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Driving force of rising renewable energy in China: Environment, regulation and employment

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ABSTRACT

This paper studies the development of renewable energy in China by examining the driving force of environment quality, regulation and employment on renewable energy generation. We adopt renewable energy as a metric for environment quality, and test the relationship between renewable energy and income using Environment Kuznets Curve (EKC) theories. The impact of employment on renewable energy is tested, and dummy variables are used to indicate when the regulation was in effect. The results show that there exists a quadratic relationship between renewable energy and income. But the results fail to provide that the renewable energy generation is a job creator when the lagged unemployment rate is included as an explaining variable. We consider the employment population, and the finding shows that the employment can promote the development of renewable energy. The regulation has significantly positive impacts on renewable energy. The interaction of income and employment show that along with the income increases, the impacts of employment on renewable energy decrease. Our findings are helpful for government to figure out the determinants for rising the renewable energy generation, and take efficient measures to promote its development.

1. Introduction

Since opening-up policy was implemented, China has experienced dramatic development, with averaged 9.8% annual growth rates of gross domestic product (GDP), in comparison with the world's average of 3.3%. China has become the world's second largest economy. Simultaneously abundant fossil fuel has been consumed. In 1978, coal consumption is 282.8 million tons of oil equivalent, accounting for 70.7% of primary energy consumption, well above the world's average (26.2%) [1]. The proportion decreased gradually remaining above 70% until 2000, and then falling with some fluctuations, to 66% in 2014. The total increase since 1978 has been 1.68 billion tons of oil equivalent, almost increasing 15 times. Crude oil consumption was 91.2 million tons in 1978; by 2014 it had increased 5.7 times to 520.3 million tons, and the share has decreased from a 22.7–17.1% with fluctuation. Natural gas increased by 13 times, but stayed below a 3% share until 2006, and rised to 5.7% in 2014 [2], shown in Fig. 1.

Crude oil dominates the energy picture in world primary energy consumption, accounting for 30.1% in 2014, followed with 27.7% of coal and 21.9% of natural gas, and fossil energy almost controls 80% of total consumption [1]. Compared with the world level, China's unbalanced structure results in a series of problems that may hinder sustainable development. This coal based structure weakens energy efficiency and causes environmental deterioration. Energy consumption per GDP is three-times higher than the world's average, and doubles that of developing countries. According to "Research on China's energy development strategy and policy" [3], energy consumption may decrease 20 million Mtce (million tons of coal equivalent) when the proportion of coal in total primary energy drops 1%.

This increasing combustion of fossil fuels is the largest contributor to CO_2 emissions. CO_2 emissions accounted for 1.46 million metric tons in 1978 and 10.03 million tons in 2012, almost a 10-times increase [4]. As an emerging developing country and one of the largest CO_2 emitter, China is facing great pressure to reduce fossil fuel and CO_2 emissions while maintaining unprecedented economic growth. Meanwhile, traditional fossil energy companies takes great social responsibilities for employment, and the reduction of fossil energy may significantly hurt the employment. How to balance the environment quality, economic growth and employment is an intractable problem ahead of us.

One measure to relief this dilemma is increasing the supply and consumption of renewable energy. Renewable energy generation proportion has increased more than 10% from 1980 to 2012 in China [5]. Especially, the wind turbine and photovoltaic (solar) installed capacity shift dramatically, increasing more than hundred times during the recent years [1]. For the concerns of environment and

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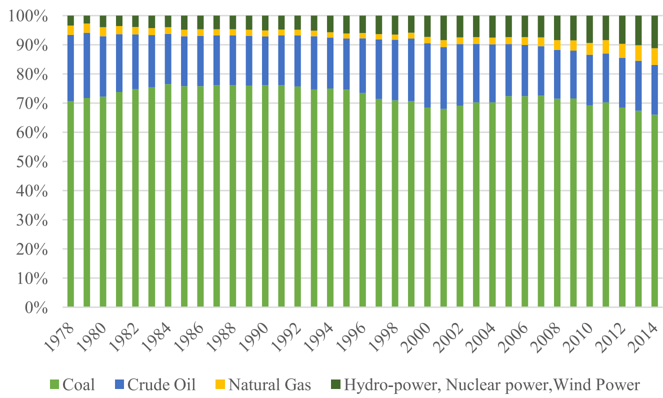


Fig. 1. China's primary energy consumption composition.
Source: NBSC, 2015 [2]

strategic security, a series of regulation and strategy plan have been proposed to support renewable energy development. The Renewable Energy Law was enacted on 28th February 2005, and major subsidy policies for renewable energy were put forward. In 2014, National Development and Reform Commission projects that the proportion of renewable energy strives upwards to 15% in primary energy consumption in 2020. More renewable energy is encouraged to contribute the low-carbon and sustainable economy.

Simultaneously, a job killer or job creator, is a controversy occurred in the transition from fossil energy to renewable energy (RE). As emerging resources, RE development creates a lot of new jobs via increasing investment. However, technical progress and energy substitution of RE will lead to “creative destruction”. Therefore, the effects of creation or destruction on employment need to be tested.

Several theories present inverted U-shaped relationship between environment pollution and economic growth. Since environment quality is stressed to promote the RE development, we use RE as a metric for environment quality, presenting U-shaped relationship between RE and per capita GDP.

This paper analyzes the transition from fossil energy to renewable energy through empirically examining the nexus between economic growth, employment, regulation and relative use of renewable energy. The rest of this paper is structured as follows. Section 2 will make a brief literature review on the nexus between renewable energy and relative factors. In Section 3 we will present the data and methodology. The empirical analysis will be displayed in Section 4, and the conclusions and policy implication will be outlined in Section 5.

