDP, squared of GDP and total population, can be represented as:

$$\Delta CM_t = \beta_0 + \sum_{i=1}^{m} \beta_{1i} \Delta CM_{t-i} + \sum_{i=0}^{m} \beta_{2i} \Delta EU_{t-i} + \sum_{i=0}^{m} \beta_{3i} \Delta GDP_{t-i} + \sum_{i=0}^{m} \beta_{4i} \Delta GDP_{t-i}^2 + \sum_{i=0}^{m} \beta_{5i} \Delta TP_{t-i} + \beta_6 CM_{t-i} + \beta_7 EU_{t-i} + \beta_8 GDP_{t-i} + \beta_9 GDP_{t-1}^2 + \beta_{10} TP_{t-i} + \upsilon_t \qquad (2)$$

Where: ΔCM_t represent change in carbon emission in a t year, β_0 is constant term, β_{1i} is the respective coefficient of ΔCM_{t-i}, ΔCM_{t-i} denoted change in carbon emissions in t-i lagged period, β_{2i} is coefficient of ΔEM_{t-i}, ΔEM_{t-i} represents change in energy use in t-i lagged period, β_{3i} is coefficient of ΔGDP_{t-i}, ΔGDP_{t-i} signify change in gross domestic product in t-i lagged period, β_{4i} is coefficient of $\Delta GDP_{t\ -i}^2$, $\Delta GDP_{t\ -i}^2$ represents change in quadratic representation of gross domestic product in t-i lagged period, β_{5i} denoted coefficient of

ΔTP_{t-i}, ΔTP_{t-i} represents change in total population in t-i lagged period, β_6 is coefficient of CM_{t-i}, CM_{t-i} represent carbon emission in t-i lagged period, β_7 is coefficient of EU_{t-i}, EU_{t-i} represent energy use in t-i lagged period, β_8 is coefficient of GDP_{t-i}, GDP_{t-i} represent gross domestic product in t-i lagged period, β_9 is coefficient of $GDP_{t}^{2}{}_{-1}$, $GDP_{t}^{2}{}_{-1}$ donates quadratic format of gross domestic product in t-i lagged period, β_{10} represents coefficient of TP_{t-i}, TP_{t-i} denotes total population in t-i and υ_t shows error term.

This technique comprises of following procedures. In first stage of the cointegration approach Fisher (F) or Wald statistics should be estimated. For that reason, a joint significance test that hypothesize of no cointegration, $H_0{:}\beta_6 = \beta_7 = \beta_8 = \beta_9 = \beta_{10} = 0$, against the alternative hypothesis, $H_1{:}\beta_6 \neq \beta_7 \neq \beta_8 \neq \beta_9 \neq \beta_{10} \neq 0$ carry out for eq. (2). The F-test utilized for this process has a non-standard distribution. Hence, Pesaran et al. (2001) estimate two series of critical values with and without a time trend. One series presume that all given variables are I(0) while other series suppose they are all integrated of order one. Then compare the F-statistic to the upper critical bunds. The null hypothesis is not accepted if estimated F-statistic go beyond the upper critical bounds value. The test become inconclusive if the F-statistics falls into the bounds. Lastly, if the F-statistic is lower than the critical bound value, signifies absent of cointegration.

After construction of long run linkages, eq. (2) is computed by applying an appropriate lag selection criterion namely, SBC or AIC. In the next step of ARDL process, a parameter stability test is possible to run to check the stability in ARDL depiction of the ECM.

