Exploring the Relationship between Urbanization and Carbon Dioxide Emission: A Case Study of China*

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ABSTRACT: Climate change is a global issue that now represents a serious threat to human health and the environment; as such, it constitutes a common concern for the entire international community. Carbon emission now constitutes the main cause of global warming, and rapid urbanization can increase carbon emission. Thus, this paper empirically investigated the relationship between urbanization and carbon emission in China. The econometric model was utilized taking the period 1995-2011 into consideration. Cointegration test indicated that urbanization and carbon emission were cointegrated. There was a long-term stable equilibrium relationship between urbanization and carbon emission. Specifically, 1% increase in urbanization will increase carbon emission by 1.648%. Granger causality test indicated that there was a one way causal relationship from urbanization to carbon emission. That is, urbanization can cause carbon emission, and carbon emission does not cause urbanization. The findings of this study have important implication that quantifying the relationship between urbanization and carbon emission can in fact help the implementation of energy saving and emission reduction policy.
KEYWORD: Urbanization; Carbon emission; Cointegration test; Granger causality test; China

1 INTRODUCTION

Global warming has in recent years become an indisputable fact，and it has posed a serious threat to human beings. According to the report of IPCC, greenhouse gases from the burning of fossil fuel constitute the main contributor to global warming. And carbon dioxide emission is identified one of the most important greenhouse gases (IPCC, 2007). Therefore, reducing carbon emission has become a global issue and challenge. In recently years，on the one hand, with the rapid urbanization and industrialization, heavy industry has become the main driver of economic growth; On the other hand, urbanization helps transfer more and more rural population into urban residents and the process consumes a large amount of energy resources which leads to rapid increase of carbon emission. According to scientific reports, China has been the largest energy consumer and carbon emitter (IEA, 2009). Thus, the country is now facing fossil energy supply crises and mounting international pressure to curb its carbon releases. As a result, the Chinese government plans to achieve a reduction of 16% in energy intensity (energy consumption per unit of GDP) and 17% in carbon intensity in its 12th Five-Year Plan. Quantifying the relationship between urbanization and carbon emission can effectively help China to realize its emission targets.

Studies are increasingly being undertaken in order to examine the relationship between urbanization and carbon emission in a range of different countries and regions. For instance, Cole & Neumayer (2004) found that there was a long run relationship between urbanization and carbon emission in developing countries. Liddle & Lung (2010) also found that urbanization had a positive correlation with carbon emission in developing countries. Similar results were found by Xu & Zhou (2011) and Guan et al. (2013) in China. However, Fan et al. (2006) find a negative correlation between urbanization and CO2 emissions in developing countries. In addition, Martinez-Zarzoso (2011) found an inverted U-shaped relationship between urbanization and carbon emission. However, taking 20 emerging countries as an example, Zhu et al. (2012) found little evidence in support of an inverted-U curve between urbanization and carbon emission based on the semi-parametric panel data analysis. And they further found a nonlinear relationship between urbanization

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and carbon emission. Based on the above analysis, to explore a clear relationship between urbanization and carbon emission, we re-investigate this topic by employing a series of econometric models.

2 METHODOLOGY AND DATA

2.1 *Unit root test*

A hot issue in time series analysis is the stationary test on time series data. As for a time series, classical regression model requires the variables to be stationary. As for non-stationary variables, classical regression model cannot be used. If not, there will be spurious regression. Unit root test is important method for estimating the stationarity of time series. If there is a unit root, the variables are not stationary. Thus, this paper will introduce two types of unit root tests: Augment Dickey-Fuller (ADF) test and Phillips-Perron (PP) to test the stationarity of the variables.

2.2 *Cointegration test*

Economic theory suggests that the long-term equilibrium relationship does exist between some economic variables. The relationship indicates that there is an internal self-correction mechanism between variables. If a series is shocked and deviate from its original state points, the internal mechanism will put the variables back to the balanced state by self-correction. Typically, this long-term equilibrium relationship will be denoted as cointegration relationship. Engle-Granger (E-G) is the most common used method to estimate the cointegration relationship between variables. To test whether the cointegration relationship exists between two stationary series y_t and x_t or not, Engle-Granger proposed the E-G test. The specific steps are as follows:

Assumption that there is a long-term relationship between variables *y* and *x*,

$$y_t = \alpha_0 + \alpha_1 x_t + \mu_t \tag{1}$$

where μ_t is random disturbance term, *t* denotes year. Eq. (1) is regressed by Ordinary least square (OLS) and obtains the non-equilibrium error,

$$\hat{y}_t = \hat{\alpha}_0 + \hat{\alpha}_1 x_t \tag{2}$$

$$e_t = y_t - \hat{y}_t \tag{3}$$

If e_t is stationary, *y* and *x* are cointegrated. If not, *y* and *x* are not cointegrated.

