A Study on the Impact of Carbon Emission Intensity on Ecological Sustainable Development of Provinces

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Abstract. This paper studies how rivals’ carbon emission intensity affects focal province’s growth of the tertiary industry. Using data from 2004 to 2017, the study reveals that rivals’ carbon emission intensity reduces focal province’s growth of the tertiary industry. This result is reliable for sensitivity tests. Furthermore, this “competitive” effect of the rivals’ carbon emission intensity turns out to be less prominent when focal province has higher level of financial development and innovation. Overall, these findings indicate that rivals’ carbon emission intensity matters for focal province’s growth of the tertiary industry.

Keywords: carbon emission intensity, competing effect, the growth of the tertiary industry, innovation

1. Introduction
This paper studies the economic effect of rivals’ carbon emission intensity on focal province’s growth of the tertiary industry. Carbon emission intensity, a phenomenon characterized by carbon emissions per GDP, has been the subject of a large number of theoretical and empirical studies (Lee, 2013; Wang and Zhang, 2020). We do not just add another evidence to the massive literature on carbon emission intensity; rather we study how focal province’s growth of the tertiary industry is affected by the competing effect, such as rivals’ carbon emission intensity. Although numerous studies investigate carbon emission intensity in China, its competing effect, such as rivals’ carbon emission intensity, on the growth of the tertiary industry has not been studied. So this study aims to fill this gap by studying the relationship between rivals’ carbon emission intensity and focal province’s growth of the tertiary industry.

Government behavior has an important effect on economic growth. With China's special economic growth, this feature is more obvious. Focal province’s policy is the main force to promote the economic development. And prior studies showed that political promotion incentive is the source of promoting focal province’s economic development (Timothy and Shleifer, 1997). To obtain vertical promotion and financial benefits, focal province needs to surpass other provinces in economy. Therefore, the focal province needs to observe the economic development strategies of their rivals and takes corresponding measures. Under this circumstance, the carbon emission policies of rivals can affect the decisions of focal province.

Using data in 2004-2017 period, we study whether rivals’ carbon emission intensity affects focal province’s growth of the tertiary industry. We find that rivals’ carbon emission intensity reduces focal
province’s growth of the tertiary industry. This negative impact of rivals’ carbon emission intensity on focal province’s growth of the tertiary industry is obvious. We also find that the relationship between rivals’ carbon emission intensity and focal province’s growth of the tertiary industry is less prominent when focal province has high innovation or high financial development.

Also, the negative relationship between rivals’ carbon emission intensity and focal province’s growth of the tertiary industry is likely to be affected by omitted variables or reverse causality. For instance, both rivals’ carbon emission intensity and focal province’s growth of the tertiary industry is likely to be affected by some unobservable variables. We use GMM, fixed model and random model to solve potential problems. We obviously find the negative effect of rivals’ carbon emission intensity on focal province’s growth of the tertiary industry after controlling for endogeneity concerns.

The paper is directly related to the literature on the consequences of carbon emissions. While much effort has been devoted to studying the consequences of carbon emissions (Luo et al., 2020; Wang et al., 2020), little is known about whether rivals’ carbon emission intensity has a real effect on focal province’s actions. The paper adds to the literature by offering new insights to the consequences of rivals’ carbon emission intensity, and it provides a new evidence with rivals’ carbon emission intensity and focal province’s growth of the tertiary industry. What’s more, the paper contributes to the literature on sustainable growth. Different from previous research in focal province’s actions, the paper adds competing effect to the literature by offering new insights to the sustainable growth.

2. Hypothesis development

The effect of rivals’ carbon emission intensity on focal province’s growth of the tertiary industry is heterogeneous. The paper mainly studies the relationship between rivals’ carbon emission intensity and focal province’s growth of the tertiary industry based on the competition among different provinces. The important basis for promoting officials is the relative position of economic growth in different regions, and the incentive of political promotion provides the institutional basis for focal province to fully promote its local economy growth (Kong et al., 2018). For higher political status, focal provinces not only need to regulate its economy well, but also surpass the rivals. Thus, to promote economic growth, focal provinces will not only pay more attention to the growth of their own provinces, but also adjust the industrial structure of their own provinces according to the carbon emissions policies of their competitors.

