Decoupling between industrial environmental pollution and industrial economic growth in Guangxi Beibu Gulf Economic Zone

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Abstract. In order to gain a deeper understanding of the decoupling change trajectory of the industrial environment pollution and industrial economic growth in Guangxi Beibu Gulf Economic Zone, and to better solve the problem of sustainable economic development under the concept of low-carbon economy, based on the decoupling theory, six major indicators such as COD, ammonia nitrogen, SO2, NOx, PM and industrial added value were selected to conduct the empirical analysis of the decoupling relationship between industrial environmental pollution and industrial economic growth in Guangxi Beibu Gulf Economic Zone from 2009 to 2016. The results showed that they were basically in an unstable state of incomplete decoupling, most of which were manifested as strong decoupling, accompanied by other types of decoupling, and no obvious evolutionary law. In terms of time, the decoupling reached its best in 2013 and 2016. In terms of space, the decoupling in Nanning was the best.

1. Introduction

In general, economic growth needs to be supported by resources and environment. However, traditional extensive production methods have led to excessive use of resources and environmental damage. Accompanied by the lack of resources and environmental destruction worldwide, the development model of green economy has become a new trend of global economic development. Its goal is to achieve a balance of economic growth, resource conservation and environmental friendliness [1]. Therefore, research on the relationship between economic growth and resource utilization, environmental pollution has been a major research focus of green economy. In recent years, academics have done a lot of researches on low-carbon economy and green economy research [2-3], Simultaneously, using decoupling theory, they have carried out decoupling relations between economic growth and land use [4-6], environmental pollution [6-8], energy consumption [9-11], and have achieved a phased achievements. In the aspect of the connection between environmental pollution and economic growth, researches on economic growth and air pollution [12-13], economic growth and industrial wastewater discharge [14-16] have been mainly carried out. As a development zone in the backward areas of southwest China, the open development of Guangxi Beibu Gulf Economic Zone is inevitably accompanied by resource utilization and environmental pollution.
However, only a small amount of literature has carried out the coupling study of economic growth and resource environment in Guangxi Beibu Gulf Economic Zone [17-18], and no studies have involved the decoupling of economic growth from environmental pollution. Therefore, this article selected Guangxi Beibu Gulf Economic Zone with obvious location characteristics to analyze the decoupling change process of industrial economic growth from industrial environmental pollution, which may be conducive to enriching the academic accumulation in the field of decoupling research.

Guangxi Beibu Gulf Economic Zone was established in March 2006. In January 2008, China authorized to implement the "Development Plan of the Guangxi Beibu Gulf Economic Zone", and incorporated the open development of the Guangxi Beibu Gulf region into the national development strategy. With the continuous development, Guangxi Beibu Gulf Economic Zone is evolving towards urban dense areas in terms of regional spatial structure. Judging from the current development status, traditional extensive development method has not been fundamentally reversed, the resource and environmental costs of economic development are still high. Therefore, how to reduce resource utilization and environmental pollution while developing the economy, realize the decoupling of economic growth from resources and environment will be an important breakthrough point for the study area to transform the economic growth mode. In order to quantitatively identify the decoupling evolution law of industrial environmental pollution and industrial economic growth in the study area, and to better understand the impact of industrial environmental pollution on industrial economic growth, this article used decoupling theory to carry out related research. It may be expected to provide reference for reducing industrial environmental pollution and achieving coordinated development of regional economic growth and environmental protection.

2. Methodology
To discuss how to break the link between economic development and environmental degradation, decoupling was proposed by OECD (Organization for Economic Co-operation and Development) in 1992, then some theoretical studies on the decoupling index of economic activities were started [19]. The determination of decoupling state and its classification are the main content of decoupling study. Currently, there are mainly the following three judgment methods, including IPAT model method [20], decoupling factor theory put forward by OECD [21], Tapio decoupling index model [22]. Studies have shown that Tapio decoupling model can effectively improve the accuracy and objectivity of research results in terms of both total and relative values, it was widely used because of more flexibility and stability in the choice of research period [23]. Therefore, this article established a model for economic growth and environmental pollution on the basis of the Tapio model [22], such as formula (1):

$$ D_i = \frac{\% \Delta P}{\% \Delta E} = \frac{(P_{end} - P_{start})/P_{start}}{(E_{end} - E_{start})/E_{start}}, $$

where, $D_i$—the elastic decoupling index of industrial environmental pollution factor emissions and industrial economic growth in a certain period, $\Delta P$—the amount of changes in the emissions of industrial environmental pollution factors, $\Delta E$—the amount of changes of industrial economic added value, $\% \Delta P$ and $\% \Delta E$ represent respectively the elastic change rate of industrial environmental pollution factor emissions and industrial economic growth, $P_{start}$ and $P_{end}$ represent respectively the industrial environmental pollution factor emissions in the beginning year and ending years, $E_{start}$ and $E_{end}$ represent the industrial added value in the beginning and ending years, respectively.

