# Regional Collaborative Development and Emission Reduction in the Chengdu-Chongqing Economic Circle

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**Abstract.** Developing a low-carbon economy is a necessary path for the Chengdu-Chongqing Economic Circle to achieve the goal of high-quality development. This study measured the level of synergistic development of the two urban economic circles in Chengdu and Chongqing and established a fixed-effect model to verify that the synergistic development emissions have an inverted "U" shape relationship, with industrial structure upgrading as an important mediating variable. Promoting the synergistic development of economy and society is conducive to reduce carbon emission.

**Keywords:** Coupling coordination degree · Carbon emission · Environmental Kuznets Curve

## 1 Introduction

Since the mid-20th century, carbon dioxide emissions from human activities severely damaged the ecosystem. As the world's largest $CO_2$ emitter, China regards low-carbon development as an important goal for the country's high-quality development [9]. In the report of the 20th National Congress, the Party Central Committee put forward the need to thoroughly implement the concept of high-quality development and implement low-carbon development in regional development [2]. Since October 2020, the Chengdu-Chongqing Economic Circle is an important engine leading the development of western China. Therefore, it is important to study the relationship between the Chengdu-Chongqing synergistic development and regional carbon emissions in this paper.

## 2 Literature Review

In the process of economic agglomeration in China, many scholars have studied the effect of regional synergistic development. The overall coupling coordination of Chengdu-Chongqing economic circle shows an "inverted M" rising trend from 2014 to 2019, and the development differences between regions will become more obvious [1]. The


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regional synergistic level in Sichuan province is increasing year by year. The ecological and environmental protection, openness and medical welfare are the main factors of synergistic development [10]. Meanwhile, numerous articles have studied the impact of economic agglomeration on carbon emissions. The inverted U-shaped curve reflect the effect of industrial synergistic agglomeration on urban carbon emission intensity in the Yangtze River economic belt [11]. From 2008 to 2018, the total and per capita carbon emissions of Chengdu and Chongqing urban agglomerations showed an increase. The influencing factors of each city show spatial and temporal heterogeneity, and energy intensity, economic development level, and population size intensify the carbon emissions [7]. At present, there are few studies that consider regional synergy as the main influencing factor of carbon emissions. In this paper, we establish a regression model by combining the STIRPAT and EKC model on the basis of measuring its degree of synergistic development to find the influence mechanism of regional synergistic development on carbon emissions.

## 3 Analytical Framework

### 3.1 Measurements of the Coordinated Development

Following previous research [5], this paper selects 12 indicators to construct a comprehensive evaluation index system for the synergistic development of Chengdu-Chongqing regions. In the economic development dimension, indicators such as tertiary industry development, income level, consumption level, fixed asset investment, financial status and import and export level are selected. In the social development dimension, five indicators such as population density, medical level, education level, employment status and environmental protection are selected for measurement.

**Comprehensive Evaluation Score**

Firstly, this paper standardizes the data with the polar transformation method to calculate $y_{ij}$. This paper uses the information entropy redundancy degree to calculate the weight of the j indicator $w_j$. Finally, the multiplication of the weights of each indicator and the standard value is summed to calculate the comprehensive evaluation score $S_i = \sum_{j=1}^{n} w_j y_{ij}$. In this paper, the economic development index $es_i$ and social development index $ss_i$ are derived.

**Coupling Coordination Degree**

The degree of coupling coordination is considered the strength of multiple systems that promote and influence each other in the development process. According to available literature, the coupling degree of economic and social development $C_i$ were calculated as follows [5]:

$$C_i = \left\{ (es_i \times ss_i) / \left( \frac{es_i + ss_i}{2} \right)^2 \right\}^{1/2} \tag{1}$$

$$H_i = \sqrt{C_i \cdot T_i}, T_i = aes_i + bss_i \tag{2}$$

Here, $H_i$ was the coupling coordination degree. Coefficient a and b respectively reflected the $es_i$ and $ss_i$ contributions, 0.5 was set for each.

### 3.2 Econometric Model

The STIRPAT model has been widely used in the literature to study carbon emissions [3][4][6]. In order to verify the inverse "U"-shaped relationship between regional synergistic development and carbon emissions, this paper adds the primary and secondary terms of the coupling coordination degree to the STIRPAT model to verify the environmental Kuznets hypothesis and establish a nonlinear model:

$$\ln carbon_{it} = \alpha_0 + \beta_1 \ln coor_{it} + \beta_2 \ln coor_{it}^2 + \alpha_1 \ln P_{it} + \alpha_2 \ln A_{it} + \alpha_3 \ln T_{it} + e_{it} \tag{3}$$

In model (3), the core explanatory variable is the coupling coordination and the carbon emission is the dependent variable. The environmental pressure is represented by carbon emission. The remaining major factors are population size ($P$), wealth ($A$), and technology ($T$), $e$ represents error terms, respectively.

### 3.3 Variable Selection

Following the study of Wu and Guo (2019) [8], the dependent variables are total carbon emissions and carbon emissions intensity. The core explanatory variables is the coupled coordination degree. The control variables include per capita GDP, population, research expenditure, industrial upgrading, energy consumption intensity, and foreign direct investment. This paper takes 16 cities' 2010–2019 panel data as research object. Relevant data are from "Sichuan Statistical Yearbook", "Chongqing Statistical Yearbook", "China City Statistical Yearbook "and "China Energy Statistical Yearbook". The Table 1 shows the variables.

