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The impact of urbanization on carbon emission: empirical evidence in Beijing

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Abstract

Based on the historical data in Beijing from 1980 to 2013, this paper uses the ARDL approach to examine the impact of urbanization on carbon emission. The results show that, first, the urbanization level plays a positive role in promoting carbon emission no matter in the long or short term during the sample period. Second, the impact of per capita energy consumption on carbon emission does not seem significant no matter in the long or short term, which is due to the energy efficiency improvement and energy consumption structure adjustment in the past decades. Third, the growth of per capita GDP may curb carbon emission growth in the long term although its impact in the short term does not appear statistically significant, and we find significant inverted U-shaped relationship between per capita GDP and per capita carbon emission in Beijing during the sample period. Finally, there exists significant negative adjusting mechanism from the short term towards the long term among these variables.

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Keywords: carbon emission; urbanization; GDP; ARDL model

1. Introduction

Since 2012, China's new central government has reiterated that China should attach great attention to urbanization in the following decades to promote economic growth and people's living standard. Then a series of policies have been presented to support this new reform but we cannot neglect that China's rapid urbanization may also bring about the sharp increase of energy demand [1]. On the one hand, the large-scaled construction of infrastructure and buildings in urban regions may need to consume huge cement, steel and iron. On the other hand, each urban citizen on average may often consume more energy and emit more carbon dioxide. Therefore, the impact of urbanization process on carbon emission has become a heated topic in academia and governmental policymaking.

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Beijing is the capital of China and has many characteristics in socio-economic development. In 2014, the urbanization rate in Beijing reached 86.4% and the per capita GDP arrived at 99,995 Yuan (i.e., 16,278 US dollar) per person, which reached the level of medium developed country. With the improvement of economic level in Beijing, the citizens have attached increasing importance on environmental quality, and the words like "low-carbon" and "environmental protection" have aroused hot discussions among citizens. As professor Nanshan Zhong said in 2013, a leading Chinese specialist in respiratory diseases, air pollution was more frightening than SARS because no one could escape it and the cases of lung cancer have increased by 60% in Beijing in the past decade. As for the reasons of the smog or PM 2.5 in the air, a related study from Chinese Academy of Sciences shows that the PM 2.5 in Beijing mainly has six causes, i.e., secondary inorganic aerosols - sulfates and nitrates (caused by automobile exhausts and coal combustion), industrial production, coal burning, soil dust, biomass incineration, automobile exhausts and waste incineration, accounting for 26%, 25%, 18%, 15%, 12% and 4%, respectively, and Beijing's heavily industrialized neighboring provinces added to pollution in the capital. In the end, days of smog caused traffic jams and school closures. It should be noted that most of the causes are closely related with the urbanization process in Beijing. Just under this severe circumstance, in 2013, China's central government stipulated that Beijing municipality should set a target of cutting its annual average PM 2.5 concentration by 25% by 2017 compared to the 2012 level. Therefore, it is an urgent concern to find out the impact of urbanization on environmental quality and control the reasonable growth of carbon emission in the urbanization process in Beijing.

With China's rapid urbanization process and the growing awareness of environmental protection, the relationship between urbanization and carbon emissions has become a heated topic [2-3]. To sum up, previous related literature generally discusses the relationship among urbanization, carbon emission, energy consumption and GDP while little literature focuses on the topic in Beijing. In fact, no matter the urbanization level or per capita GDP, Beijing has far exceeded the national average level and displays much difference from other provinces. So it is necessary to take into account the characteristics in Beijing. To this end, this paper aims to explore the impact of urbanization on carbon emission in Beijing, using the ARDL model. Based on the empirical research, we may also provide some policy implications for related regulators so as to promote the timely realization of environmental protection goals by 2017 in Beijing.

The rest of the paper is structured as follows. Section 2 introduces the data and models. Section 3 puts forward results and discussions and Section 4 concludes the paper.

2. Data and models

This paper selects relevant historical data from 1980 to 2013 from the "Beijing Statistical Yearbook 2014". Given that carbon emission is mainly caused by fossil fuel burning, this paper obtains the carbon emission based on the approach by Zhang et al. [1]. Meanwhile, we consider the intermediary roles of economic growth and energy consumption in the impact of urbanization on carbon emission, and bring the per capita GDP and energy consumption into the model, with the 1980 constant price. Urbanization rate is the ratio of urban resident population to the total resident population, i.e., the population urbanization. Besides, the unit root test results show that urbanization rate, per capita energy consumption, per capita GDP and per capita carbon emission are all I(0) series during the sample period.

