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IMPACT OF RENEWABLE ENERGY CONSUMPTION ON CARBON EMISSIONS: A CASE STUDY OF CHINA

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ABSTRACT

This study aims at exploring the relationship between renewable energy consumption and carbon dioxide emissions in China, and through the significance of renewable energy consumption, the hypothesis of environmental Kuznets curve at individual country level is tested as well as. Autoregressive distributes lag bounds testing approach is employed for empirical analysis. The results show that a quadratic relationship between renewable energy and CO2 emission has been found for the period support EKC relationship, and there exists a negative causality from renewable energy consumption to CO2 emissions.

Keywords: Renewable energy consumption; carbon emissions; quadratic relationship; environmental Kuznets Curve hypothesis

NONMENCLATURE

Abbreviations	
Y	Per Capital GDP
Y^2	Per Capita GDP Squared
CO2	Carbon Dioxide Per Capita
Re	Renewable Energy Consumption
Symbols	
t	Year

1. INTRODUCTION

Currently, global warming caused by greenhouse gases such as CO2 is bringing more and more significant impacts to economic and social development in various regions [1]. China surpassed the United States as the world's largest emitter of carbon dioxide in 2006 [2]. In 2015, the Chinese government has issued a statement that intending to increase the proportion of non-fossil fuels to primary energy consumption about 20% by 2030 on the U.S-China Joint Announcement on Climate Change [3]. The consumption of renewable energy is considered to be the main direction of future energy structure [5]. Hence, renewable energy as an alternative energy has attracted most scholars to study the relationship between energy structure and economic transformation [7]. Most researchers focus on the analysis of the impact of renewable energy on China from the economic level [4-6], policy [7, 8] and technological levels [9, 10]. Whether renewable energy can effectively promote economic growth, ease the tension between China's energy supply and demand, and whether it will improve the environment is worth studying. Thus the innovation of this article is mainly reflect in the following: first, the economic development and renewables in China are included in the framework model, and the relationship between renewable energy and carbon emissions and its impact degree are analyzed. Second, the existence of EKC model is quite controversial. Therefore, this paper explores whether the EKC model exists in the time period of the study.

The structure of the paper as follows. Section 2 shows the data and methodology. Section 3 provides the results, and section 4 presents the conclusions.

2. ECONOMETRIC MODEL

2.1 Data source

In this study, we select the annual data of China during the period of 1980-2014. The per capita GDP is the gross domestic product per capita which is in constant 2000 and collected from China Statistic Yearbooks. CO2 emission per capita is proxy as the greenhouse gas emission, the data is collected from The Word Bank. Electricity generated from wind, solar and hydroelectric

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power can be used as a proxy for renewable energy consumption. BP Statistical Review of World Energy provided the data about the renewable energy consumption.

2.2 Methodology

ARDL research method is employed in this study, this method is relative new research method is closely followed by recent research [11, 12]. This research method can find the nexus in a quadratic form between the variables and also can test the effectiveness of EKC hypothesis at an individual level of a country. Thus the following equation is:

$$\Delta CO_{2t} = \alpha_0 + \alpha_1 t + \sum_{i=1}^{m} \beta_1 \Delta CO_{2t-i} + \sum_{i=1}^{m} \beta_2 \Delta Y_{t-i} + \sum_{i=1}^{m} \beta_3 \Delta Y2_{t-i} + \sum_{i=1}^{m} \beta_4 \Delta RE_{t-i}$$
$$+ \beta_5 CO_{2t-1} + \beta_6 Y_{t-1} + \beta_7 Y2_{t-1} + \beta_8 RE_{t-1} + \mu$$

In the formula, Δ represents a difference operation, m is the maximum lag order, β_1, β_2, β_3, β_4 is the short-term dynamic coefficient respectively, the ARDL model about the error correction model is established. β_5, β_6, β_7 , β_8 is the long-term dynamic coefficient respectively.

In this test, the null hypothesis is that there is non-existence of the long run relationship in the equation, we could give: H0: $\beta_5 = \beta_6 = \beta_7 = \beta_8 = 0$. The alternative hypothesis is that H1: $\beta_5 \neq \beta_6 \neq \beta_7 \neq \beta_8 \neq 0$. The F-statistics is used to test whether the lag level of variables is consistent and whether has a long-term stable relationship between variables. Pesaran et al. [13] provided two sets of critical values: one set assumes that all variables are I(0) another is I(1). The null hypothesis will be rejected if the calculated F statistics value exceeds the upper critical value I (1). If the F statistics below the lower value then the null hypothesis will not be rejected. However, if the calculated results fall inside the critical value band, the test results are inconclusive.