Error correction model (EMC) of eq. (3) is constructed in this way:

$$\Delta CM_t = \gamma_0 + \sum_{i=1}^{m} \gamma_{1i} \Delta CM_{t-i} + \sum_{i=0}^{m} \gamma_{2i} \Delta EU_{t-i} + \sum_{i=0}^{m} \gamma_{3i} \Delta GDP_{t-i} + \sum_{i=0}^{m} \gamma_{4i} \Delta GDP_{t-i}^{2} + \sum_{i=0}^{m} \gamma_{5i} \Delta TP_{t-i} + \lambda ECT_{t-1} + \mu_t \quad (3)$$

In eq. (3), γ_0 represent constant term. While γ_{1i}, γ_{2i}, γ_{3i}, γ_{4i}, γ_{5i} are respective coefficients. λ characterizes the swiftness of adjustment parameter and ECT_{t-1} denotes residuals taken from the eq. (1). The CUSUM and CUSUMSQ are also utilized to scrutinize the goodness of fit for auto regressive distribution model. So, that to use these econometric procedures, time series data on release of carbon dioxide metric tons per capita, Gross Domestic Product in current US dollar, use of energy per capita equivalent to kg of oil along with total population for period 1971 to 2013 are gathered from World Bank website. Eviews 9 are used for data analysis.

To scrutinize the stability of parameters, CUSUM and CUSUM square tests have been performed (figure 1 and 2). Pesaran et al. (Pesaran et al., 2000, 2001) propose that in such model testing for stability of coefficients CUSUM and CUSUMSQ are acceptable. Figure 1 indicates that the graph of CUSUM is significant at the 5% level of significance showing the stability of parameters. Figure 2 signify that the graph of CUSUM of square is signify that the blue line is located within red lines which means all parameters are stable.

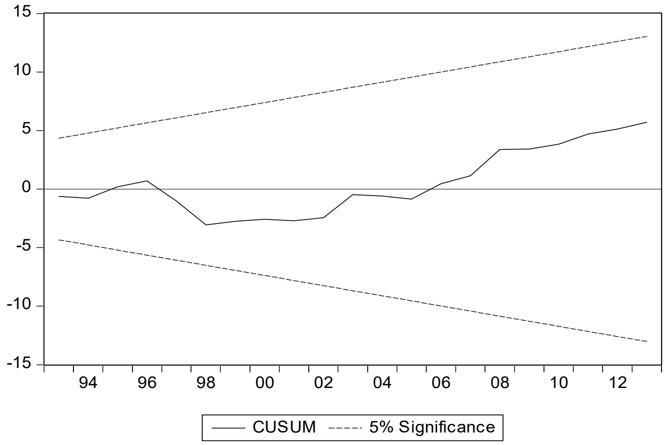

Figure 1. CUSUM

Note: The straight lines in the figure symbolize critical bounds at 5% significance level

Source: author's own work.

Figure 2. CUSUM of Square

Source: author's own work.

Some diagnosis tests are also run on the short run dynamic model. These tests include ARCH, Breusch-Godfrey Serial Correlation LM Test and Ramsey RESET Test. The final findings of all diagnostic tests verify that short run dynamic model is free of heteroscedasticity and serial correlation. Moreover, Ramsey RESET test identify that there is no specification error in the model.

Empirical findings and discussion

This study utilizes ADF unit root test to inspect stationarity. The outcomes of unit root test are demonstrated in table 1. The findings divulge that all variables are non-stationary at level while become stationary at first difference. Hence, no variable is stationary at second difference.

Table 1. Unit root test

Variable	T-Statistics	P value*
ADF test at level with intercept		
$\ln CM_t$	0.304289	0.9758
$\ln EU_t$	0.974143	0.9955
$\ln GDP_t$	2.489667	1.0000
$\ln GDP_t^2$	2.654390	1.0000
$\ln TP_t$	-0.832336	0.7983
ADF test at first difference with intercept		
$\Delta\ln CE_t$	-3.810335	0.0058**
$\Delta\ln EU_t$	-3.565168	0.0110**
$\Delta\ln GDP_t$	-5.200094	0.0001**
$\Delta\ln GDP_t^2$	-4.823599	0.0003**
$\Delta\ln TP_t$	-2.681757	0.0863***

*MacKinnon (1996) one-sided P values. **,*** 5% and 10% level of significance

Source: author's own work.

