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Boundary Coordinating for Energy Consumption and Environmental Pollution

Chang-Qing LI[1, a], Li-Jian LIU[1,b], Wei DUAN1[,c]

[1]School of Management, Inner Mongolia University of Technology, Hohhot, China, 010051
[a]*nmgdlcq@163.com*, [b]*1554062346@qq.com*, [c]*523392831@qq.com*

Abstract: *One reason of environmental degradation is the use of energy. Therefore it is necessary to research the relationship between energy consumption and different pollutants. We established autoregressive distributed lag - error correction model and used Bounds Testing to study the relationship between energy consumption of China and environmental pollution from 1995 to 2014. The results show that the total energy consumption, coal accounted for the proportion of total energy consumption and hydropower, nuclear power, wind power accounted for the proportion of total energy consumption has a significant impact on SO_2 emissions in the long term. It is significant that coal to total energy consumption in the proportion impact on SO_2 emissions, and the total energy consumption and hydropower, nuclear power, wind power accounted for the proportion of total energy consumption in the short term.*

Keywords: *Energy consumption; environmental pollution; ARDL- ECM; Bounds Testing.*

1. INTRODUCTION

Energy is an important material basis for economic and social development, although contributed to the rapid economic development. But it has brought serious environmental pollution problems. It determines the current primary energy consumption is coal-based for China's "less oil-rich coal" resource endowments, which is one of the important causes of the deteriorating quality of the environment, resources and environmental costs of economic growth has been too large. How to promote sustainable development of economy, energy and the environment, has become one of the issues of common concern to all walks of life, but also attracted national attention.

More Chineseschola rs study the relationship between energy consumption and the environment. GuoJuan analyzed impact on of energy consumption to environment and environmental costs of energy activities [1]. Ren Biao, Li Shaoying analyzed the relationship between China energy consumption and environmental pollution and economic development with gray correlation[2]. Zeng Bo, Su Xiaoyan pulled gray relational analysis in the study of the relationship between China's energy consumption and environmental quality[3]. The author studied the relationship between the empirical study of the total energy consumption, energy consumption structure and between different environmental pollutants by using autoregressive distributed lag-error correction model and margin testing for long-term and short-term relationship.

2. SELECT DATA

Coal-dominated energy consumption structure in current in China, causing serious air pollution, the main pollutant is SO_2, soot and nitrogen oxides. Figure 1 shows the cases of primary energy consumption from 1992 to 2014. Figure 2 reflects the changing trend of emissions of SO_2 and industrial fumes from1992 to 2014 in China.

Figure 1 show that China's coal accounts for the proportion of total energy consumption has remained at around 70%.It reached its lowest point after 66.32% in 2002, then on the rise again. It began to decline after 2010.Hydropower, nuclear power, wind power accounted for the proportion of total energy consumption has been rising.

In this paper, sulfur dioxide (SO2), industrial smoke (GY) emissions to measure the status of environmental pollution, the author measure the status quo of China's energy consumption with using

three indicators which are total energy consumption (EC), coal accounted for the proportion of total energy consumption (CC) and hydropower, nuclear power, wind power accounted for the proportion of total energy consumption (XC) and selecting data from 1992 to 2014 as the sample interval.

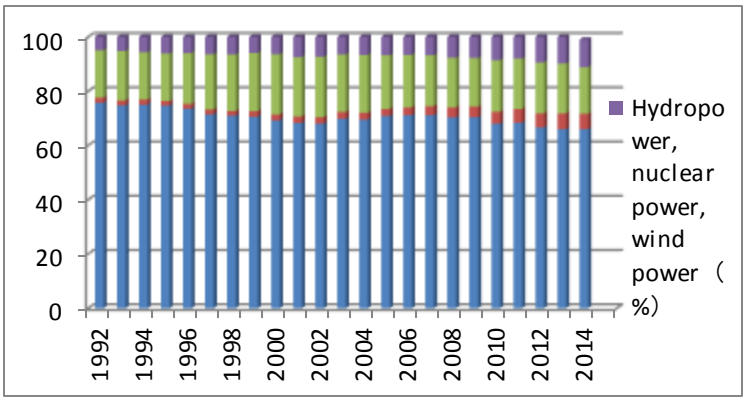

Fig1. *The composition of primary energy consumption in China*

3. RESEARCH METHODS

In the multivariate model, due to non-stationary sequences may bring "spurious regression" problems for traditional regression model. Pesaran and Shin et al. (1999) and Pesaran (2001) proposed Autoregressive Distributed Lag Approach (ARDL) Cointegration test methods and margin. The author used ARDL model and a more robust margin cointegration test to identify long-term relationship between energy consumption and environmental pollution, while using an error correction model (ECM) to analyze the short-term dynamic relationship between energy consumption and environmental pollution.

The non-constraint and non-error correction model of Bounds Testing expressions based on the following:

$$\Delta \ln WR = \alpha + \alpha_0 T + \sum_{k=1}^{n} \varphi_k \Delta \ln WR_{t-k} + \sum_{k=0}^{n} \beta_k \Delta \ln EC_{t-k} + \sum_{k=0}^{n} \gamma_k \Delta \ln CC_{t-k} + \sum_{k=0}^{n} \lambda_k \Delta \ln XC_{t-k} + \delta_1 \ln WR_{t-1} + \delta_2 \ln EC_{t-1} + \delta_3 \ln CC_{t-1} + \delta_4 \ln XC_{t-1} + \mu_t \quad (1)$$

Null hypothesis is that there is no relationship between the variables cointegration, as shown in the expression formula(2).

$$H_0: \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$$

$$H_1: \delta_1, \delta_2, \delta_3, \delta_4 \; not \; all \; 0 \quad (2)$$

Using F statistic from formula (1) tests level may exist between the variables cointegration. Pesaran (2001) constructed two sets of upper and lower check condition error correction model of margin threshold, and upper threshold is assumed that all variables are integrated of order one, the lower threshold is assumed that all variables are zero-order single whole.