2.3 *Granger causality test*

The Granger causality test will be utilized to examine the casual relationship between urbanization and carbon emission. If the variables are cointegrated, the Granger causality test will be used. The Granger causality can detect the direction (one-way and two-way) of the casual relationship between variables. The specific models of Granger causality test are as follows:

$$y_t = \alpha_0 + \sum_{i=1}^{m} \alpha_i y_{t-i} + \sum_{i=1}^{m} \beta_i x_{t-i} + \varepsilon_t \tag{4}$$

$$x_t = \alpha_0 + \sum_{i=1}^{m} \alpha_i y_{t-1} + \sum_{i=1}^{m} \beta_i x_{t-1} + \varepsilon_t \tag{5}$$

The null hypothesis is β_i=0, which means x does not cause y. If the null hypothesis is rejected, which denotes that x can cause y. similarly, we can test y can cause x or not by examining β_j.

2.4 *Data acquisition*

Since carbon emission estimates are not currently provided by the Chinese government, it is very difficult to acquire precise data of carbon emission officially. However, given that fuel burning and cement production are reported to constitute the main sources of global carbon emission, it is a useful method to approximate the carbon emission through energy-related statistical data. In this paper, we calculated the carbon emissions only from fossil energy consumption and cement production using a unified standard method recommended by the IPCC Guidelines (IPCC, 2006).

Urbanization is defined here as the percentage of the total population that lives in the urban areas. All data used in this paper, with the exception of carbon emission, were obtained from the China Statistical Yearbook and China Energy Statistical Yearbook, from 1995 to 2011. The data on the carbon emission of China were derived from calculations using the method described previously. The total primary energy consumption and consumption of coal, coke, gasoline, kerosene, diesel, fuel oil, and natural gas were all converted into standard coal measures (units of 10^4 tons).

Fig.1 displays the urbanization and estimated carbon emission data of China from 1995 to 2011. As shown in Fig. 1, the urbanization level in 1995 was 29.04%. The urbanization rate increased from 29.04% to 51.27% between 1996 and 2011, rising approximately 1.31% annually. Urbanization accelerated carbon emission in the same period. From Fig.1, we find that per capita carbon emission jumped from 2.45 tons in 1980 to 5.89 tons in 2011. Rapid carbon emission increased began in 2005. Fig. 3 displays a scatter plot and distribution overlay of carbon emission and urbanization data in the form of box chart with the bottom and top of the box representing the 25th and 75th centiles.

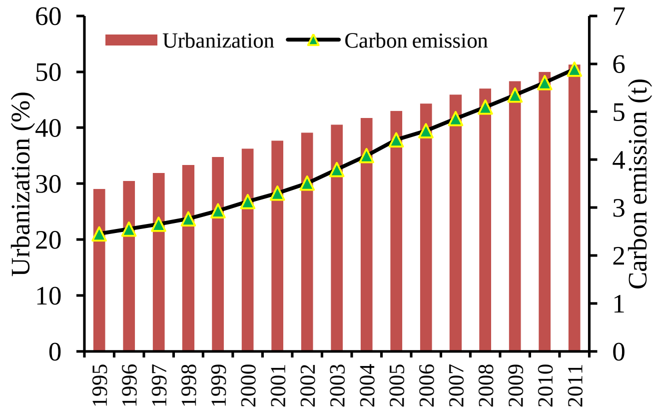

Fig. 1 The changing pattern of urbanization and carbon emission in China from 1995 to 2011

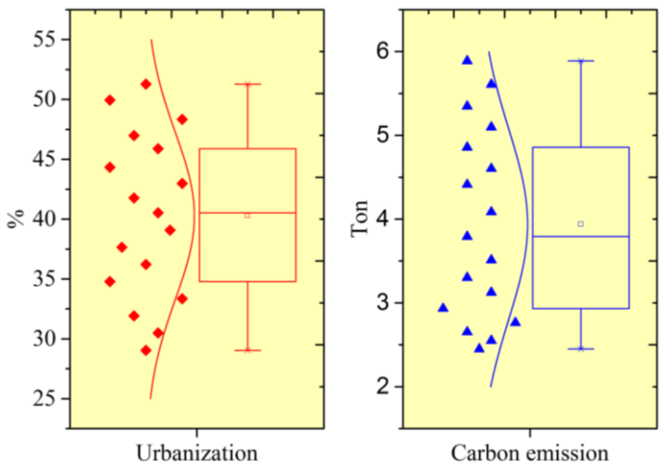

Fig. 2 Box chart of urbanization and carbon emission data with scatter plot and distribution overlay

3 RESULTS AND DISCUSSION

In order to estimate the relationship between urbanization and carbon emission quantitatively, this paper establishes an econometric model for urbanization (the independent variable) and carbon emissions ((the dependent variable) taking the period 1995-2011 into consideration. Meanwhile, all data must undergo natural logarithm transformation to avoid heteroskedasticity phenomena in the time series variables. The model that will be built is specified as follows:

$$CE_t = \alpha + \beta URBAN_t + \varepsilon_t \qquad (6)$$

where URBAN denotes urbanization level; CE represents carbon emission; t denotes time.