2. Brief literature review

The nexus between renewable energy and the determinants has attracted attention of researchers in different countries or areas during recent years. These studies differ in countries chosen, time period covered, econometric techniques employed and data type. Recent literature concerning renewable energy indicates that capital, labor, technological progress, and economic growth are the basic elements. The analytical framework used is neoclassical Cobb-Douglas production function, which is developed by Liao et al. [6] and justified by Arbex and Perobelli [7]. Fang [8] studies the relationship between GDP, renewable energy consumption and its share, capital, labor and per capita R & D expenditure using Cobb-Douglas production function. She finds that renewable energy consumption has significantly positive impacts on real GDP and GDP per capita. Salim et al. [9] adopt production function to estimate the relationship between GDP (industrial output), renewable and non-renewable energy, capital and labor. The results show bidirectional causality between industrial output and both renewable and non-renewable energy consumption. Inglesi-Lotz [10] also employs Cobb-Douglas function to describe the impact of renewable energy consumption, employment, R & D expenditure on economic welfare by using panel data techniques. The results showed there was positive and statically significant influence between them.

Some authors adopt the autoregressive distributed lag (ARDL) method to determine the cointegration relationship among variables. Lin and Moubarak [11] analyze the relationship between GDP, renewable energy consumption, carbon dioxide emissions and labor employing ARDL and Johansen cointegration techniques. The results show that there is a bi-directional causality between renewable energy consumption and economic growth, and labor influences renewable energy consumption in the short term, but there is no evidence of causality between carbon emissions and renewable energy consumption. Sebri and Ben-Salha [12] investigated the causal relationship between renewable energy consumption, economic growth, trade openness and CO_2 emission in the BRICS countries using ARDL bounds testing approach and vector error correction model. They found the bi-directional Granger causality existing among the competing variables. Jebli and Youssef [13] use ARDL bounds testing and the vector error correction model (VECM) and Granger causality approach to investigate relationships between per capita CO_2 emissions, GDP, renewable and non-renewable energy consumption and international trade for Tunisia. They find a short-run unidirectional causality running from trade, GDP, CO_2 emission and non-renewable energy to renewable energy, and renewable energy impacts on CO_2 emission weakly and insignificantly. The inverted U-shaped environmental Kuznets curve (EKC) hypothesis is not supported graphically.

Renewable energy as a means to mitigate the environmental impact of carbon emissions. The EKC is used to describe the relationship between environmental pollutants and economic growth with turning point. Several empirical studies test the validity of the EKC hypothesis, most of them focusing on fossil energy. Apergis and Payne [14] find that there is bidirectional causality between energy consumption and emissions, and real output exhibits the inverted U-shape pattern of EKC. Jalil and Mahmud [15] examine the long-run relationship between carbon emissions and energy consumption, income and foreign trade in China. They find there exists EKC relationship between CO_2 emissions and per capita real GDP, unidirectional causality from economic growth to CO_2 emissions and insignificant impact of trade on CO_2 emissions. Ozturk and Acaravci [16] examine the long run causal relationship between economic growth, carbon emissions, energy consumption and the employment ratio in Turkey. They find that only the employment ratio impacts real GDP per capita in the short run, and the EKC hypothesis is not valid in Turkey. Pao and Tsai [17] examine dynamic causal relationships between pollutant emissions, energy consumption and output for a panel of BRIC countries. They find real output exhibits the inverted U-shape pattern associated with the EKC hypothesis, and bidirectional causality between energy consumption and emissions, energy consumption and output.

Renewable energy is an engine to create green jobs presented by several studies. Kammen et al. [18] find that more renewable generation can lead to job creation. They calculate the job impacts of replacing one unit of electricity generation from conventional technologies by renewable technologies. U.S Environmental Protection Agency (EPA) and Renewable Energy Policy Network for the 21st Century (REN21) make statistics that the employment of renewable energy has increased along with the enlarging scale of this industry. Some articles include the impacts of employment in analyzing the relationship between renewable energy and economic growth. Fang [8] presents a positive and insignificant coefficient of the number of employees relative to GDP in China. Salim et al. [9] and Inglesi-Lotz [10] show a significant and positive coefficient of labor on GDP for OECD countries.

Several studies consider the impacts of regulation on energy supply and consumption or carbon emissions. Johnstone et al. [19] examines the effect of environmental policies on technological innovation of renewable energy by patent data. They find that public policy plays a significant role in determining patent applications. Yin et al. [20] use the proportion of the regional industrial pollution-elimination investment in the GDP to represent the environmental regulation, and test the effects of regulation on CO_2 Kuznets curve. The results indicate that environmental regulation had a significant moderating effect on the CO_2 curve, and the turning point could come earlier under stricter regulation. Zhang et al. [21] find that strict and systematic environmental regulation could change the shape of the EKC and the arrival of its turing point. Ohler [22] uses market restructure as a dichotomous variable that controls for the regulation status of a state, where a value of one indicates a state that has begun restructuring away from the traditional natural monopoly regulation. He finds that the regulation has insignificantly negative impacts on renewable energy generation.

Other studies, like Chien et al. [23,24], Apergis and Payne [25,26], Sadorsky [27,28], Qi et al. [29] focus on the relationship between economic growth and renewable energy consumption using top-down or bottom-up models. Chien et al. [23] analyze the effects of renewable energy on the technical efficiency of 45 economies through data envelopment analysis (DEA), and find that OECD economies had higher technical efficiency and a higher share of geothermal, solar, tide and wind fuels in renewable energy. They also present the effects of renewable energy using Structural Equation Modeling (SEM) approach [24], and show that the positive relationship between renewable energy and GDP through the path of increasing capital formation. Qi et al. [29] employ China-in Global Energy Model (C-GEM) to evaluate the energy and CO_2 emissions impacts of China's renewable energy development in some policy scenarios. They find renewable electricity share increases and results in slightly higher economic growth, if renewable electricity cost falls due to policy or other reasons. Apergis and Payne [25] examines the relationship between renewable energy consumption and economic growth of twenty OECD countries using panel cointegration and error correction models. Meanwhile, the relationship between renewable and non-renewable energy consumption and economic growth is examined within a multivariate panel framework by Apergis and Payne [26]. Sadorsky [27] adopts panel cointegration model to examine the influence of real per capita income on renewable energy consumption. He also involves the effects of CO_2 emissions and oil price on renewable energy consumption, and finds real GDP per capita and CO_2 per capita are major drivers for per capita renewable energy consumption, and oil price has some negative impacts on renewable energy consumption [28].