Carbon emission intensity is considered to play a significant role in almost all economic activities (Li and Cheng, 2020; Du et al., 2020). The expansion of economic growth will lead to a large number of carbon emissions. However, considerable economic growth can be achieved through this expanding economic growth model in short time, so it is enough to accumulate relatively strong capital for political promotion of local officials in short time. This expanding economic growth strategy is a favorable weapon for each province to gain competitive advantage in short time. Therefore, when the rivals adopt the growth model of pollution, focal province may give up the growth of the the tertiary industry under the pressure of economic competition. What’s more, the income of economic growth represented by GDP can be well measured, with easier assessment and larger weight. The cost of economic growth represented by ecological environment is more difficult to measure because of the existing accounting system for statistics, and the weight is very small. The asymmetric weight of economic growth income and cost in the performance evaluation index has induced local officials to choose to maximize GDP and ignore the negative impact of carbon emissions, which forms a substantial incentive bias. When rivals emit a lot of carbon dioxide to support its economic growth, it is difficult for the focal province to have the impetus to develop the tertiary industry for its economy. According to the above analysis, we use the prediction as our first hypothesis.

Hypothesis 1. All else being equal, rivals’ carbon emission intensity reduces focal province’s growth of the tertiary industry.
3. Research Design

3.1. Sample and Data
We construct our sample starting with all Chinese provinces in the 2004–2017 period from China Statistical Yearbook and China Emission Accounts and Datasets. The paper deals with the data as follows: (1) Exclude Hong Kong, Macao, Taiwan and Tibet. (2) Exclude missing data samples. According to the above standards, there are 420 data in total. At the same time, to avoid the influence of extreme value, the data is processed by 1% and 99% quantile winsorizing.

3.2. Definition of main variables.

3.2.1. Measuring the growth of the tertiary industry. We define $SER_{i,t}$ as the growth of the tertiary industry. We use Eq. (1) to calculate the growth of the tertiary industry.

$$SER_{i,t} = ATR_{i,t} / GDP_{i,t}$$ (1)

Where, the subscripts $i$ and $t$ represents respectively the province $i$ and the end of year. The dependent variable, $SER_{i,t}$ is the growth of the tertiary industry for province $i$ in year $t$. $ATR_{i,t}$ is the added value of the tertiary industry for province $i$ in year $t$, $GDP_{i,t}$ is the gross domestic product for province $i$ in year $t$.

3.2.2. Measuring carbon emissions. We use Eq. (2) to calculate the carbon emissions according the primary energy (coal, oil and natural gas) consumption in 30 provinces.

$$CE_{i,t} = \sum CE_{j,i,t}$$ (2)

Where, $CE_{i,t}$ is the total carbon emissions for province $i$ in year $t$. $CE_{j,i,t}$ is the carbon emissions of j-type energy for province $i$ in year $t$.

3.2.3. Measuring carbon emission intensity. Following Zhang et al. (2020), we define $CEI_{i,t}$ as the carbon emission intensity. We use Eq. (3) to calculate carbon emission intensity.

$$CEI_{i,t} = CE_{i,t} / GDP_{i,t}$$ (3)

Where, $CEI_{i,t}$ is the carbon emission intensity. $GDP_{i,t}$ is the gross domestic product for province $i$ in year $t$.

3.2.4. Measuring rivals’ carbon emission intensity. We define $CEI_{i,t}$ as rivals’ carbon emission intensity for province $i$ in year $t$. Rivals’ carbon emission intensity is computed as the average carbon emission intensity of all Chinese provinces, excluding province $i$.

3.3. Definition of the variables.
Table 1 reports summary definition for variables used in the empirical analysis.
Table 1. Definition of the variables

| Variable | Definition | Source |
|----------|------------|--------|
| SER_{i,t} | The growth of the tertiary industry, calculated as Eq. (1) | China Statistical Yearbook |
| CEI_{i,t} | rivals’ carbon emission intensity, calculated as above text | China Emission Accounts and Datasets |
| CEI_{i,t} | carbon emission intensity, calculated as Eq. (3) | China Emission Accounts and Datasets |
| TC_{i,t} | Innovation, calculated as patent applications per capita | China Statistical Yearbook |
| Finance_{i,t} | Financial development, calculated as total credit of financial institutions divided by GDP | China Statistical Yearbook |
| Road_{i,t} | Infrastructure, calculated as road construction area per capita | China Statistical Yearbook |
| Pop_{i,t} | Population density, calculated as population per unit area | China Statistical Yearbook |
| Urban_{i,t} | Urbanization, calculated as urban permanent population divided by total population | China Statistical Yearbook |
| Open_{i,t} | Openness, calculated as total imports and exports divided by GDP | China Statistical Yearbook |
| Pi_{i,t} | Primary industry growth, calculated as the added value of primary industry divided by GDP | China Statistical Yearbook |