3 EMPIRICAL RESULTS AND DISCUSSION

3.1 Unit root test results

Augmented Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) are used to test for all variables to ensure stochastic stationary. The results about all variables on the natural logarithms of the levels and the first differences present in Table 1.

In Table 1, under the ADF test all variables are nonstationary at their levels, CO2 and Re both reject the null hypothesis after differences at the level of 1%. By the KPSS test, all the variables are stationary at 1% significant level. Phillip and Perron [14] through the Monte Carlo simulations have found that the less effective about the ADF test in the case of small samples. The ADF test method can be supplemented by the characteristics of KPSS test in the case of small samples. Thus, if the ADF test and KPSS test results are inconsistent in the small simple case, we take the KPSS test results. Therefore, all the variables meet the condition that is not more than I(1), which is in accordance with the application requirements of the ARDL.

Table 1. Results of unit root tests

Regressors	ADF	KPSS
CO_2	-1.93	0.17***
ΔCO_2	-1.64***	0.39***
Y	0.42	0.21***
ΔY	-2.14	0.16***
Y^2	-1.92	0.20***
ΔY^2	2.32	0.56***
Re	-1.42	0.41***
ΔRe	-5.90***	0.24***

Note: ***, **, * is an indication of rejection of null hypothesis at 1%, 5%,10% level of significance, respectively.

3.2 *Empirical results and discussion Long- and short-run results of renewable energy consumption and CO2 emissions in China*

The calculation of ARDL model involves two steps. The first step is based on F statistic to test whether there is a long-run causal relationship between variables. If the boundary value test is used to prove that all the variables have no more than I(1), and then the next step can be carried out to estimate the long-run elasticity and short-run elasticity.

The lag order is determined by Akaike information criterion (AIC) or Schwarz Information criterion (SIC). According to the actual data and the minimum AIC, the optimal lag order is six. It has now been determined that none of the selected series is I(2) or beyond, and the long run relationship can be tested through boundary tests.

Pesaran et al. [13] have been provided the critical values presented in Table 2, the F-statistic result is 4.48. According to the critical value showed in table 3, at the 5% level of significance I(0) is 3.23 and I(1) is 4.35. So the result is higher than the upper critical value. Therefore, it provides enough evidence to show that there exists a stable long-term relationship between variables at the level of 5% significance. The coefficients are obtained based on the AIC criterion to present the result of the model. The estimating results are shown in Table 3 and Table 4.

Table 2. Bound test.

Significance	I(0) Bound	I(1) Bound
10%	2.72	3.77
5%	3.23	4.35
1%	4.29	5.61

Table 3. Long-run estimation results between renewable energy and CO2 emissions.

Variable	Coefficient	P-value
Y	0.002008	0.0091
Y^2	-3.11E-70	0.0003
RE	-0.017605	0.0121
C	-0.072425	0.0471
Diagnostic tests:		
Adjusted R^2		0.8312
DW Statistic		1.4067
Serial correlation LM		1.9329(0.1797)
Normality test		0.5928(0.0743)
Heteroscedisticity		0.8766(0.0590)
Ramsey reset test		1.5589(0.2635)

In Table 3, the long-run estimation results are presented. The coefficient of the variable Y is positive which is 0.002, and the coefficient of the variable Y^2 is -3.11 showed the negative relationship with CO2 emissions. The coefficient of RE conform to the expected sign that is -0.0176 which implies in the long-run that 1% increase in per capita electricity generated from the renewable energy will lead to 0.0176% decrease in the per capita CO2 emissions. Therefore, according to the definition of the EKC hypothesis, there exist a turning down point which means that does support the EKC hypothesis exist in China between the variables. This result is consistent with the former researches about the EKC hypothesis for China such as [15].