The empirical literature on the relationship between renewable energy and the determinants is extensive, and the findings are diverse. Table 1 summarizes the main finding of empirical studies. However, surveying the existing studies on the driving forces of renewable energy is no consensus, neither on the driving variables nor the causality direction between these variables in the literatures. Therefore, this study aims to contribute to the literatures by identifying the impacts of environmental quality, regulation and employment on renewable energy generation.

3. Data and methodology

3.1. Model framework for renewable energy and the determinants

Renewable energy is developed toward environmentally friendly, clean energy supply. This paper contributes the EKC theories by using the renewable energy generation as a metric for environment quality. The EKC theories tend to analyze the environment pollution, such as CO_2, nitrogen oxide, sulfur dioxide emissions, water pollutants etc. We use renewable energy generation instead to measure the environment quality. Meanwhile, we consider employment factor that impacts renewable energy generation. Renewable energy is considered to be a job creator, and thus we follow the hypothesis that unemployment rate impacts renewable energy generation, which is supported by Sari et al. [30], Wei et al. [31], and Ohler [22]. Simultaneously, regulation throws its impacts on promoting renewable energy development. The model framework to analyze the relationship between renewable energy generation, income and other determinants, such as unemployment rate and regulation, using EKC theories are shown as follows.

$$Log(RE_t) = \alpha + \beta Log(income_t) + \gamma Log(income_t)^2 + \mu X_t + \varepsilon_t \tag{1}$$

In this formula, RE_t represents the renewable energy generation at the year t, including the hydro, solar, wind, geothermal and biomass and other renewable generation; α is the constant, and coefficient β and the coefficient γ are expected opposite signs in EKC hypothesis; $income_t$ denotes the GDP per capita at the year t, and X_t represents a vector of variables that control for the renewable energy generation, such as unemployment rate and regulation; μ is a vector of associated coefficients, and ε_t is the random error term. The annual time series of renewable energy generation are from BP Statistic Review of World Energy [1], with unit of Terawatt-hours; annual data for GDP per capita is from World Development Indicators (WDI) produced by World Bank [32], with units of constant 2005 US dollars; annual data of unemployment rate is from Statistic Survey of China [2].

3.2. ARDL bound testing approach for cointegration

A cointegration test is used to analyze the long-run equilibrium relationship among variables and is the first step to establish regression models with classic ordinary least square (OLS) method. We carry out the cointegration test using the ARDL bounds testing approach which was developed by Pesaran et al. [33]. It is adopted to investigate the relationship among renewable energy generation, economic growth, unemployment rate and regulation of renewable energy in case of China. We prefer to deploy this methodology because this bounds test has several advantages. First, the ARDL does not require a unique order integration of the variables. It can be applicable irrespective of whether the variables are integrated of order zero $I(0)$ or order one $I(1)$. Other cointegration tests such as Engle-Granger (EG) and Johansen-Juselius (J-J) require that all variables are integrated at the same level. Second the short- and long-run coefficients can be estimated simultaneously. Third, the ARDL has better small sample properties. Other methods such as the EG test will lead to unreliable results with small samples.

The long-term relationship among the variables are described in Eq. (1). Following Pesaran and Shin [34], we have established the ARDL models to estimate the short-run dynamic added into the long-run relationship shown as:

$$\begin{aligned}\Delta Log(RE_t) = {} & \mu + \alpha_{1i} Log(RE_{t-1}) + \alpha_{2i} Log(income_{t-1}) \\ & + \alpha_{3i} Log(income_{t-1})^2 + \alpha_{4i} X_{t-1} + \sum_{i=1}^{n} \beta_{1i} \Delta Log(RE_{t-i}) \\ & + \sum_{i=0}^{n} \beta_{2i} \Delta Log(income_{t-i}) + \sum_{i=0}^{n} \beta_{3i} \Delta Log(income_{t-i})^2 \\ & + \sum_{i=0}^{n} \beta_{4i} \Delta X_{t-i} + \varepsilon_t\end{aligned} \tag{2}$$

Where Δ represents the first difference operator; μ is the constant; α_{1i}, α_{2i}, α_{3i}, α_{4i} denote the long-run coefficients; β_{1i}, β_{2i}, β_{3i}, β_{4i} are short-run coefficients.

The joint significance of the variables needs to be examined by F-statistic, with the null hypothesis H_0: $\alpha_{1i}=\alpha_{2i}=\alpha_{3i}=\alpha_{4i}=0$ which are tested against their alternative H_1: $\alpha_{1i} \neq \alpha_{2i} \neq \alpha_{3i} \neq \alpha_{4i} \neq 0$. The F-test is conducted for the existence of long-run relationship of the variables. Since the asymptotic distribution of F statistics is nonstandard, the critic bounds values produced by Pesaran et al. [33] are introduced.

According to Pesaran et al. [33], there are two sets of critical values for a given significance level when the variables are assumed as $I(0)$ and $I(1)$. They are respectively known as upper critical bounds (UCB) and lower critical bounds (LCB). If the computed F-statistic exceeds the

Table 1
Summary of previous studies on the driving force of renewable energy development.

