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Relationship between Economic Growths, Energy Consumption and Carbon Emissions in China and OECD

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Abstract: This paper analyzes the relationship between economic growth, energy consumption and carbon emissions in China and OECD countries. The empirical results based on panel data of China's provinces and OECD countries both prove that there is a two-way causal relationship between economic growth and energy consumption, as well as economic growth and carbon emissions. However, China's energy consumption and carbon emissions are mutually causal, while OECD countries only have one-way causal relationship.

Keywords: Economic growth, Energy consumption, Carbon emissions, Causal relationship

INTRODUCTION

With the increasingly global climate problem, scholars begin to pay attention to the relationship between economic growth, energy consumption and carbon emissions. Soytas et al found that there is no obvious causal relationship between economic growth and carbon emissions or between economic growth and energy consumption in the United States from 1960 to 2004. However, energy consumption is the Granger cause of carbon emissions [Soytas, *et. al.*, 2017]. Apergis et al. found that energy consumption and carbon emissions are mutually causal in six Central-American countries from 1971 to 2004 [Apergis, *et. al.*, 2009]. Halicioglu found that there was a causal relationship between economic growth and carbon emissions in Turkey from 1960 to 2005 [Halicioglu, *et. al.*, 2009]. Soytas et al found that carbon emission was the Granger cause of energy consumption in Turkey from 1960 to 2000 [Soytas, *et. al.*, 2009]. Arouri et al. found that there is a two-way causal relationship between energy consumption and carbon emissions in 12 Countries of the Middle-East and North-Africa [Arouri, *et. al.*, 2021] Saboori et al. found the bi-directional causal relationship between energy consumption and carbon emissions in five ASEAN countries [Saboori, *et. al.*, 2012].

Domestic scholars have also conducted in-depth studies based on different perspectives and using different methods. Cao Guangxi found that China's energy consumption was negatively correlated with carbon emissions, while the other three countries were positively correlated. Based on the data of China from 1960 to 2008, Hu Zongyi et al. found that both economic growth and energy consumption are one-way Granger causes of carbon emissions, and there is a two-way causal relationship between energy consumption and economic growth. Chen Hongmei et al. believed that China's energy consumption was the main cause of carbon emissions during 1965-2007, carbon emissions would promote economic growth. Based on panel data of 30 Provinces in China from 1997 to 2010, Li Xiaosheng et al. found that economic growth and carbon emissions are mutually causal. There is a one-way causal relationship between economic growth and energy consumption, energy consumption and carbon emissions, but not vice versa. Wang Jianmin et al. found that if economic growth increase by 1%, energy consumption will increase correspondingly by 1.5% and carbon emission will increase correspondingly by 1.57%.

Scholars at home and abroad have used different empirical data, models and methods, and came to different conclusions in different periods and objects. Therefore, this paper compares the development process of economic growth and carbon emissions in China and OECD countries, uses Granger causality test to clarify the causal relationship based on panel data in China and OECD countries. It can not only enrich the theory of low-carbon economic development, but also has important practical significance for China to realize modernization and double carbon targets.

DATA COLLECTION

The data of GDP, energy consumption and carbon emission of 30 provinces, autonomous regions and municipalities in China (data for Xizang is missing) from 1995 to 2017 are selected, which form China's provincial panel. Provincial GDP and energy consumption are obtained from China's National Bureau of Statistics web site. Carbon emission data of each province comes from China Carbon Accounting Database.

The data of GDP, energy consumption and carbon emission of 17 OECD countries from 1965 to 2019 are selected to form the OECD countries panel,

which are obtained from the world Bank website. All three types of data are in the form of natural logarithms, denoted as LnGDP, LnE, LnC.

EMPIRICAL RESEARCH

Based on panel data of Chinese provinces and OECD countries, panel unit root test, co-integration test and Granger causality test are utilized to verify the long-term equilibrium and causality relationship between economic growth, energy consumption and carbon emissions.

Panel unit root test

Before Granger causality test is performed , the stationarity of the data should be tested firstly. The most commonly used method is panel unit root test, including Fisher-ADF test and Hadri LM test.The panel unit root test results of China are shown in Table 1, and OECD in Table 2. The results show that economic growth, energy consumption and carbon emissions of China and OECD countries are integrated with the same order, and pass all the test at the significance level of 1%, indicating that three groups of variables are all stationary series.