To get rid of any serial correlation the ARDL bound testing founded by Pesaran et al. (Pesaran et al., 2001) needs an appropriate lag length in variables. This length has been carefully chosen by taking first difference of conditional error correction version of ARDL. Akaike information criteria is utilized to get maximum lag. Table 2 reports the outputs of VAR lag order selection criteria. The minimum value of AIC shows the maximum lag 5 is appropriate lag length for our current model. As to get reliable and unbiased results an appropriate lag order is necessary.

Table 2. VAR lag order selection criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	81.72637	NA	0.001034	-4.038230	-3.822758	-3.961567
1	86.45742	7.968079	0.000850	-4.234601	-3.976035*	-4.142605
2	87.91583	2.379506	0.000831	-4.258728	-3.957067	-4.151399
3	89.22025	2.059609	0.000820	-4.274750	-3.929995	-4.152089
4	89.94484	1.105959	0.000834	-4.260255	-3.872405	-4.122261
5	93.55964	5.327076*	0.000730*	-4.397876*	-3.966932	-4.244549*

**Lag order selected by the criterion. LR: Sequential modified LR test statistic (each test at 5% level), FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion*

Source: author's own work.

The presence of long run nexus among the independent and dependent variables of equation (2) by means of ARDL bound test. The finding of bound test of cointegration is shown in table 3. Seeing that the estimated value of F-Statistic is more than the tabulated Pesaran et al. (Pesaran et al., 2001) upper bound value at 5 percent level of significance, hereafter the null hypothesis of no cointegration (H_0:$\beta_6 = \beta_7 = \beta_8 = \beta_9 = \beta_{10} = 0$) has been rejected at 5 percent level of significance. Consequently, it validates existence of long run association.

Table 3. Bound test of cointegration

Test Statistic	Value	K
F-statistic	4.269633	4
Critical Value Bounds*		
Significance	**I0 Bound**	**I1 Bound**
10%	2.45	3.52
5%	2.86	4.01

*Pesaran et al. (Pesaran et al., 2001) critical values 0.08 percent.

Source: author's own work.

Table 4 signify the long-run coefficients of ARDL (1,5,4,0,2) model. The findings confirm a positive nexus between use of energy and emission of carbon dioxide. The coefficients of both GDP_t and GDP_t^2 validate the presence of upturned U-relationship between gross domestic product and emissions of carbon. The coefficients of both GDP_t and GDP_t^2 are 2.62 and -0.05, respectively which means that a percent boost in gross domestic product bring a 2.62% upsurge in carbon emissions. The statistically significant negative coefficients of GDP_t^2 infer that the national income rises consistently with the level of carbon emission. This result support the EKC hypothesis which stated that at the initial stage environmental pollution rises with income, but when income goes up to the stabilization point it declines.

The coefficients on total population (TP_t) shows a positive relationship between total population and carbon emanations. But the coefficient of TP_t on CE_t is positive and statistically insignificant. This small coefficient of TP_t signify that a one percent rise in total population leads an increase in CO_2 emission by 0.08 percent.

Table 4. Long-Run coefficients of ARDL (1,5,4,0,2) Model Dependent Variable ln CE_t

Regressor	Coefficient	Standard error	t-ratio
Constant	-46.105408	6.484743	-7.109829*
ln EU_t	2.056343	0.295804	6.951705*
ln GDP_t	2.620768	0.439341	5.965221*
ln GDP_t^2	-0.051541	0.009096	-5.666099*
ln TP_t	0.081186	0.082534	0.983665

*Signify significance level at 5 percent

Source: Author's own work.

As all the variables are stationary at first difference, hence Granger-Causality test can be applying to study the causal association between GDP and CO_2 emission. The Granger causality test findings are depicted in table 5. The findings also signify that in the long run GDP cause CO_2 emission. This result also supports some other studies that investigate the association between GDP and carbon emission, for instance, Jalil and Mahmud (Jalil, Mahmud, 2009) and Zhang and Cheng (Zhang, Cheng, 2009) for China, Muhammad et al. (Muhammad et al., 2010) for Pakistan and Ghosh (Ghosh, 2010) for India.