Authors	Countries	Sample period	Methodology	Variables	Co-integration	Causality
Fang [8]	China	1978–2008	Multivariate OLS	GDP, GDPPC, RIPC, UIPC	N.A.	N.A.
Salim et al. [9]	29 OECD countries	1980–2012	Panel cointegration	GDP, K, L, REC, NREC	Yes	REC↔NREC
Inglesi-Lotz [10]	34 OECD countries	1990–2010	Panel cointegration	GDPPC, REC, share of REC, K, L, R & D expenditure	Yes	N.A.
Lin and Moubarak [11]	China	1977–2011	ARDL	REC, GDP, CO_2, L	Yes	L→REC
Sebri and Ben-Salha [12]	BRICS countries	1971–2010	ARDL, VECM	GDP, REC, CO_2, OPEN	India, South africa	India: GDP, OPEN, CO_2→REC; REC→ OPEN;South Africa: GDP, CO_2→REC, REC→GDP
Jebli and Youssef [13]	Tunisia	1980–2009	ARDL, VECM	REC, CO_2, OPEN, GDP, NREC	Yes	CO_2, GDP, NREC→REC
Apergis and Payne [14]	Six central American countries	1980–2004	Panel cointegration, ECM	GDP, K, L, E	Yes	E,K,L→GDP
Jalil and Mahmud [15]	China	1975–2005	ARDL, ECM	CO_2PC, CEPC, GDPPC, GDPPC2, OPEN	Yes	GDPPC, GDPPC2→CO_2PC
Ozturk and Acaravci [16]	Turkey	1968–2005	ARDL	CO_2PC, EPC, L ratio, GDPPC	Yes	EPC→GDPPC
Pao and Tsai[17]	BRIC countries	1990–2005	Panel cointegration	CO2, E, GDP, GDP2	Yes	E→CO_2, CO_2→E, CO_2→GDP, CO_2→GDP2
Johnstone and Hascic [19]	25 countries	1978–2003	Panel regression, Principal components analysis	Patents, policy, R & D, electricity consumption, electricity price, EPO filings	N.A.	N.A.
Ohler [22]	U.S	1990–2008	Panel regression	RE capacity, RE development, GDPPC, restructure, restructure score, SO_2, manufacturing GDP, RPS, Unemployment	N.A.	N.A.
Chien and Hu [23]	45 countries	2001–2002	DEA	L, K, E, GDP	N.A.	N.A.
Chien and Hu [24]	116 countries	2003	SEM	GDP, REC, K, OPEN	N.A.	N.A.
Apergis and Payne [25]	20 OECD countries	1985–2005	Panel cointegration, ECM	GDP, REC, K, L	Yes	REC→GDP, GDP→REC
Apergis and Payne [26]	80 countries	1990–2007	Panel cointegration, ECM	REC, NREC, GDP, K, L	Yes	REC→GDP, GDP→REC
Sadorsky [27]	18 emerging countries	1994–2003	Panel cointegration	REC, GDPPC	Yes	GDP→REC
Sadorsky [28]	G7 countries	1980–2005	Panel cointegration	RECPC, GDPPC, CO_2PC, oil price	Yes	N.A.
Qi et al. [29]	China	2007–2015	C-GEM	GDP, cost, policy, technologies	N.A.	N.A.

Note: GDP means Gross Domestic Product; GDPPC is GDP per capita; GDPPC2 means square of GDP per capita; K represents capital; L denotes labor; REC is renewable energy consumption; RECPC represents the renewable energy consumption per capita; NREC means non-renewable energy consumption; CO_2 represents CO_2 emissions; CO_2PC means CO_2 emissions per capita; OPEN is trade openness; E represents energy consumption; EPC means energy consumption per capita; RIPC is per capita annual income of rural households; UIPC represents the per capita annual income of urban households; CEPC is the commercial energy use per capita.

UCB, we can reject the null hypothesis that there is no long-run relationship between the variables; if the F-statistics is lower than the LCB, we cannot reject the null hypothesis; however, if the F-statistic fall within these bounds, the inference would be inconclusive.

However, these critical value bounds are generated for 500 and 1000 observations and 20,000 and 40,000 replications respectively, and thus they cannot be used for small sample. Narayan [35,36] presents critical values for sample sizes ranging from 30 to 80 observations. The optimal lag structure in the ARDL approach is determined by estimating $(p+1)^*k$ regressions for each equation, where p is the maximum number of lags and k is the number of variables. Akaike's Information criteria (AIC) is employed to select the optimal lag length.

The cointegration relationship between these variables is tested by the ARDL approach. The vector error correction model (VECM) are carried out to examine both the short-run and long-run relationship. Since the other variables are used as dependent variables, the ARDL bounds test with error correction terms is formulated in multivariate VECM as follows:

$$\Delta Log(RE_t) = \omega_0 + \sum_{i=1}^{n} \omega_{1i} \Delta Log(RE_{t-i}) + \sum_{i=0}^{n} \omega_{2i} \Delta Log(income_{t-i}) + \sum_{i=0}^{n} \omega_{3i} \Delta Log(income_{t-i})^2 + \sum_{i=0}^{n} \omega_{4i} \Delta X_{t-i} + \varphi EC_{t-1} + \upsilon_t \quad (3)$$

Where EC_{t-1} is the lagged error correction term derived from the long-run cointegration function. All other variables are as defined previously. A significant t-statistic on the EC indicates the presence of a long-run relationship, while the presence of significant variables in first differences provides evidence of short-run relationships. The EC reflects the speed of the adjustment and how quickly the variables return to the long-run equilibrium with a statistically significant coefficient. To ensure the goodness of fit of the model we perform diagnostic test for serial correlation, function form, normality, and heteroscedasticity. Furthermore, the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) tests of recursive residuals are used for testing the stability of the estimated model's parameters [37].