The autoregressive distributed lag (ARDL) model is improved and generalized by Pesaran and Skin[4], which is mainly applied for co-integration test of economic time series. The ARDL model uses the following unconditional error corrected model (UECM) to conduct the bounds testing for the long-term co-integration among variables:

$$\Delta LC_t = a_0 + \sum_{i=1}^{k} b_i \Delta LC_{t-i} + \sum_{i=0}^{l} d_i \Delta LU_{t-i} + \sum_{i=0}^{m} e_i \Delta LE_{t-i} + \sum_{i=0}^{n} f_i \Delta LG_{t-i} + \delta_1 LC_{t-1} + \delta_2 LU_{t-1} + \delta_3 LE_{t-1} + \delta_4 LG_{t-1} + v_t \quad (2)$$

where Δ represents first-difference operator, *LE, LU, LG, LC* represents urbanization rate, per capita energy consumption, per capita GDP and per capita carbon emission, respectively. All the variables are in the natural logarithmic forms. *b, d, e, f* are the short-term factors in the model, while δ_i is the long-term factor in the model and v_t represents the independent white noise sequence. The null hypothesis for testing co-integration among variables is that there is no long-term equilibrium relationship among them, namely: null hypothesis: $H_0 : \delta_1 = \delta_2 = \delta_3 = \delta_4 = 0$, and alternative hypothesis: $H_1 : \delta_1 \neq 0$ or $\delta_2 \neq 0$ or $\delta_3 \neq 0$ or $\delta_4 \neq 0$.

Then we compare the F statistics of related coefficients with the critical values of ARDL co-integration test provided by Pesaran and Skin [4]. If the F statistic is larger than the corresponding upper critical bound value, we can reject the null hypothesis, thus accept the long-term co-integration relationship; otherwise, we cannot reject the null hypothesis.

Based on the co-integration relationship, we further estimate the long-term equilibrium coefficients as follows:

$$LC_t = \xi_0 + \sum_{i=1}^{h} \chi_i LC_{t-i} + \sum_{i=0}^{z} \phi_i LU_{t-i} + \sum_{i=0}^{r} \theta_i LE_{t-i} + \sum_{i=0}^{q} \varsigma_i LG_{t-i} + \mu_i \quad (3)$$

where *h, z, r, q* are the optimal lagged orders, which are determined by the AIC and SBC criteria, and $\chi, \phi, \theta, \varsigma$ represent the long-term elasticity coefficients.

Based on the estimated results of Eq. (3), we further employ the ECM model to estimate the short-term elasticity coefficients as follows:

$$\vartriangle LC_t = \alpha_0 + \sum_{i=1}^{u} \beta_i \vartriangle LC_{t-i} + \sum_{i=0}^{v} \gamma_i \vartriangle LU_{t-i} + \sum_{i=0}^{w} \eta_i \vartriangle LE_{t-i} + \sum_{i=0}^{x} \lambda_i \vartriangle LG_{t-i} + \varphi ecm_{t-1} + \xi_t \quad (4)$$

where *ecm* is the residual term in Eq. (3).

3. Empirical results and discussions

According to Eq. (2), we obtain the regression results, which show that the F statistic is equal to 4.9325, greater than the upper critical value 2.90 at the 5% significance level. Therefore, we can say that there is co-integration relationship among urbanization rate, energy consumption, GDP and carbon emission in Beijing. In other words, when the changes of urbanization level, energy consumption, and economic level occur in Beijing, it is expected that the carbon emission may change accordingly.

3.1 The long-term impact analysis

Based on Eq. (3) and the minimum AIC value criteria, the regression model is singled out and the co-integration regression results are shown in Table 1. We find that the adjusted R-squared value and AIC value of the regression are equal to 0.91 and -2.86, respectively, with no statistically significant series correlation. Several arguments are obtained as follows.

Table 1 The long-term regression coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ξ_0	1.4075	0.3077	4.5744	0.0001
LC(-1)	0.9515	0.0360	26.4655	0.0000
LU	0.5064	0.1801	2.8125	0.0092
LE	0.0359	0.2139	0.1680	0.8679
LG	-0.1398	0.0418	-3.3421	0.0025

Note: The dependent variable is *LC*, with R squared value 0.91, AIC value -2.86 and DW value 1.99. In the LM test for series correlation, the p-value of Chi-square statistic is 0.15.