4. MODEL ESTIMATION RESULTS

When we use ARDL model according to formula (1) for each differential variable lag and using AIC information criterion to select the best lag period, taking into account the presence of SO2 emissions upward trend, the paper added the trend during the estimated equation entry, and then according significant factor to determine whether you want to keep. Then use margin threshold tested and determine whether there is a long-term stable relationship between variables. If existing long-term and stable relationship will put the variables into the condition error correction model, and finally the use of long-term relationships between variables method to estimate the level of ARDL estimates and Short-term dynamic relationship between the difference variables.

Because of the longer the sequence of samples related to lag more severe and limit the capacity of the data sample, we choose the maximum difference variable lag order of 2 (p = 3). Get AIC value depending on the time lag of first order difference variables, 1st and 2nd order serial correlation LM test

statistics, and F statistics margin test value, as shown in Table 1.

Tab1. *Lag order of the ARDL model, AIC criterion, serial correlation LM statistic and bounds testing*

Pollut-ion	No trend					Trend				
	Lag	AIC	$X^2(1)$	$X^2(2)$	F-Statistic	Lag	AIC	$X^2(1)$	$X^2(2)$	F- Statistic
SO_2	1	-1.77	1.22	2.36	1.01	1	-2.63	9.52***	15.52***	5.16**
	2	-1.48	7.52***	13.64***	0.12	2	-3.07	9.53***	19.48***	3.64
GY	1	-1.06	8.71***	16.60***	8.53***	1	-0.96	8.73***	17.22***	7.37***
	2	-1.27	16.88***	19.50***	4.29	2	-1.17	17.03***	20***	3.11

According to AIC information criterion and combine LM test statistic for serial correlation, the author compared the coefficient constrainthysteresis F statistic WALD test level variable in formula (1)with Pesaran (2001) calculated the margin threshold to determine whether it exists long-term cointegration relationship between the variables. As can be seen from Table 1, SO2 contained on the trend term significance level at 5% (p = 2) refusal of the original hypothesis which does not exist long-term cointegration relationship in formula (1). Regardless of whether industrial smoke contains trend items or not, it rejects the null hypothesis in the significance level 1% (p = 2).

The last set according to the model, we have re-estimated the formula (1), and the results shows in Table 2 below.

Tab2. *The ARDL- ECM model estimation results between SO2and energy consumption*

Variable	**Coefficient**	**Std. Error**	**t- Statistic**	**Prob.**
C	26.71	5.77	4.63	0
T	-0.14	0.03	-4.74	0
DLOGSO2(- 1)	0.36	0.19	1.87	0.09
DLOGEC	-2.01	1.33	-1.52	0.16
DLOGCC	3.31	2.55	1.3	0.22
DLOGCC(- 1)	5.89	2.75	2.14	0.06
DLOGXC	-0.23	0.28	-0.83	0.42
LOGSO2(- 1)	-1.54	0.28	-5.56	0
LOGEC(- 1)	2.62	0.44	5.94	0
R2= 0.87, R2= 0.73, D-Wvalue:2.89, AIC value:- 2.80, Fvalue:6.54, Fvalue with the probability:0.00				

As can be seen from Table 2, the total energy consumption, the impact of coal accounts for the proportion of total energy consumption and hydropower, nuclear power, wind power accounted for the proportion of total energy consumption of SO_2 emissions in the 1% significance level are significant in the long run. In the short term, coal of the total energy consumption at the 10% significance level may well explain the emissions of SO_2. Total energy consumption, coal accounts for the proportion of total energy consumption and hydropower, long-term elasticity of nuclear power, wind power accounted for the proportion of total energy consumption are: 1.70 - 6.47 and - 0.59.

To test the model fitting results, this paper made a diagnostic test, and in order to test the reliability of the model finally set, also made use of cumulative sum of recursive residuals and cumulative sum of squares of recursive residuals on the stability of the structure of the model parameters tested. The results are shown in Table 3

Tab3. *The diagnostic tests for the model estimation results*

Type of test	**SO_2**	**Industrial fumes**
$X^2(4)_{SC}$	7.55	7.69
	(0.11)	(0.10)
$X^2(2)_{N}$	0.37	0.79
	(0.83)	(0.67)
$X^2(1)_{AECH}$	2.06	0.20
	(0.15)	(0.65)
CUSUM	stable	stable
CUSUMSQ	Unstable	stable

From Table 4, the test results can be seen ARDL-ECM fitting better, more stable model, estimated reliable results.

5. CONCLUSION

Integrated the above findings, the following conclusions can be drawn: 1)In the long run, the total energy consumption, coal accounts for the proportion of total energy consumption and hydropower, nuclear power, wind power accounted for the impact of the proportion of the total energy consumption of the SO_2 emissions are significant; 2) In the short term, coal accounts for only a proportion of total energy consumption has a significant impact on emissions of SO_2. We recommended 1) optimize energy consumption structure, accelerate the development of clean energy and renewable energy to achieve energy consumption as soon as possible clean; 2) to improve the efficiency of energy use as much as possible; 3) speed up the upgrading of industrial structure and product structure; 4) increase energy saving awareness of the whole society.

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