Decoupling Analysis of Economic Growth and Carbon Emissions from the Perspective of City Scale

Caijing Zhang¹, Na Lu¹,* and Yang Chen¹

¹School of Finance and economics, Jiangsu University, Zhenjiang, Jiangsu 212013, China
*Corresponding author. Email address: luna@ujs.edu.cn

Abstract. The cities of China are different in scale, studying the decoupling relationship between economic growth and carbon emissions, and the influencing factors will help to achieve China’s "low carbon economy" development strategy. In this paper, the Tapio decoupling model is used to study the decoupling relationship between carbon emissions and economic growth in six different scale cities, including Shanghai, Wuhan, Xianyang, Qinhuangdao, Shizuishan and Jinchang. The conclusions are as follows: the greater the scale of the city, the stronger ability of decoupling; compared with the population, the per capita GDP, the industrial structure has the most positive effect on the decoupling; only the energy intensity has a negative effect, but the effect is greater. Therefore, we should focus on industrial structure optimization and energy intensity reduction.

1. Introduction

For a long time, the rapid economic growth of major cities in China has led to the formation of high-consumption, high-emission extensive energy consumption in China. To achieve sustainable economic development in an all-round way, it is necessary to continuously weaken the correlation between economic growth and energy consumption growth, so that the two are effectively decoupled. For cities of different scales, because of the large differences between their economic development and energy consumption, the degree of correlation between the two will be different. Therefore, this paper takes different scale cities as the research object, studies the decoupling state of economic growth and carbon emissions and whether there are differences, and analyzes the factors that may affect the decoupling, so as to propose more effective energy-saving and emission reduction policies for cities of all sizes, which will help to achieve China’s "low carbon economy" development strategy.

In the context of global warming, how to effectively control greenhouse gas emissions while maintaining sustained economic growth, in order to achieve the decoupling of economic growth and carbon emissions, has become a hot issue of concern to both the government and academia. The study of decoupling relationship is mostly based on the Tapio decoupling elastic coefficient[1]. Researchers are more focused on the decoupling between carbon emissions from energy consumption and industry development, such as carbon emissions and economic growth in the transportation industry[2], carbon emissions from tourism and industrial development[3], or carbon emissions and economic growth in a region[4] or country[5]. It can be seen that the existing research has paid less attention to the difference in city size. The economic development of different scale cities and the carbon emissions of energy consumption are significantly different. The decoupling relationship between the two is worthy of attention.
2. Research methods and data sources

2.1. Research methods

2.1.1 Decoupling index. In this paper, the more sensitive model of Tapio decoupling is used to study the decoupling relationship between economic growth and carbon emissions, as in equation (1).

\[
e = \frac{\% \Delta C}{\% \Delta G} = \frac{C_t - C_0}{G_t - G_0} = \frac{\Delta C}{\Delta G}
\]

(1)

Where \( C \) represents carbon emissions, \( G \) is GDP, \( e \) is the decoupling index, 0 is the base period, and \( t \) is the t-th period. The index further divides the indicator system into three states, which are negative decoupling, decoupling, and connecting. In the three basic states, Tapio again uses 0, 0.8, and 1.2 as the critical value, and the decoupling index is further subdivided into 8 kinds of decoupling states, namely, expansion negative decoupling, weak negative decoupling, strong negative decoupling, declining decoupling, and strong decoupling, weak decoupling.

2.1.2. Analysis of influencing factors. This paper constructs a multiple linear regression model to explore the influencing factors of decoupling, as in equation (2).

\[
e_i = \alpha_0 + \alpha_1 P_i + \alpha_2 G_i + \alpha_3 I_i + \alpha_4 E_i + \epsilon_i
\]

(2)

Where \( i \) and \( t \) represent the city and time respectively; \( P \) is the total population, \( G \) is the per capita GDP; \( I \) is the industrial structure, expressed as the proportion of the secondary industry; \( E \) is the energy intensity, expressed as the ratio of the total energy consumption to the total production value; \( \alpha \) is the coefficient of the variable; \( \epsilon \) is the residual.

2.2 Data source

This paper takes the selected cities of different scales in China as the research object, and the research period is 2007-2016. The energy consumption, economic and demographic data of each city are derived from the statistical offices of the provinces and cities of the People's Republic of China. Carbon emissions data are calculated based on the carbon emission factor method published by the IPCC.

3. Choices of cities of different scale

According to the number of permanent residents in urban areas, China divides cities into seven categories (super-large cities, mega-cities, large cities, medium-sized cities and small cities). See Table 2 for details. Since the number of Type II small cities is only three in China, namely, Nyingchi, Guoluo and Ali, the research on them has little significance, so only small cities of type I are considered. In order to make the research results representative, the cities of different scales selected in this paper are all with significant energy consumption. The cities selected are shown in Table 1.

| City scale         | Urban resident population (10,000) | Representative city | Population (10,000) |
|--------------------|-----------------------------------|---------------------|---------------------|
| Super-large city   | Super-large city                   | >1000               | Shanghai            | 2301.91              |
| Mega-city          | Mega-city                          | 5000-1000           | Wuhan               | 978.54               |
| Large city         | Type I large city                  | 300-500             | Xianyang            | 489.48               |
|                    | Type II large city                 | 100-300             | Qinhuangdao         | 289.74               |
| Medium-sized city  | Medium-sized city                  | 50-100              | Shizuishan          | 72.55                |
| Small city         | Type I small city                  | 20-50               | Jinchang            | 46.41                |
|                    | Type II small city                 | <20                 | -                   | -                    |
4. Results analysis

4.1 Decoupling state analysis

According to formula (1), the calculation of the decoupling elastic index of carbon emissions and economic growth of cities in different scales is carried out. The calculation results are shown in Table 2. It can be seen that the decoupling state of carbon emissions and economic growth in selected cities is decoupling, which indicates that China’s great effort on carbon emissions reduction in recent years and related policies formulated during the “Twelfth Five-Year Plan” have played a significant role. Among them, Shanghai is strongly decoupled, and the other five cities are weakly decoupled. The reason for the stronger decoupling in Shanghai may be the optimization of its industrial structure, its outstanding achievements in energy conservation and emission reduction, and its sustained and steady economic growth. In contrast, the decoupling elastic index increases with the scale of the city expanding. From this point of view, the scale of the city has a positive effect on the decoupling of economic growth from carbon emissions.