## 4 Empirical Results

### 4.1 Coupling Coordination Degree of Chengdu-Chongqing Urban Circle

By categorizing the coupling coordination level of each city, we find that 2 cities were in good coordination, 1 city in primary coordination, 4 cities in barely coordinated, 4 cities in near dissonance, 4 cities in mild dissonance, and 1 cities in moderate dissonance in 2010. By 2019, Chengdu rises to be a high-quality coordination city, and the number of cities in barely coordinated cities increased to 10, and the synergistic development of the Chengdu-Chongqing Economic Circle improved.

### 4.2 Basic Regression Analysis

We perform ordinary least square (OLS) and fixed effect (FE), to estimate model (3) respectively. In column (2) of Table 2, the estimation coefficient of $coor^2$is negative, which means inverted "U" shape relationship between coupling coordination and carbon emissions. As for the other variables, an increase in population density, research expenditure, energy intensity and tertiary sector cause an increase in carbon emissions similarly.

**Table 1.** Variable Description.

| Variables | Symbol | Mean | Std. Dev. | Min. | Max. | Unit |
|---|---|---|---|---|---|---|
| Coupling coordination degree | coor | 0.3983 | 0.1080 | 0.1016 | 0.9725 | - |
| Economic development index | es | 0.2831 | 0.1994 | 0.0774 | 0.9775 | - |
| Social development index | ss | 0.4362 | 0.1516 | 0.1141 | 0.8959 | - |
| Carbon emission intensity | cint | 0.2571 | 0.1387 | 0.0938 | 0.8562 | ton/10,000 yuan |
| Carbon emission | cem | 0.8280 | 0.2585 | 0.4341 | 2.1465 | ten thousand tons |
| Economic development | pgdp | 35413.33 | 16748.74 | 9518.96 | 102603.3 | yuan/person |
| Population | popu | 612.92 | 687.57 | 150.7 | 3124.32 | 10,000 people |
| Technology | rd | 0.0019 | 0.0014 | 0.0002 | 0.0087 | - |
| Industrial structure | struc | 0.9318 | 0.3367 | 0.4633 | 2.1278 | - |
| Energy consumption intensity | eint | 0.0770 | 0.0386 | 0.0273 | 0.2095 | tons of standard coal/10,000 yuan |
| Foreign direct investment | fdi | 0.0115 | 0.0168 | 0.0003 | 0.0966 | - |

### 4.3 Mechanism Verification

In order to further understand the mechanism of coordinated regional development affecting carbon emissions, this study develops the following panel data model:

$$M_{it} = \delta_0 + \gamma_1 coor_{it} + \gamma_2 coor_{it}^2 + \delta X_{it} + e_{it} \tag{4}$$

Here, $M_{it}$ denotes the mediator variable, other variables are consistent with the previous section. We use the proportion of tertiary industry and research input as mediating variables to test the mechanism. Table 3[1] shows that regional synergy has an inverse "U" shape effect on carbon emissions through industrial structure. When the coordination

[1] The regression results of control variables can be obtained from the author if necessary.

**Table 2.** Main regression results.

| Variable | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | OLS-cem | FE-cem | OLS-cint | FE-cint |
| lncoor | 1.5364*<br>(2.12) | -1.0604**<br>(-2.10) | 1.5223*<br>(1.79) | -0.5600<br>(-1.14) |
| $lncoor^2$ | 0.8719*<br>(1.96) | -0.5329*<br>(-1.95) | 0.8646<br>(1.65) | -0.2784<br>(-1.04) |
| $R^2$ | 0.9349 | 0.9279 | 0.6093 | 0.3644 |
| Hausman test | | 20.38*** | | 19.86** |

Note: T statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

**Table 3.** Mechanism verification.

| Variable | (1) | (2) |
|---|---|---|
| | FE-struc | FE-rd |
| lncoor | -1.2692***<br>(-3.77) | 1.3544<br>(0.92) |
| $lncoor^2$ | -0.6381***<br>(-3.47) | 0.9219<br>(1.16) |
| $R^2$ | 0.3501 | 0.1041 |
| Hausman test | 14.68** | 14.99** |

Note: T statistics in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

degree is high, the share of tertiary industry will be reduced and thus reduce carbon emissions. As scientific research does not have an inverted "U" shape relationship with coordination degree.

### 4.4 Robustness Test and Further Discussion

In this section, two low-carbon pilot cities, Chengdu and Chongqing, are excluded. The impact of synergistic development on carbon emissions remains evident. Further, economic development score and social development score are used as the core explanatory variables respectively. It has been verified that compared to economic development, social and livelihood synergy has a more obvious impact on low carbon development[2].

[2] The regression results can be obtained from the author if necessary.

## 5 Conclusions

The realization of low-carbon economy is an inevitable requirement for high-quality development in regional economy. This paper measured synergistic development degree of Chengdu-Chongqing Economic Circle and verified that synergistic development and carbon emission have an inverted "U" shape relationship. Furthermore, industrial structure upgrading is an important mediating variable. Achieving synergistic social development is crucial to green development in Chengdu-Chongqing economy.

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