(1) In the long term, the urbanization level has a significantly positive impact on carbon emission, which indicates that the urbanization level enhancement in the past years has significantly driven carbon emission growth. Specifically, 1% increase of urbanization level in Beijing will propel the growth of per capita carbon emission by 0.5064%. There are similar cases in other regions of China. For instance, Ren et al. [5] also find that there is strong positive correlation between carbon emission and urbanization level

in Shandong from 1980 to 2009. However, Makoto et al. [6] show that when the urbanization level enters into the advanced stage (60%-100%), the impact of urbanization on carbon emission may decrease. The different performance in Beijing may have some far-reaching reasons. For one thing, during the urbanization process in the past years, the real estate industry experienced steady growth, which consumed a huge amount of cement, steel and energy and emitted tremendous carbon dioxide. For another, the number of motor vehicles has seen rapid increase in the past years, from 2 million in 2003 up to 5.6 million in 2014, which have brought about enormous pressure on environment pollution.

(2) The growth of per capita energy consumption in Beijing has a positive but statistically insignificant impact on per capita carbon emission at the 10% level. This is a little bit different from some previous literature for other regions. For instance, JaeHyun and TaeHoon [7] argue that energy consumption growth will promote the increase of carbon emissions in Korea, and the biggest impact on carbon emission comes from coal consumption growth. The difference may arise from some important reforms in Beijing in the past decades. For instance, due to the strict control of environmental pollution and effective stimulating measures for technology advance and low-carbon development, the energy efficiency has enhanced a lot in the past years. Specifically, from 2008 to 2013, the GDP in Beijing increased 8.8% annually while the energy consumption only increased 3.1% annually. On the other hand, the energy consumption structure has been increasingly cleanized and the coal consumption has been restricted all the time. According to the government plan, by the end of 2015 and 2017, the coal consumption will be further reduced by 8 and 13 million ton based on the 2012 level (23 million), respectively, and the ratio of coal consumption will reduce to less than 10% by 2017.

(3) Per capita GDP has a statistically significant negative effect on carbon emission at the 1% level; specifically, 1% increase of per capita GDP will lead to 0.1398% decrease of per capita carbon emission, which indicates that the wealth growth of Beijing residents has contributed to the reduction of their carbon emission in the past decades overall. If we use per capita GDP as the independent variable and per capita carbon emission as the dependent variable to develop a quadratic regression equation, and the regression results are shown in Table 2, with the adjusted R-squared value 0.8872, AIC value -2.7478 and no significant series correlation.

Table 2 Regression results for per capita carbon emission and GDP.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-24.3392	4.5615	-5.3358	0.0000
LG	6.1423	1.0545	5.8248	0.0000
*LG*LG*	-0.3581	0.0606	-5.9039	0.0000

Note: The dependent variable is *LC*. *C* is the constant term.

As shown in Table 2, the coefficient of quadratic term is negative with statistical significance at the 1% level, which implies that the relationship between per capita GDP and per capita carbon emission in Beijing basically conforms to the inverted U-shaped curve, i.e., the EKC curve. In other words, with the growth of per capita GDP, carbon emission will increase first and then decrease. The result is consistent with that by Giovanni et al. [8] on the relationship among GDP, energy consumption and carbon emission in OECD countries. In fact, with the rapid economic development, Beijing's per capita GDP has reached the level of moderately developed countries, while its per capita energy consumption and per capita carbon emission have crossed the top of the EKC curve and entered into a downward stage.

There are some characteristic reasons for the inverted-U shaped EKC curve in Beijing. On the one hand, it may have close relationship with the industrial structure in the past years. Just as stated by Fatih and Karanfil [9], there is an important linkage between carbon emission and industrial structure, and carbon emission will decline with the proportion reduction of the Secondary industry. In fact, with the continual restructuring, Beijing's economic development no longer mainly rely on the Secondary industry, but more on the Tertiary industry. In 2014, the ratio of the Tertiary industry in Beijing reached 77.9%, much higher than that of the Secondary industry (21.4%). Specifically, from 2008 to 2014, the added values of scientific studies and technology services (ST), information transmission, software and information technology services (ISI) and financial services (FS) increased 11.5%, 10.9% and 9.8% annually, respectively, which are higher than the average level of the Tertiary industry by 3, 2.4 and 1.3 points. These service industries have lower carbon emission intensity, and may further the reduction of carbon emission in related industries through its technology advances. As a result, the continuously increased GDP has not brought about the upsurge in per capita carbon emission but the stable decline.