Table 1 Results of stationarity test in China

variables	Fisher-ADF				Hadri LM
	Chi-square value P	Inverted gamma value Z	Inverted logarithmic value L*	Modified Chi-square value P_m	Z
LnGDP	153.8815***	-6.8709***	-7.0299***	8.5702***	9.2557***
LnE	173.951***	-7.7252***	-8.2205***	10.4023***	9.8508***
LnC	145.0859 ***	-6.5196 ***	-6.6128***	7.7672 ***	7.4344 ***

Note：*、**、***Represents significant at 10%, 5% and 1% levels, respectively.

Table 2 Results of stationarity test in OECD

variables	Fisher-ADF				Hadri LM
	Chi-square value P	Inverted gamma value Z	Inverted logarithmic value L*	Modified Chi-square value P_m	Z
LnGDP	101.3313***	-5.3007***	-5.6807***	8.1651***	13.7276 ***
LnE	123.0966***	-5.7488***	-6.9509***	10.8045***	20.5622***
LnC	111.6335***	-6.1577***	-6.8102***	9.4144***	20.7622***

Note：*、**、***Represents significant at 10%, 5% and 1% levels, respectively.

Co-integration test

In order to prevent false regression, Kao test, Pedroni test and Westerlund test are used to carry out co-integration test on economic growth, energy consumption and carbon emissions of China and OECD countries. The co-integration test results of China are shown in Table 3, and OECD in Table 4. The statistics of the three test methods are all significant, hence, it can be considered that there is a long-term and stable co-integration relationship between economic growth, energy consumption and carbon emissions in China and OECD countries, which lays the foundation for Granger causality test.

Table 3 Results of co-integration test in China

Test methods	Statistic	Statistic value	P value
Kao test	Modified Dickey-Fuller t	1.5622	0.0591
	Dickey-Fuller t	1.9006	0.0287
	Augmented Dickey-Fuller t	0.1296	0.4484
	Unadjusted modified Dickey-Fuller t	2.6688	0.0038
	Unadjusted Dickey-Fuller t	3.1131	0.0009
Pedroni test	Modified Phillips-Perron t	5.2075	0.0000
	Phillips-Perron t	2.8621	0.0021
	Augmented Dickey-Fuller t	3.7082	0.0001

Westerlund test	Variance ratio	5.5128	0.0000

Table 4 Results of co-integration test in OECD

Test methods	Statistic	Statistic value	P value
Kao test	Modified Dickey-Fuller t	1.4746	0.0702
	Dickey-Fuller t	1.5293	0.0631
	Augmented Dickey-Fuller t	2.0744	0.0190
	Unadjusted modified Dickey-Fuller t	2.1540	0.0156
	Unadjusted Dickey-Fuller t	2.3193	0.0102
Pedroni test	Modified Phillips-Perron t	2.3504	0.0094
	Phillips-Perron t	1.3532	0.0880
	Augmented Dickey-Fuller t	3.1315	0.0009
Westerlund test	Variance ratio	-1.4113	0.0791

Granger causal test

The original hypothesis of Granger causality test is: "X is not the Granger cause of Y ". Granger causality test is greatly influenced by the choice of lag length, and different lag order may produce different test results. Therefore, BIC information criterion is used to select the optimal lag order.

The Granger test results of economic growth and energy consumption in China and OECD countries are shown in Table 5. Test results show that China and OECD countries exists bidirectional causality between economic growth and energy consumption, that is, the increase of energy consumption will promote economic growth, and further economic growth requires more energy input , which form a vicious circle.