Table 2. Decoupling elastic index and decoupling status of carbon emissions and economic growth in different cities.

| City        | %ΔC  | %ΔGDP | e(C,GDP) | Decoupling state       |
|-------------|------|-------|----------|------------------------|
| Shanghai    | -0.010 | 1.255  | -0.008   | Strong decoupling      |
| Wuhan       | 0.031 | 2.792  | 0.011    | Weak decoupling        |
| Xianyang    | 0.037 | 3.084  | 0.012    | Weak decoupling        |
| Qinhuangdao | 0.035 | 1.434  | 0.024    | Weak decoupling        |
| Shizuishan  | 0.114 | 1.941  | 0.059    | Weak decoupling        |
| Jinchang    | 0.209 | 1.536  | 0.136    | Weak decoupling        |

4.2 Analysis of influencing factors

The simulation was performed using Eviews software, and the results are shown in Table 3.

Table 3. Regression results of influencing factors on decoupling*

| Regression indicator | P       | G       | I       | E       |
|----------------------|---------|---------|---------|---------|
|                      | R²      | Coefficient |        |         |
| Shanghai             | 0.814   | 0.0486** | 0.0001** | 77.3559*** | -20.2794** |
| Wuhan                | 0.904   | 0.0238***| 0.0017** | 63.9124** | -17.7301*** |
| Xianyan              | 0.893   | 0.3147** | 0.0006** | 78.8172** | -31.9136*** |
| Qinhuangdao          | 0.791   | 0.0916** | 0.0183** | 84.9101** | -26.3606** |
| Shizuishan           | 0.774   | 0.0332***| 0.6548** | 90.1639***| -18.8172** |
| Jinchang             | 0.907   | 0.6128***| 0.3967** | 73.8164***| -15.3102** |

* Note: * p < 0.1, ** p < 0.05, *** p < 0.01.

It can be seen from the results in the table 3 that the model goodness of fit (R²) of each scale city is closer to 1, that means the sample fits the model better; the P value of each variable coefficient is also less than 0.05, indicating the per capita GDP, population, industrial structure and energy intensity all have a significant effect on the decoupling of carbon emissions and economic growth in cities of all scales.

Judging from the regression coefficients of various factors, the influencing factors of cities of different scales have regularity: (1) The per capita GDP, population and industrial structure of each city have a positive effect on decoupling, while the energy intensity is negative. (2) Among the three
positive influencing factors, the regression coefficient of the industrial structure is the largest, which indicates that the optimization of industrial structure has the greatest impact on the decoupling of carbon emissions and economic growth regardless of the scale of the city, so the industry structure should be continuously optimized. The effect of population and per capita GDP is relatively small, indicating that the demographic and economic scale of the city has a positive effect on the decoupling of its carbon emissions and economic growth, but the effect is weak. The energy intensity of cities of all scales has a negative effect on the decoupling of carbon emissions and economic growth. The coefficients of Xianyang and Qinhuangdao are prominent. The reason may be that these two cities are resource-based cities, and they do not pay attention to increase energy efficiency, resulting in greater energy intensity, and the decoupling effect is relatively weak. It can be seen that continuously reducing the energy intensity of cities of all scale also has a good effect on the decoupling of carbon emissions and economic growth.

5. Conclusions and policy recommendations
The carbon emissions and economic growth of each city selected in this paper are decoupled, and the larger the city scale, the smaller the decoupling index and the better the decoupling state, indicating that the scale of the city has a certain influence on its decoupling state.

The results of influencing factors on the decoupling show that the industrial structure has the most prominent role in promoting the decoupling development, energy consumption intensity has prominent negative impact, and the per capita GDP and population have weakly positive effect. Therefore, the effective decoupling of carbon emissions and economic growth in different scale cities in China must further optimize the industrial structure and reduce the energy intensity through technological advancement and optimization of energy consumption structure.

Acknowledgments
The authors sincerely acknowledge financial support by College Students Practice Innovation Training Program (No. 201810299018Z).

References
[1] TAPIO P 2005 Towardsa theory of decoupling: Degrees of decoupling in the EU and the case of road traffic in Finland between 1970 and 2001 J. Transport Policy 12 137-151
[2] Gao J, Wang J W and Zhao J 2012 Decoupling of transportation energy consumption from transportation industry growth in China J. Procedia - Social and Behavioral Sciences 43 33-42
[3] Tang Z, Shang J, Shi C B, Liu Z and Bi K X 2014 Decoupling indicators of CO2 emissions from the tourism industry in China: 1990–2012 J. Ecological Indicators 46 390-397
[4] Wang W W, Liu R, Zhang M and Li H N 2013 Decomposing the decoupling of energy-related CO2 emissions and economic growth in Jiangsu Province J. Energy for Sustainable Development 17 63-71
[5] Zhang M, Song Y, Su B and Sun X M 2015 Decomposing the decoupling indicator between the economic growth and energy consumption in China J. Energy Efficiency 8 1231-39