3.4. Empirical model

This section tests our hypothesis by examining the relationship between rivals’ carbon emission intensity and focal province’s growth of the tertiary industry using Eq. (4). The baseline regression model is designated as:

\[ SER_{i,t} = a_0 + a_1 CEI_{i,t-1} + a_2 CEI_{i,t-1} + a_3 Pop_{i,t-1} + a_4 Urban_{i,t-1} + a_5 Open_{i,t-1} + a_6 Pi_{i,t-1} + \epsilon_i \]  

(4)

Where, the dependent variable is the focal province’s growth of the tertiary industry for province \( i \) in the year \( t \), measured by \( SER_{i,t} \). The variable of interest, \( CEI_{i,t-1} \), captures the level of rivals’ carbon emission intensity of province \( i \) in the year \( t-1 \). \( CEI_{i,t-1} \) is the carbon emission intensity of \( i \) province in the year \( t-1 \). \( Pop_{i,t-1} \) is the population density of \( i \) province in the year \( t-1 \). \( Urban_{i,t-1} \) is the urbanization of \( i \) province in the year \( t-1 \). \( Open_{i,t-1} \) is the openness of \( i \) province in the year \( t-1 \). \( Road_{i,t-1} \) is infrastructure of \( i \) province in the year \( t-1 \). \( Pi_{i,t-1} \) is the primary industry growth of \( i \) province in the year \( t-1 \). \( a_0 \) is the intercept of Eq. (4). \( \epsilon_i \) is the residual item of Eq. (4).

4. Empirical Analyses

Table 2 displays the descriptive statistics of the variables in our paper. The average of focal province’s growth of the tertiary industry (\( SER_{i,t} \)) is 0.463. The average of rivals’ carbon emission intensity (\( CEI_{i,t} \)) is 0.024. The average of focal province’s carbon emission intensity (\( CEI_{i,t} \)) is 0.024. The average of innovation (\( TC_{i,t} \)) is 10.23. The average of financial development (\( Finance_{i,t} \)) is 0.345. The average of population density (\( Pop_{i,t} \)) is 2.613. The average of urbanization (\( Urban_{i,t} \)) is 0.475. The average of openness (\( Open_{i,t} \)) is 0.008. The average of infrastructure (\( Road_{i,t} \)) is 13.20. The average of the primary industry growth (\( Pi_{i,t} \)) is 0.11.

Table 2. Descriptive statistics

| Variable | Obs | Mean | Max | Min | Median | Sd |
|----------|-----|------|-----|-----|--------|----|
| SER_{i,t} | 420 | 0.427 | 0.776 | 0.310 | 0.408 | 0.087 |
| CEI_{i,t} | 420 | 0.024 | 0.123 | 0.003 | 0.020 | 0.015 |
| CEI_{i,t} | 420 | 0.024 | 0.036 | 0.015 | 0.022 | 0.007 |
| TC_{i,t} | 420 | 10.23 | 66.66 | 0 | 4.206 | 14.82 |
| Finance_{i,t} | 420 | 0.345 | 1.634 | 0 | 0.259 | 0.316 |
| Pop_{i,t} | 420 | 2.613 | 5.938 | 0.241 | 2.415 | 1.316 |
| Urban_{i,t} | 420 | 0.475 | 0.893 | 0 | 0.492 | 0.210 |
| Open_{i,t} | 420 | 0.008 | 0.043 | 0 | 0.005 | 0.009 |
| Road_{i,t} | 420 | 13.20 | 25.34 | 4.110 | 12.71 | 4.388 |
| Pi_{i,t} | 420 | 0.110 | 0.281 | 0.005 | 0.107 | 0.05 |
Table 3 provides the regression results of Eq.(4). Columns (1) presents the regression result with rivals’ carbon emission intensity ($CEI_{i,t-1}$) and focal province’s growth of the tertiary industry ($SER_{i,t}$) without province’s characteristics. The coefficient between rivals’ carbon emission intensity ($CEI_{i,t-1}$) and focal province’s growth of the tertiary industry ($SER_{i,t}$) is -4.037, and it remains significant. Columns (2) presents the regression results with rivals’ carbon emission intensity ($CEI_{i,t-1}$) and the growth of the tertiary industry ($SER_{i,t}$) while controlling for province’s features, which are found in prior studies. The coefficient between rivals’ carbon emission intensity ($CEI_{i,t-1}$) and focal province’s growth of the tertiary industry ($SER_{i,t}$) is -4.383, and it remains significant. The results support Hypothesis 1 that the rivals’ carbon emission intensity reduces focal province’s growth of the tertiary industry. This evidence is consistent with Hypothesis 1 in the table 3.