Table 5 Granger test results of economic growth and energy consumption

China	OECD
H0: Energy consumption is not the Granger cause of economic growth	
Optimal lag order (BIC): 2	Optimal lag order (BIC): 2
W-bar =4.1696	W-bar = 3.2221
Z-bar = 5.9418 (p-value = 0.0000)	Z-bar =2.5194 (p-value = 0.0118)
Z-bar tilde = 3.6430 (p-value = 0.0003)	Z-bar tilde = 2.1471 (p-value = 0.0318)
H1: Economic growth is not the Granger cause of energy consumption	
Optimal lag order (BIC): 2	Optimal lag order (BIC): 1
W-bar = 9.2516	W-bar =2.3833
Z-bar = 19.8593 (p-value = 0.0000)	Z-bar =4.0328 (p-value = 0.0001)
Z-bar tilde = 13.7252 (p-value = 0.0000)	Z-bar tilde = 3.6458 (p-value = 0.0003)

Table 6 Granger test results of economic growth and carbon emissions

China	OECD
H0: carbon emissions is not the Granger cause of economic growth	
Optimal lag order (BIC): 2	Optimal lag order (BIC): 2
W-bar = 5.0809	W-bar =3.6957
Z-bar = 8.4373 (p-value = 0.0000)	Z-bar = 3.4958 (p-value = 0.0005)
Z-bar tilde =5.4508 (p-value = 0.0000)	Z-bar tilde = 3.0431 (p-value = 0.0023)
H1: Economic growth is not the Granger cause of carbon emissions	
Optimal lag order (BIC): 2	Optimal lag order (BIC): 1
W-bar =12.4217	W-bar = 3.4891
Z-bar = 28.5411 (p-value = 0.0000)	Z-bar = 7.2569 (p-value = 0.0000)
Z-bar tilde = 20.0144 (p-value = 0.0000)	Z-bar tilde =6.6490 (p-value = 0.0000)

The Granger test results of economic growth and carbon emissions in China and OECD countries are shown in Table 6. It can be seen that there is bidirectional causality between economic growth and carbon emissions in both China and OECD countries. That is, the increase of carbon emissions will promote economic growth, and economic growth further produce more carbon emissions, creating another vicious cycle.

The Granger test results of energy consumption and carbon emissions are shown in Table 7. It shows that there is a two-way causal relationship between energy consumption and carbon emissions in China, that is, the increase of energy consumption will lead to the increase of carbon emissions, and vice versa , which forms the third vicious circle. For example, carbon emissions bring about climate warming, which leads to the need for more air conditioning in summer, increasing energy consumption will further lead to more carbon emissions. However, there is only one-way causal relationship in OECD countries, that is, the increase of energy consumption will lead to the increase of carbon emissions, but not vice versa. To some extent, it indicates that reducing carbon emissions will be harder for China than OECD countries, and it is particularly important to implement carbon emission reduction policies in China.

Table 7 Granger test results of energy consumption and carbon emissions

China	OECD
H0: Energy consumption is not the Granger cause of carbon emissions	
Optimal lag order (BIC): 2	Optimal lag order (BIC): 1
W-bar =7.0747	W-bar =3.4853
Z-bar = 13.8977 (p-value = 0.0000)	Z-bar = 7.2459 (p-value = 0.0000)
Z-bar tilde =9.9384 (p-value = 0.0000)	Z-bar tilde = 6.6388 (p-value = 0.0000)
H1: carbon emissions is not the Granger cause of energy consumption	
Optimal lag order (BIC): 2	Optimal lag order (BIC): 1
W-bar = 5.6993	W-bar =1.4965
Z-bar =10.1309 (p-value = 0.0000)	Z-bar = 1.4476 (p-value = 0.1477)
Z-bar tilde =7.0840 (p-value = 0.0000)	Z-bar tilde =1.2376 (p-value = 0.2158)

CONCLUSION

By comparing the development process of economic growth and carbon emission between China and OECD countries, it is found that China has become the world's largest carbon emitter and the second largest economy, carbon emission intensity are significantly higher than those of 17 OECD countries, indicating that China's economic growth is characterized by "high input and high pollution". It is necessary to change the current extensive economic growth mode, reduce the dependence of economic growth on energy consumption,.

Empirical results based on China's provincial and OECD countries panel data prove that there is a two-way causal relationship between energy consumption and carbon emissions in China, however, OECD countries only have a one-way causal relationship. Therefore, it is more difficult to reduce carbon emissions and more important to implement carbon emission policies for China, including accelerating development of low-carbon energy technologies, optimizing the industrial structure, establishing national carbon emission trading market, promoting forestry carbon sequestration trading , increasing people's low carbon awareness, and so on .

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