The short-run estimation results are presented in Table 4. The coefficient of Y is 0.00205 which is positive and the coefficient of Y^2 is negative which implies that in the short run the EKC hypothesis is valid for China as well as. The coefficient of RE is negative that means in the short-run, the consumption of electricity from renewable energy source could curb carbon emission to some extent. The ECM's coefficient is a negative sign that is -0.3657. The coefficient is used to measure the rate of adjustment from short-run fluctuations to long-run equilibrium. It shows that the one year time can be adjusted 36.57% in the case of deviation from the equilibrium level.

Table 4. Short-run estimation results between renewable energy and CO_2 emissions.

Variables :	Coefficient	T-Statistic	P-value
ΔY	0.002905	3.435844	0.0923
ΔY^2	-2.36E-07	-3.47031	0.0034
ΔRE	-0.02275	-2.05960	0.0664
ΔC	-0.049387	-3.09969	0.0059
ECM	-0.365719	0.714977	0.0001
Diagnostic test:			
F-statistic	16.56439	Prob. F(17,10)	0.0008
Obs*R-squared	27.03976	Chi-Squared(17)	0.0057
DW	3.392665		

From the above results analysis, we can make clear that carbon emissions and renewable energy are negatively correlated in China. Therefore, renewable energy consumption can inhibit carbon emissions to a certain extent, but the effect is not obvious.

In order to make sure the result is reliability and validity, Lagrange multiplier test, Ramsey's rest test, in addition to the normality test results were both performed at the bottom of Table 3. Besides, the sensitive analysis tests like modified least squares, dynamic least squares and canonical co-integration regression are used to check the results from ARDL approach. The results present in Table 5.

The results as seen in Table 5 which present the findings indicate that GDP has positive relation with the CO2 emission, GDP square has negatively impact on CO2 emission. Furthermore, renewable energy consumption is helpful to curb the CO2 emission. To conclude, the results produced through three alternative techniques support our findings acquired from ARDL bound testing approach.

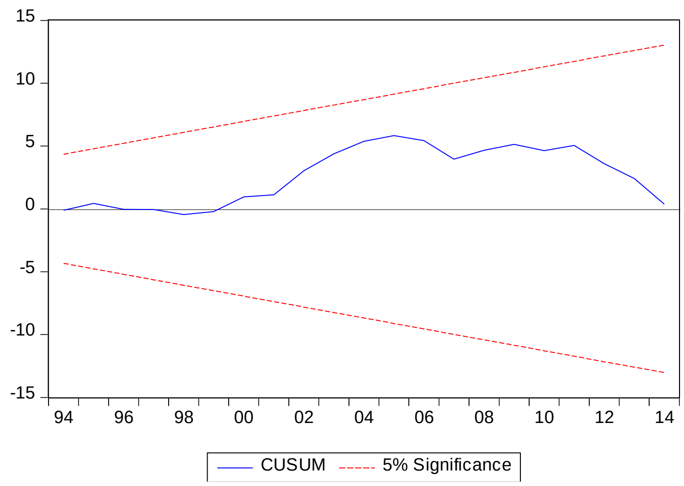
In this paper, CUSUM and CUSUMSQ are used to test the stability of the estimation results of the ARDL model. The results showed in the Fig. 1 and implied that both CUSUM and CUSUMSQ remained at 5% significant level and did not deviate from the boundary. This shows that when carbon dioxide emissions are interpreted as explanatory variables, the results from the test between

CO2 emissions, renewable energy consumption and economic growth is stable and reliable. Therefore, we can give corresponding conclusions and meaningful suggestions based on the results.

Table 5. FMOLS, DOLS and CCR analysis results.

Variables	FMOLS	DOLS	CCR
	Coefficient	Coefficient	Coefficient
Y	0.0029***	0.0013*	0.0028***
Y^2	-1.91E-07***	-7.31E-08*	-1.99E-07***
RE	-0.0040**	-0.0150*	-0.0076*
C	-0.1475**	-0.0930*	-0.1524*

Note: ***, **, * is an indication of rejection of null hypothesis at 1%, 5%,10% level of significance, respectively.