4. Empirical results and discussion

The driving variables, such as environmental quality, employment and regulation, are involved in the models in sequence. Since we use renewable energy generation as a metric to represent environmental quality, the EKC theory is applied here to describe this relationship between them. The GDP per capita denotes the income in EKC model, and lagged unemployment rate is adopted to test the job creator hypothesis.

We begin with the descriptive statistic of the selected variables, and the main central tendency, discreteness and distribution and so on are listed, seen in Table 2. Although the ARDL method is applicable irrespective of whether the underlying regressors are purely $I(0)$, purely $I(1)$ or mutually cointegrated [33], we still conduct the stationary test to make sure that there is no series of $I(2)$ or higher. Common testing methods applied to test the stationary are Augmented Dickey and Fuller (ADF), Phillips and Perron (PP) tests and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test. ADF test based on the assumption that is tested the sequence may contain autoregression process, and PP test assumes that the data contains moving average process. For the data of small size, ADF testing may lack of efficiency. The KPSS test is more convenient for small samples, because it chooses a lower lag truncation parameter. There exists complementarity within these three testing methods, so the testing confidential level will increase when combining these methods.

The augmented Dickey and Fuller (ADF) and Phillips and Perron (PP) tests, as well as the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test are used to identify the order of integration of these variables as shown in Table 3. The results indicate that all the variables are integrated of order $I(0)$ or $I(1)$.

Table 2
Statistic description.

	Log (income)	*Log (RE)*	*Log (UE)*
Mean	2.8986	2.2942	1.5081
Median	2.9010	2.2831	1.4983
Maximum	3.5543	3.0419	1.7324
Minimum	2.2772	1.6357	1.2553
Std. Dev.	0.3905	0.3823	0.1338
Skewness	0.0793	0.2954	−0.2881
Kurtosis	1.8005	2.1807	1.9831
Jarque-Bera	2.1959	1.5302	2.0491
Probability	0.3335	0.4653	0.3590

Note: *Log*(*income*) denotes the log form of income; *Log*(*RE*) is the log form of renewable energy generation; *log*(*UE*) represents the log form of lagged unemployment rate for one period.

The ARDL bounds approach is adopted to confirm the existence of cointegration between variables using Eq. (3) with an F-test. The optimum lag length is determined by minimizing the AIC. We estimate the relationship between the renewable energy generation (RE) and economic growth, RE and employment, RE and regulation, as well as RE and interaction of the determinants, respectively.

4.1. Income and renewable energy

We examine the relationship between income and renewable energy generation by establishing the ARDL and error correction models. The log-linear model of RE and income, and U-shaped model of RE, $income$ and $income^2$ are tested respectively. Table 4a presents the estimated ARDL models and the testing results. The table demonstrates that with renewable energy generation as the dependent variable, the computed F-statistic exceeds the upper bounds of 1% critical values for U-shaped model. For this model, we reject the null hypothesis of no cointegration among the variables and conclude that there is a long-run relationship among the renewable energy generation and the determinants. For the log-linear model, the F-statistic is much lower than the bottom bound and EC_{t-1} is not significant, so we cannot reject the null hypothesis of no cointegration.

We can see that the EC_{t-1} and F-statistics are significant in the second model, which means that there is long-run relationship among the renewable energy generation, $income$ and $income^2$. The coefficients of EC_{t-1} represents the proportion by which the long-run disequilibrium in the dependent variable is corrected in each short-run period. The coefficients of EC_{t-1} are equal to −0.4387, meaning that the deviation from the long-run path of renewable energy generation is corrected by 43.87%.

The estimated coefficients of $Log(income)$ and $Log(income)^2$ are jointly significant, which provide evidence of a quadratic relationship between income and RE, shown in Table 4b. The estimated turning point of income is calculated as 274,386 USD, and current GDP per capita is far away from the turning point, and thus the renewable energy generation is rising exponentially at a dramatic rate along with the increase of income for a long time.

In the diagnostic test, the Lagrange multiplier test suggests that there is no serial correlation in the models. Ramsey's RESET test confirming the functional form of the model is well specified, and the normality test indicates that the error is normally distributed. The statistic shows the residuals are homoscedastic in the models. The cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) reveal the parameters are stable over the period for all the equations (Appendix A). The diagnostic tests suggest all the models have the desired econometric properties.

Table 3
Unit root test.

	ADF		PP		KPSS	
	No trend	With trend	No trend	With trend	No trend	With trend
Log(income)	0.5009	−4.4526***	0.6425	−2.4035	0.7129*	0.1472*
Log(RE)	0.7390	−0.8197	0.7965	0.8193	0.7171*	0.1651*
Log(UE)	−2.4343	−4.2078**	−1.9155	−2.8553	0.2996***	0.1398*
ΔLog(income)	−4.2526***	−4.2103**	−2.7546*	−2.7440	0.0987***	0.0410***
ΔLog(RE)	−5.9700***	−6.0747***	−5.9706***	−6.0747***	0.2490***	0.1481*
ΔLog(UE)	−3.1346**	−3.4227*	−3.1588**	−3.4710*	0.2934***	0.1384**

Note: Δ indicates series in first difference.
The optimal lag length was selected automatically using the Schwarz Information Criteria for ADF test and the bandwidth is selected using the Newey-West method for PP test.
* 10% of significant levels.
** 5% of significant levels.
*** 1% of significant levels.

Table 4a
ARDL bounds test results for cointegration.

Estimated model	Optimal lag length	*F*-statistics	EC_{t-1} (*t*-ratio)	Results
(*LRE/LY*)	(1,0)	1.61	−0.05455 (−0.8544)	Non-cointegration
(*LRE/LY,LY*^{2})	(1,0,0)	7.1081***	−0.4387 (−3.8044)***	Co-integration

Notes: *LRE* represents the *Log*(*RE*), *LY* denotes the *Log*(*income*), and LY^2 is the *Log*(*income*)^2. The critical value for unrestricted intercept and no trend for bottom and for top are [3.437, 4.470] at 10% level {*k*=2, *n*=30}, [5.333, 7.063] at 1% level {*k*=3, *n*=30}.
* 10% of significant levels. ** 5% of significant levels. *** 1% of significant levels.