### Table 3. The effect of rivals’ carbon emission intensity on the growth of the tertiary industry

| VARIABLES     | (1)       | (2)       |
|---------------|-----------|-----------|
|               | SER$_{i,t}$ | SER$_{i,t}$ |
| $CEI_{i,t-1}$ | -4.037*** | -4.383*** |
|               | (-6.18)    | (-5.05)   |
| $CEI_{i,t-1}$ | -0.490    |           |
|               | (-1.50)    |           |
| Population$_{i,t-1}$ | -0.011*** |           |
|               | (-4.08)    |           |
| Urban$_{i,t-1}$ | 0.126***  |           |
|               | (5.57)     |           |
| Open$_{i,t-1}$ | -0.674    |           |
|               | (-1.29)    |           |
| Road$_{i,t-1}$ | -0.007*** |           |
|               | (-7.33)    |           |
| $Pi_{i,t-1}$  | -0.396*** |           |
|               | (-5.89)    |           |
| Constant      | 0.527***   | 0.658***  |
|               | (32.17)    | (18.99)   |
| Observations  | 420        | 420       |
| R-squared     | 0.090      | 0.488     |
| F             | 38.15      | 52.08     |

**t-statistics in parentheses**
***p<0.01, **p<0.05, * p<0.1

5. Robustness test

Our analysis suggests that the rivals’ carbon emission intensity has a negative relationship on focal province’s growth of the tertiary industry. The relationship between rivals’ carbon emission intensity and focal province’s growth of the tertiary industry could also be affected by omitted variables or reverse causality. We use fixed-effect, random-effect and GMM model to test endogeneity. The results of fixed-effect model is reported in column (1) of table 5. This negative impact of rivals’ carbon emission intensity on focal province’s growth of the tertiary industry is economically significant. The results of random-effect model is reported in column (2) of table 5. This negative impact of rivals’ carbon emission intensity on focal province’s growth of the tertiary industry is economically significant. The results of GMM model is reported in column (3) of table 5. This negative impact of rivals’ carbon emission intensity on focal province’s growth of the tertiary industry is economically significant.

Overall, there is a negative relationship between rivals’ carbon emission intensity and focal province’s growth of the tertiary industry after controlling for endogeneity concerns.
Table 4. Robustness tests

| VARIABLES | (1)       | (2)       | (3)       |
|-----------|-----------|-----------|-----------|
| CEI\(_{t-1}\) | -5.333*** | -3.922*** | -5.341*** |
|           | (-7.71) (-6.27) (-4.43) |
| CEI\(_{t}\)  | 0.598*    | 0.334     | -0.583    |
|           | (1.84)    | (1.05)    | (-1.34)   |
| Population\(_{t-1}\) | -0.004* | -0.004* | -0.013*** |
|           | (-1.81)    | (-1.69)    | (-3.95)   |
| Urban\(_{t}\) | 0.078     | 0.193***  | 0.119***  |
|           | (1.32)    | (4.56)    | (5.60)    |
| Open\(_{t}\)  | -1.373*** | -1.401*** | -0.630    |
|           | (-4.11)    | (-4.02)    | (-0.86)   |
| Road\(_{t}\)  | 0.001     | -0.000    | -0.008*** |
|           | (1.28)    | (-0.27)    | (-7.86)   |
| P\(_{t}\)   | 0.857***  | 0.497***  | -0.393*** |
|           | (7.02)    | (4.45)    | (-3.63)   |
| Constant   | 0.418***  | 0.395***  | 0.695***  |
|           | (9.52)    | (10.19)   | (17.99)   |
| Observations | 420      | 420       | 420       |
| R-squared  | 0.571     | 0.553     | 0.505     |

**t-statistics in parentheses*** p<0.01, ** p<0.05, * p<0.1

6. Conclusions

The paper provides several pieces of evidence that rivals’ carbon emission intensity affects focal province’s growth of the tertiary industry. Using data from 2004 to 2017, the analysis reveals that larger rivals’ carbon emission intensity reduces focal province’s growth of the tertiary industry. Our results can stand robustness checks. In addition, we find that innovation and financial development affect the relationship between rivals’ carbon emission intensity and focal province’s growth of the tertiary industry.

Our study has implications for provinces and policy makers. For the former, rivals’ carbon emission intensity cannot be ignored in China. Our findings suggest that rivals’ carbon emission intensity matters for the focal province’s growth of the tertiary industry. For the latter, the governmental policies of advancing innovation and easing financial constraints have an important role on provinces’ economic restructure.

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