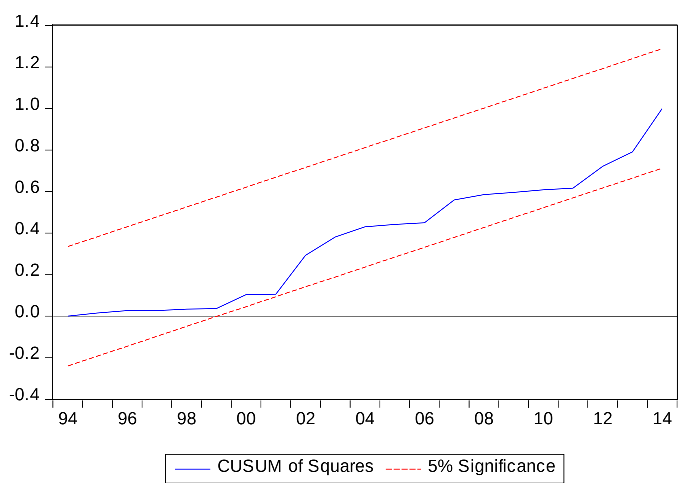


Fig. 1 Graph of CUSUM and CUSUMSQ.

4 CONCLUSIONS

This paper explores the effect of renewable energy consumption on carbon dioxide emissions during 1980 to 2014. In this paper, the ARDL bound testing approach is employed to estimate the co-integration relationships between the variables taken China as an example. The main findings of this study are: first, each variable has a long run equilibrium relationship with carbon dioxide emissions. Second, the consumption of renewable energy can suppress carbon dioxide emissions in China, but the effect is not obvious. Third, after joining the renewable energy consumption variables, we found that economic growth and carbon emissions support the inverted U shaped EKC curve.

REFERENCE

[1]. Wang, S., et al., The relationship between economic growth, energy consumption, and CO2 emissions: Empirical evidence from China. Sci Total Environ, 2016. 542(Pt A): p. 360-71.

[2]. Wang, Y., R. Han, and J. Kubota, Is there an Environmental Kuznets Curve for SO 2 emissions? A semi-parametric panel data analysis for China. Renewable and Sustainable Energy Reviews, 2016. 54: p. 1182-1188.

[3]. Mohiuddin, O., et al., The relationship between carbon dioxide emissions, energy consumption, and GDP: A recent evidence from Pakistan. Cogent Engineering, 2016. 3(1).

[4]. Fang, Y., Economic welfare impacts from renewable energy consumption: The China experience. Renewable and Sustainable Energy Reviews, 2011. 15(9): p. 5120-5128.

[5]. Lin, B. and M. Moubarak, Renewable energy consumption – Economic growth nexus for China. Renewable and Sustainable Energy Reviews, 2014. 40: p. 111-117.

[6]. Liu, W., Is renewable energy effective in promoting local economic development? The case of China. Journal of Renewable and Sustainable Energy, 2016. 8(2).

[7]. Hong, L., et al., Assessment of China's renewable energy contribution during the 12th Five Year Plan. Energy Policy, 2013. 62: p. 1533-1543.

[8]. Lo, K., A critical review of China's rapidly developing renewable energy and energy efficiency policies. Renewable and Sustainable Energy Reviews, 2014. 29: p. 508-516.

[9]. Zhang, X., S. Chang, and M. Eric, Renewable energy in China: An integrated technology and policy perspective. Energy Policy, 2012. 51: p. 1-6.

[10]. Qi, T., X. Zhang, and V.J. Karplus, The energy and CO2 emissions impact of renewable energy development in China. Energy Policy, 2014. 68: p. 60-69.
[11]. Amri, F., The relationship amongst energy consumption (renewable and non-renewable), and GDP in Algeria. Renewable and Sustainable Energy Reviews, 2017. 76: p. 62-71.
[12]. Peng, J., et al., Marginal abatement costs of CO2 emissions in the thermal power sector: A regional empirical analysis from China. Journal of Cleaner Production, 2018. 171: p. 163-174.
[13]. Pesaran, M.H., Y. Shin, and R.J. Smith, Bounds testing approaches to the analysis of level relationships. Journal of Applied Econometrics, 2001. 16(3): p. 289-326.
[14]. Damane, M., Empirical Analysis of Private Consumption in Lesotho: An ARDL Bound Test Approach. Modern Economy, 2018. 09(03): p. 400-421.
[15]. Chen, W. and W. Geng, Fossil energy saving and CO2 emissions reduction performance, and dynamic change in performance considering renewable energy input. Energy, 2017. 120: p. 283-292.