4.2. Employment and renewable energy

Some scholars argue that an alternative explanation for the increase in renewable energy is that of job creation [31,38]. Thus states with unemployment rate are more likely to support RE. We use unemployment rate lagged as a control in the X vector, to examine whether the RE plays a role in job creation. We test the relationship between the renewable energy, income, lagged unemployment rate and their interaction. Only the cointegration models are shown in Tables. Tables 5a and 5b present the ARDL bounds test results and long-run coefficients.

We can see from the tables, the computed F-statistics exceed the upper bound of critical value at 5% and 10% level, and all the coefficients of EC_{t-1} are significant. Thus there exist long-run cointegration relationship among the RE and the lagged unemployment rate. But all the coefficients of lagged unemployment rate are not significant, meaning that this variable is not an appropriate explaining factor for renewable energy, that is to say, the unemployment rate did not promote renewable energy in China. On the other hand, the fact also indicates that the data of registered unemployment rate might not be accurate, and it is only for urban population.

Here we adopt employment population instead to estimate the

Table 5a
ARDL bounds test results for cointegration.

Estimated model	Optimal lag length	*F*-statistics	EC_{t-1} (*t*-ratio)	Results
(*LRE/LY,LY*^{2}*,LUE*)	(1,0,0,0)	5.8008**	−0.6944 (−4.0245)***	Co-integration
(*LRE/LUE,LY*LUE,LY*^{2}**LUE*)	(1,0,0,0)	4.1841*	−0.5337 (−3.2540)***	Co-integration

Notes: *LRE* represents the *Log*(*RE*), *LY* denotes the *Log*(*income*), and LY^2 is the *Log*(*income*)^2. The critical value for unrestricted intercept and no trend for bottom and for top are [4.768, 6.670] at 1% level, [3.354, 4.774] at 5% level, and [2.752, 3.994] at 10% level.
* 10% of significant levels. ** 5% of significant levels. *** 1% of significant levels.

Table 5b
Estimated long-run coefficients for ARDL model.

Dependent Variable: RE	(*LRE/LY,LY*^{2}*,LUE*)	(*LRE/LUE,LY*LUE,LY*^{2}**LUE*)
AIC-based ARDL	(1,0,0,0)	(1,0,0,0)
LY	−1.8816(−4.8276)***	
LY^2	0.4810(7.1934)***	
LUE	−0.0664(−0.8752)	0.5665(1.1773)
*LY*LUE*		−0.8819(−2.5131)**
LY^2**LUE*		0.2504(4.1671)***
Intercept	3.7683(6.1268)***	2.1042(14.2345)***
Diagnostic test statistics	R^2: 0.99; SER: 0.02; DW: 1.96; LM: 0.04 (0.835); RESET: 2.05 (0.153); NOR: 0.38 (0.825); HET: 0.23 (0.631)	R^2: 0.99; SER: 0.03; DW: 2.07; LM: 0.15 (0.697); RESET: 0.56 (0.453); NOR: 0.91 (0.635); HET: 0.52 (0.473)

* 10% of significant levels. ** 5% of significant levels. *** 1% of significant levels.

Table 4b
Estimated long-run coefficients for ARDL model.

Dependent Variable: RE	AIC-based ARDL	*LY*	*LY*^{2}	*Intercept*	Turning point (in logs)	Diagnostic test statistics
(*LRE/LY,LY*^{2})	(1,0,0)	−1.6302 (−2.9684)***	0.4422 (4.7095)***	3.3000 (4.1017)***	5.4384	R^2: 0.99; SER: 0.02; DW: 2.25; LM: 0.94 (0.331); RESET: 0.09 (0.766); NOR: 0.58 (0.749); HET: 1.31 (0.252)

Notes: R^2 represents the R-Squared; SER is standard error of regression. LM is the Lagrange multiplier test of residual serial correlation; RESET denotes the Ramsey's RESET test using the square of the fitted values; NOR is the normality test of residuals; HET means the heteroscedasticity test based on the regression of squared residuals on squared fitted; All the above diagnostic tests are based on Chi-squared test (X^2).
* 10% of significant levels. ** 5% of significant levels. *** 1% of significant levels.

Table 6a
ARDL bounds test results for cointegration.

Estimated model	Optimal lag length	F-statistics	EC_{t-1} (t-ratio)	Results
(LRE/LY^2, LE, $LE*LY$)	(1,0,0,0)	7.0205***	−0.4499 (−3.8063)***	Co-integration

Notes: *LE* represents the *Log*(*Employment*). The critical value for unrestricted intercept and no trend for bottom and for top are [4.768, 6.670] at 1% level, [3.354, 4.774] at 5% level, and [2.752, 3.994] at 10% level.
* 10% of significant levels. ** 5% of significant levels. *** 1% of significant levels.

Table 6b
Estimated long-run coefficients for ARDL model.

Dependent Variable: RE	(LRE/LY^2, LE, $LE*LY$)
AIC-BASED ARDL	(1,0,0,0)
LY^2	0.4223(5.6952)***
LE	0.6247(5.2805)***
$LE*LY$	−0.3057(−3.5899)***
Diagnostic test statistics	R^2: 0.99; SER: 0.03; DW: 2.21; LM: 0.72 (0.393); RESET: 0.99 (0.321); NOR: 0.59 (0.745); HET: 1.25 (0.263)

* 10% of significant levels. ** 5% of significant levels. *** 1% of significant levels.

impacts of employment on renewable energy. The data series of employment include both urban and rural population, from National Bureau of Statistics of China (NBSC) during 1978–2013. The data series are integrated of $I(0)$. Here also we only show the cointegration model with employment and their interaction as explanatory variables.