3.1 *Results of unit root tests*

The cointegration test requires the variables to be stationary at the first difference; thus the unit root test is used. Table 1 reviews the ADF and the PP test results which clearly show that all the variables are not stationary at levels. Thus, we need to do the first difference for both the urbanization and carbon emission variables. The differenced variables are displayed in Fig. 3. From Fig. 3, we find that the two variables fluctuate with time, which indicates that the differenced variables might be stationary. These results from Table 1 also clearly show that all the variables are stationary at the first deference rejecting the null hypothesis. Thus, this study can proceed with the cointegration test to examine whether the long run relationship exists between the variables.

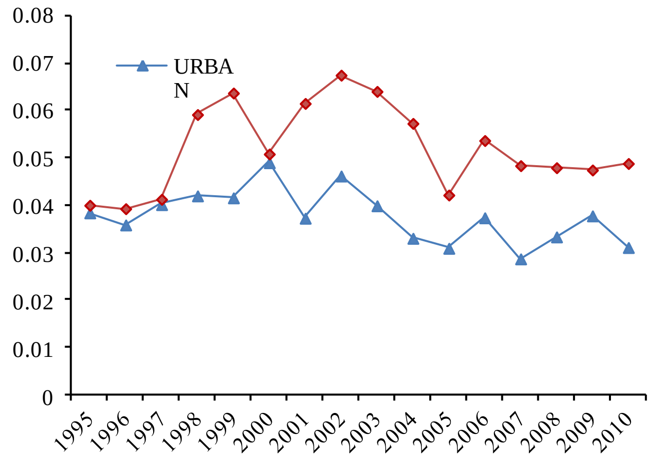

Fig. 3 the first differenced variables

Table 1 Unit root results

Variable	**ADF test**			
	Level		First difference	
	Intercept	Intercept and trend	Intercept	Intercept and trend
URBAN	0.194565	2.518937	4.664908**	9.342695***
CE	0.149656	2.075164	2.620203*	4.969181***
	PP test			
URBAN	1.439378	3.140697	6.687686**	17.76362***
CE	0.051026	1.924878	2.120203	3.895851**

Note: * Denotes significance at the 1% level. ** Denotes significance at the 5% level. *** Denotes significance at the 10% level.

3.2 *Results of cointegration test*

Since the variables are stationary at the first difference, the E-G cointegration test will be utilized. First, Ordinary least squares (OLS) will be used to regress the series *CE* and *URBAN*, and obtain a residual series *L*. Then, the ADF test is used to test whether the stationarity of *L*. The results of Table 2 show that *L* is stationary which indicating that urbanization and carbon emission have a cointegration relationship. It also indicates that urbanization and carbon emission have a long run relationship. The specific form of cointegration relationship is as follows:

$$CE = -4.734622 + 1.647745 URBAN \quad (7)$$

(-24.842***) (31.860***)

Eq. (7) shows that 1% increase in urbanization will increase carbon emission by 1.647745%.

Table 2 ADF test for series L

Series	ADF test	1% level	5% level	10% level	Results
L	3.12901	3.95914	3.08100	2.68133	Stationarity**

Note: ** Denotes significance at the 5% level.

3.3 *Results of Granger causality test*

Since the variables are cointegrated, the Granger causality will be utilized. Results based on Granger causality tests are generally found to be sensitive to the lag length of the variables, so we selected different lag lengths to explore. If the results were identical for different lag lengths, it would lend credence to our conclusions. We selected four different lag lengths considering the length of the time series: two, three, and four. And we tested two null hypotheses. The first null hypothesis is that urbanization does not cause carbon emission. The other is that carbon emission does not cause urbanization. Table 3 reviews the Granger causality test results. From Table 3, we find that there is only a one way causal relationship from urbanization to carbon emission. It indicates that urbanization can cause carbon emission, and carbon emission does not cause urbanization.

Table 3 Results of Granger causality tests

The null-hypothesis	Lag lengths	Observations	F-statistic	Probability
URBAN does not cause CE	2	15	3.07482	0.0910
CE does not cause URBAN			5.38103	0.1259
URBAN does not cause CE	3	14	4.25986	0.0522
CE does not cause URBAN			2.65524	0.1297
URBAN does not cause CE	4	13	14.3797	0.0121
CE does not cause URBAN			0.73067	0.6158

4 CONCLUSIONS

This study estimated the relationship between urbanization and carbon emission in China. Economic models were utilized taking the period 1995-2011 into consideration. Unit root tests, cointegration test, and Granger causality test were utilized to estimate whether the long run relationship exists between the two variables. The results indicated that urbanization and carbon emission were cointegrated, and there is a long-term stable equilibrium relationship between the two variables. That is, 1% increase in urbanization will increase carbon emission by 1.648%. The Granger causality test revealed that there is a one way causal relationship from urbanization to carbon emission. It means that urbanization can cause carbon emission, and carbon emission does not cause urbanization.

From the results of this study it is important for the urban planners and policy makers in China to control the growth rate of urbanization. Because rapid urbanization can increase energy consumption, and lead to a large amount of carbon emission. Thus slowing down the urbanization level can help reduce carbon emission. In addition, boosting energy-saving technologies, optimizing energy structure and improving energy efficiency can in fact reduce reliance on fossil energy resources and constitute an effective measure to reduce carbon emission.

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