On the other hand, it may be also attributed to the adjustment of consumption structure of citizens in Beijing. With the increase of people's income level in Beijing, they are more aware of environmental pollution and quality lives. Therefore, they tend to be more willing to increase their consumption of energy-saving products, which further reduces carbon emission. From this point of view, it is noteworthy for our government to shape some encouraging policies to guide the consumption structure of citizens, in the wake of the acceleration of urbanization and the sustainable growth of GDP.

3.2 The short-term impact analysis

According to Eq. (4), we get the estimated short-term coefficients as shown in Table 3, with the adjusted R-squared value and AIC value 0.60 and -3.25, respectively, and statistically insignificant series correlation. Some findings are identified from Table 3 as follows.

Table 3 The short-term regression coefficient

Variable	Coefficient	Std. Error	t-Statistic	Prob.
α_0	0.0018	0.0212	0.0837	0.9340
DLC(-1)	1.0169	0.0742	13.7089	0.0000
DLU	0.6412	0.3338	1.9209	0.0662
DLE	0.4508	0.3350	1.3456	0.1905
DLG	-0.3349	0.3024	-1.1074	0.2787
Ecm(-1)	-0.9730	0.1772	-5.4900	0.0000

Note: The dependent variable is *LC*. *D*(•) means the first-difference operator.

(1) In the short term, the impact of urbanization level on carbon emission is still statistically significant at the 10% level, and the sign of coefficient appears positive. This means that, during the sample period, the enhancement of urbanization level has significant positive promoting effect on carbon emission no matter in the long or short term. However, the short-term impact of per capita energy consumption and GDP on per capita carbon emission does not seem significant. In other words, no matter in the long or short term, per capita energy consumption does not have significant impact on per capita carbon emission in Beijing during the sample period, which indicates that the efforts for energy conservation has obtained some substantial achievements. As for the short-term insignificant impact of per capita GDP, it may be attributed to the fact the in the short term, it is hard to realize significant adjustment of industrial structure and energy consumption structure and evident improvement of residential consumption behaviors, which also reminders us that the government still has a long way to go the further the reforms in economic development and energy conservation policy implementation.

(2) The error correction coefficient is statistically significantly negative, i.e., -0.9730, indicating the negative adjusting mechanism and the adjusting speed from the short-term towards the long-term in the energy, economy, urbanization and environment system. Specifically, the deviations in short term towards long term are corrected by 97.30% in each year. In other words, the system appears relatively stable and when the short-term movement deviates from the long-term equilibrium, it will return to the long-term equilibrium state at the adjusting amplitude 97.30% in the next year. This relatively high speed of adjustment may be due to their close relationship among energy, economy and environment and the direct influence of urbanization on them.

4. Main conclusions and policy implications

This paper, based on the sample data from 1980 to 2013 of Beijing, uses the ARDL model to analyze the influencing factors of carbon emission in Beijing during the urbanization process, including urbanization rate, per capita energy consumption and per capita GDP. The results show that the enhancement of urbanization level plays a positive role in promoting carbon emission growth no matter in the long or short term. However, the influence of per capita energy consumption on per capita carbon emission does not seem significant no matter in the long or short term, which is due to the continual efforts in the past decades on energy efficiency improvement and energy consumption structure adjustment. Additionally, the growth of per capita GDP may curb carbon emission growth in the long term although its short-term impact is insignificant during the sample period, due to the relatively higher shares of clean industries in Beijing's economy. More importantly, we find significant inverted U-shaped relationship between per capita GDP and per capita carbon emission in Beijing during the sample period. Besides, in the short term, there exists significant negative adjusting mechanism towards the long-term equilibrium among these variables; in other words, the energy, economy, urbanization and environment system proves relatively stable in the long term; and the promoting impact of urbanization on carbon emission should be attached key attention.

Based on the results, we also provide several policy implications for related policy makers. First of all, the government is expected to strengthen the top-level design and make rational strategic planning for the energy conservation and carbon emission reduction in Beijing. Second, the government has to further adjust industrial structure and residential consumption structure towards more clean energy use, and encourage strategic emerging industries in the wake of urbanization process, so as to curb the promoting influence of urbanization on carbon emission increase. Finally, the government is urgently needed to promote the adjustment and upgrading of energy consumption structure. Besides the declining coal use, it is also needed to upgrade the quality of gasoline and diesel used in Beijing so as to curb the environment pollution from the motor vehicles.

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