Table 6a shows the computed F-statistics, which exceed the upper bounds of critical value. The lagged EC terms are significant, and thus there are cointegration relationship between RE and employment and other determinants. The estimated coefficients of the employment and other determinants are shown in Table 6b. The coefficient of employment is significantly positive, implying that one percentage increase of employment will increase the renewable energy by 0.62%, ceteris paribus. The estimated coefficients of *Log*(*employment*)**Log*(*income*) are negative, which means that along with the GDP per capita increases, the impacts of employment on renewable energy decrease.

4.3. Regulation and renewable energy

Since Renewable Energy Law was enacted on 28th February 2005, a series of policies supporting renewable energy has been put forward. We use dummy variables to represent when this regulation was in effect. The number "zero" denotes the year before 2005, and "one" describes the year after 2005 (included). The ARDL bound tests and ECM method are adopted to investigate the impacts of the regulation on renewable energy generation.

The ARDL models within error correction model framework are estimated to confirm the long-run relationship. The selected cointegration models and the lagged error correction terms (EC_{t-1}) are reported in Table 7a. The calculated F-statistics lie between the critical bounds at 10% level, meaning that their results are inconclusive. For the case of inconclusiveness, the error correction term (EC_{t-1}) is a useful way to test cointegration [39]. The coefficients of EC_{t-1} are significantly negative at 1% and 10% level. Thus there exists cointegration relationship between the RE, regulation (dummy variables), and other explaining variables. The regulation has positive and statistically significant impacts on RE, in Table 7b. Therefore, regulation is an important factor promoting the renewable energy development.

Table 7a
ARDL bounds test results for cointegration.

Estimated model	Optimal lag length	F-statistics	EC_{t-1} (t-ratio)	Results
($LRE/LY,DM$)	(1,0,0)	3.6170	−0.2255 (−1.914)*	Co-integration
($LRE/LY^2,LE,DM$)	(1,0,0,0)	3.6051	−0.3097 (−2.7667)***	Co-integration

Notes: *DM* represents the dummy variable. The critical values are obtained from Narayan [26], critical values for the bounds test: case III: unrestricted intercept and no trend.
* 10% of significant levels. ** 5% of significant levels. *** 1% of significant levels.

Table 7b
Estimated long-run coefficients for ARDL model.

Dependent Variable: Log (RE)	($LRE/LY,DM$)	($LRE/LY^2,LE,DM$)
AIC-BASED ARDL	(1,0,0)	(1,0,0,0)
LY	0.8221(28.6291)***	
LY^2		0.1414(11.2262)***
LE		0.238810.1480***
DM	0.2026(3.2607)***	0.1296(1.9598)*
Diagnostic test statistics	R^2: 0.99; SER: 0.03; DW: 2.33; LM: 1.19 (0.275); RESET: 0.58 (0.447); NOR: 2.30 (0.317); HET: 2.15 (0.143)	R^2: 0.99; SER: 0.03; DW: 2.24; LM: 0.90 (0.342); RESET:2.51 (0.113); NOR: 1.64 (0.439); HET: 2.69 (0.101)

* 10% of significant levels. ** 5% of significant levels. *** 1% of significant levels.

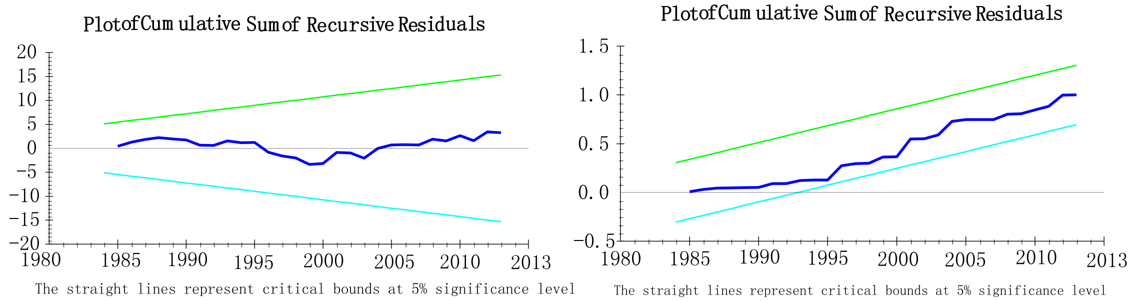
5. Policy implications and conclusion

The income and environmental quality has been studies by several literatures. This paper creates renewable energy generation as a new metric for environmental quality. Under the EKC theory, we examine the relationship between income and renewable energy generation, and find that there is a quadratic relationship between them. The current income (GDP per capita) is far away from the turning point, and thus the renewable energy generation is rising exponentially along with the increase of income for a long time.

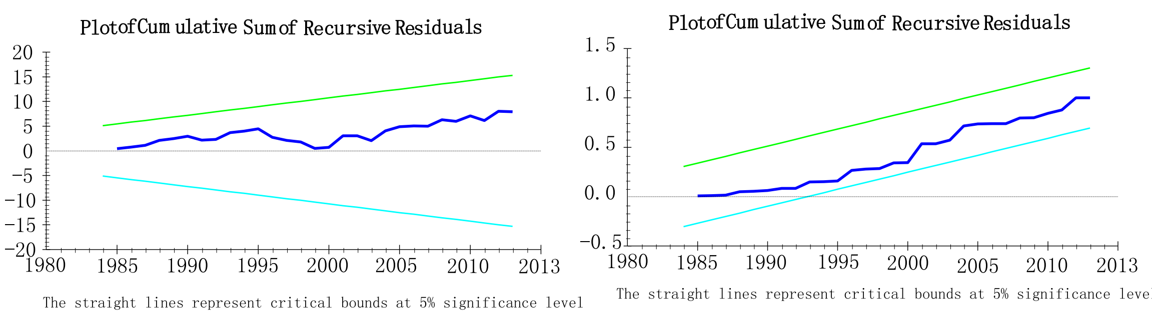
Based renewable energy generation as a metric for environmental quality, we examine other control variables for this relationship, including the employment and regulation, as well as the interaction of the determinants. The lagged unemployment rate is adopted to examine whether the renewable energy generation is a job creator or not. The results show that there exists long-and short-run relationship between renewable energy, income and unemployment rate, but the coefficients of lagged unemployment rate is not significant. So the renewable energy generation is not an engine for job creation in China using the existing data. Instead, we use employment population to analyze its impact on renewable energy, and find that the employment has significantly positive impact on RE, meanwhile, the interaction impact of income and employment on RE are negative, which means that along with the GDP per capita increases, the impacts of employment on renewable energy decrease.