Assuming different industrial environmental pollution elements have different weight, a calculation model for the comprehensive decoupling index of a certain area was constructed as shown in formula (2) [24]:

$$ D = \sum_{j=1}^{n} \omega_j D_{ij}, $$

where, $\omega_j$ is the weight of the j-th environmental pollution factor, $D_{ij}$ is the elastic decoupling index of the j-th environmental pollution factor and industrial economic growth in the i-th period, $n$ is the total number of industrial environmental pollution elements, $D$ is the comprehensive decoupling index.
of a region, with the same meaning as $D$, the corresponding decoupling relationship division standard is shown in Figure 1 [25-26].

![Figure 1. Criteria for decoupling relationship.](image)

3. Results and Analysis

3.1. The overall decoupling status in the study area

There are many factors that affect industrial environmental pollution. According to the statistics of industrial environmental pollution in Guangxi Environmental Protection Department, the main pollution factors were COD, ammonia nitrogen, SO$_2$, NO$_x$ and PM. Therefore, this article selected the above five elements as industrial environmental pollution indicators. Macroscopically, industrial added value can reflect industrial economic growth, so it can be used as an index of industrial economic growth. Data of each index at the end of 2008 in the study area was taken as the index data in early 2009, and so on. According to formula (1), the decoupling index of industrial environmental pollution factor emissions and industrial economic growth from 2009 to 2016 were calculated. The proportion of each environmental pollution element's emissions in total emissions separately was calculated, and the average proportion was taken as the weight for calculating the comprehensive decoupling index, so the weights of COD, ammonia nitrogen, SO$_2$, NO$_x$ and PM were 0.232, 0.006, 0.27, 0.206 and 0.286 respectively. Then, according to formula (2), the comprehensive decoupling indexes of industrial environmental pollution factor emissions and industrial economic growth were calculated. During the study period, the industrial economy was increasing, that is, $\Delta E > 0$. According to the division criteria in Figure 1, the decoupling index $D$ was bounded by 0, 0.8, and 1.2, and showed respectively SD, WD, EC and END, as shown in Table 1.
Table 1. Decoupling status of industrial economic growth from industrial environmental pollution in Guangxi Beibu Gulf Economic Zone from 2009 to 2016.

| Time(year) | 2009   | 2010   | 2011   | 2012   | 2013   | 2014   | 2015   | 2016   |
|---------|--------|--------|--------|--------|--------|--------|--------|--------|
| COD and industrial economy | D      | -0.749 | -0.640 | -1.578 | -0.530 | -1.444 | -0.794 | -2.198 | -7.105 |
| relationship | SD     | SD     | SD     | SD     | SD     | SD     | SD     | SD     | SD     |
| Ammonia nitrogen and industrial economy | D      | -1.440 | -0.545 | -0.301 | 0.253  | -1.239 | -0.555 | -0.957 | -5.984 |
| relationship | SD     | SD     | SD     | WD     | SD     | SD     | SD     | SD     |
| SO2 and industrial economy | D      | -0.003 | -0.334 | -1.730 | -0.923 | -0.288 | 0.281  | 0.112  | -4.626 |
| relationship | SD     | SD     | SD     | SD     | SD     | WD     | WD     | SD     |
| NOx and industrial economy | D      | -0.743 | 0.384  | 1.700  | 0.420  | -0.025 | -1.216 | -3.210 | -1.286 |
| relationship | SD     | WD     | END    | WD     | SD     | SD     | SD     |
| PM and industrial economy | D      | -0.540 | -0.743 | -1.872 | -0.502 | -0.762 | 4.551  | 6.073  | -5.060 |
| relationship | SD     | SD     | SD     | SD     | END    | END    | END    | SD     |
| Comprehensive value | D      | -0.491 | -0.375 | -1.020 | -0.428 | -0.643 | 0.939  | 0.590  | -4.645 |
| relationship | SD     | SD     | SD     | SD     | EC     | WD     | SD     |

Table 2 showed that:

(1) Overall, the industrial economic growth of Guangxi Beibu Gulf Economic Zone was decoupled from industrial environmental pollution, manifested as strong decoupling, along with expansion coupling in 2014, weak decoupling in 2015. It was mainly due to the accelerated growth of heavy industry in Fangchenggang from 2014 to 2015, the ferrous metal smelting and calendaring industry had been a pillar industry, PM emissions in this industry were more than 10 times higher than in 2013.