The error correction representation of the selected ARDL (1, 5, 4, 0, 2) model is depicted in table 6. The results divulge that there exists a positive linkage between use of energy and carbon emissions.

Table 5. Granger causality test findings

Null hypothesis	F-statistic	p-value
ln GDP_t does not Granger Cause ln CE_t	3.80101	0.0318
ln CE_t does not Granger Cause ln GDP_t	1.11160	0.3401
ln GDP_t^2 does not Granger Cause ln CE_t	3.60575	0.0374
ln CE_t does not Granger Cause ln GDP_t^2	1.24678	0.2995

Source: author's own work.

The short run coefficients and error correction term are depicted in table 6. The estimated model utilizes the first difference of the variables (shows short run variations). It is noted that after a temporary shock estimated short-run coefficients depict the conjunction to equilibrium in the long run. The estimated coefficient of the ECM is 49 percent. This reveals that the nearly 49% of the disequilibrium in the preceding year following shocks to the system converge back to the long run equilibrium in the current year. By this ruling, it is deduced that to some extent disequilibrium within the CO_2 emission in the short run is hastily corrected and converged back to equilibrium in the long run.

Table 6. Error Correction Representation of the selected ARDL (1, 5, 4, 0, 2) Model Dependent variable Δ ln CE_t

Regressor	Coefficient	Standard error	t-ratio
Constant	-22.39440	6.979933	-3.208397*
Δ ln EU_t	1.075894	0.122035	8.816265*
Δ ln GDP_t	1.348524	0.405301	3.327215*
Δ ln GDP_t^2	-0.025035	0.007831	-3.196717*
Δ ln TP_t	0.141948	0.076650	1.851894**
$ECM_t(-1)$	-0.485722	0.140774	-3.450363*

*,** shows level of significance at 5% and 10%. Breusch-Godfrey Serial Correlation LM Test (Obs R square) = 0.1741, Autoregressive Conditional Heteroscedasticity Test (Obs R square) = 0.5324, Ramsey RESET Test (F-Statistic) = 1.1436

Source: author's own work.

Conclusions and recommendations

The current study focuses on the relationship among use of energy, gross domestic product, carbon emission and total population for China for the period of 1971-2013. The Environmental Kuznet curve hypothesis has been tested by employing the technique of ARDL. The ADF test reveals that all the variables are stationary at first difference. ARDL Bound test reflects that there exists a long run association among variables. The findings also infer that there is a long run association among gross domestic product, carbon emission, consumption of energy. The long-run coefficients of ARDL model reveal the existence of short-run relation among consumption of energy, carbon emission, gross domestic product and total population. A positive relationship and significant influence of use of energy on carbon emissions have been found. The output of Granger's causality test suggests that there is one-way causality runs through the gross domestic product to carbon emission. The sign of the coefficient of Error Correction term is negative and statistically significant and verifies the existence of long-run nexus among variables. Moreover, the significant value of lagged error correction term depicts that variation in carbon emanations ahead of equilibrium are adjusted by 49 percent within one year. The CUSUM and CUSUMQ procedures are employed on the ARDL model.

The findings of this research are very significant for the environmental policy makers. For that reasons, the countries should extract the substitute sources of energy, for instance, natural gas and solar energy, etc. that there is an environmentally friendly. All the empirical results validate that in high economic growth causes to degradation of the environment and ultimately diminution of natural resources regardless of expanding manner of living. The results of this study are imperative in the environmental policies. Accordingly, it ought to acquire a sustainable economic growth by fewer carbon emissions and using less energy. Additionally, the environmental policy makers may incorporate exogenous impacts, for example, overseas investments to work out energy policies, in addition, to keep up economic growth for worldwide climate forewarning.

The contribution of the authors

The six authors contributed equally to this work.

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