We also test the impact of regulation on renewable energy generation. The dummy variables are adopted to indicate when the regulation was in effect. The results show that the regulation has significantly positive impacts on RE, but there is no turning point among the relationship between the RE, income and regulation. Meanwhile, both the regulation and employment have significantly positive impacts on RE in the long-run relationship, and the employment has bigger influence than the regulation.

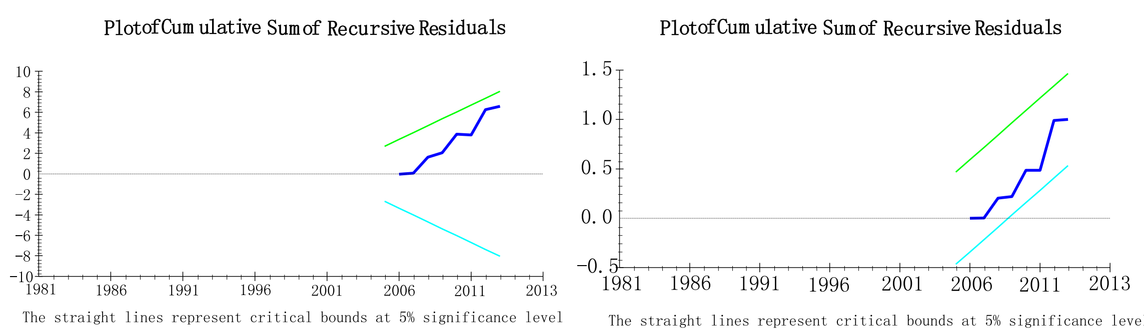
Income, employment and regulation can efficiently promote renewable energy development in China. Our research is helpful for our government to figure out the important determinants in rising renewable energy, and then to take measures to push its development efficiently. Several measures can be implemented to promote further production and consumption of renewable energy. The government should increase the investment to enlarge the production and distribution capacities of renewable energy. The other measure is to promote the research and development for technology upgrading. So far China has heavily depended on importing technologies to develop some renewable energy power generation industry. The technological gap between China and the world advanced level is still big in some aspects. What we can do is to train qualified researchers and engineers to conduct renewable technology R & D, design and manufacture in China. Meanwhile, China's energy markets are monopolized by a few large national companies. To ensure renewable energy products can



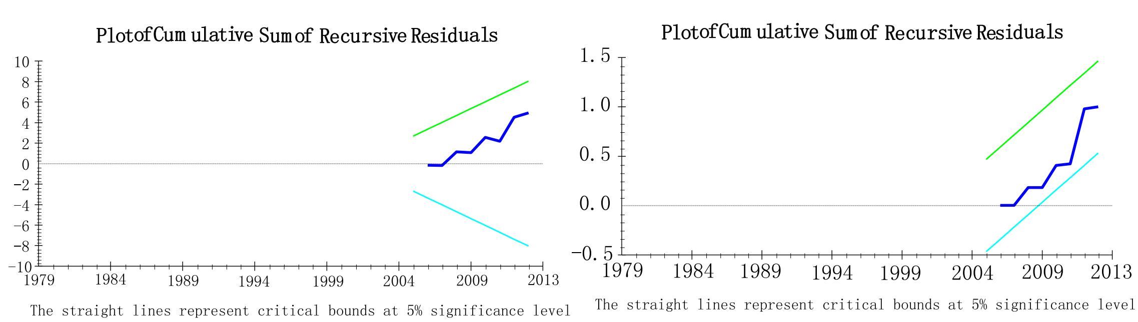
(1) CUSUM and CUSUMSQ for model (*LRE*/*LY*, LY^2)



(2) CUSUM and CUSUMSQ for model (*LRE*/LY^2,*LE*,*LE***LY*)



(3) CUSUM and CUSUMSQ for model (*LRE*/*LY*,*DM*)



(4) CUSUM and CUSUMSQ for model (*LRE*/LY^2,*LE*,*DM*)

Fig. A1. Plots of the CUSUM and CUSUMSQ stability tests statistics .

competitively enter electricity, liquid and gas markets, the government agencies should take substantive efforts to formulate measures to remove the entry barriers for renewable energy.

In the current period, economic growth and employment still keep stable, a series of regulation are gradually issued. The finding suggests that fundamental economic trends have increased the development of renewable energy. Among the renewable energy generation, hydropower takes a big proportion, and energy from wind turbine is upcoming, as well as that the production of solar, biofuel is gradually enlarging. Although in the near future, fossil energy will remain the most important energy source in China, it is necessary to promote renewable energy in order to ensure sustainable development.

This analysis and model framework can also be used in other countries with the country-specific data. Especially in the emerging economies, rapid economic growth results in abundant CO_2 emissions. Renewable energy will play an important role in promote their development. Our research can be extended in these countries and help to figure out the key factors.

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Appendix. Plots of the CUSUM and CUSUMSQ stability tests statistics

See Fig. A1.

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