(2) The decoupling status between industrial economy and SO2, ammonia nitrogen emissions were all manifested as strong decoupling, and accompanied by weak decoupling in individual years.

(3) The decoupling states between industrial economy and NOx, PM were mainly manifested as strong decoupling, along with a small amount of weak decoupling or expansive negative decoupling.

(4) The decoupling state of industrial economy and COD was the best, all showing strong decoupling.

3.2. Spatiotemporal difference of decoupling state between industrial environmental pollution and industrial economic growth

According to the same method in Section 3.1, the comprehensive decoupling status of industrial environmental pollution and industrial economic growth in each city was obtained, and the spatial pattern of the decoupling status of industrial economy from industrial environmental pollution in each city during the study period are shown in Figure 2.

Figure 2 showed that:

(1) In terms of time series, the industrial environmental pollution and industrial economic growth in each city of Guangxi Beibu Gulf Economic Zone were all in a decoupling state in 2009-2011, 2013, and 2016, of which all were in a strong decoupling state in 2013 and 2016.

(2) Compare to the past year, the industrial added value of Qinzhou in 2012, Beihai and Chongzuo in 2015 decreased, so their industrial environmental pollution and industrial economy showed DD, SND and WND respectively.

(3) As PM emissions in Fangchenggang increased significantly in 2014-2015 compared with 2013, its environmental pollution and the industrial economy showed an expansion negative decoupling state. Moreover, NOx emissions in 2012 and 2014, PM emissions in 2014 increased significantly compared with the previous year in Yulin, so environmental pollution and industrial economy showed expansion negative decoupling and expansion coupling in 2012 and 2014 respectively. In the remaining years,
the industrial environmental pollution and industrial economy in each city were dominated by strong
decoupling, accompanied by a small amount of weak decoupling.

(4) In terms of space, the decoupling state of industrial environmental pollution and industrial
economy in Nanning was the best, with 6 years showing strong decoupling, and 2 years showing weak
decoupling.

(a) Decoupling status in 2009.

(b) Decoupling status in 2010.

(c) Decoupling status in 2011.

(d) Decoupling status in 2012.

(e) Decoupling status in 2013.

(f) Decoupling status in 2014.
4. Conclusions

By analyzing the decoupling indexes and decoupling status of industrial economic growth from industrial environmental pollution in the study area from 2009 to 2016, the following conclusions are drawn:

(1) On the whole, the industrial economic growth in the study area has been decoupled from industrial environmental pollution. It is mainly manifested as strong decoupling, supplemented by weak decoupling and expansion coupling.

(2) The relationship between industrial economic growth and industrial environmental pollution in each city of Guangxi Beibu Gulf Economic Zone was still unstable, and there was no obvious evolution rule.

(3) In terms of space, Nanning had the best decoupling. In terms of time, the best decoupling was in 2013 and 2016, and all cities were in a strong decoupling state.

In general, the relationship between industrial economic growth and industrial environmental pollution in the study area was still in an unstable and disorderly state. On the one hand, since the opening of Beibu Gulf Economic Zone, cities have accelerated the layout of major industrial projects, leading to increased emissions of industrial environmental pollution elements. On the other hand, by comparing and analyzing industrial value-added and environmental pollution factor emission industries in each city, it was found that the industries involved in the major industrial environmental pollution elements in each city were different, and the proportion of pollution emissions in various industries in each city also varied, and industries with serious pollution emissions did not necessarily have a greater contribution rate to industrial economic growth. Overall, the agricultural and sideline food processing industry had achieved good industrial added value in each city, and it was also an important pollutant emission industry. Among the six high-energy-consuming industries, chemical industry in Nanning, Fangchenggang, Qinzhou and Chongzuo; non-metallic mineral products industry in Nanning, Fangchenggang, Yulin and Chongzuo; the ferrous metal smelting and calendering industries in Beihai, Fangchenggang, Qinzhou, and Chongzuo; industry of colored metals smelting and pressing in Fangchenggang and Yulin; petroleum refinery industry in Beihai and Qinzhou; electricity, heat production and supply industries in Qinzhou and Chongzuo had achieved better industrial added value while also generating more pollution emissions. The relatively better trends were that the industrial value added of high-tech industries in Nanning and Beihai such as electrical machinery and equipment manufacturing, manufacture of computers and other electronic equipment, had been rising in recent years, and the pollution emissions generated by them were minimal. It can be seen that the industrial layout, industrial structure, and the application of high and new technologies...
have a great influence on the decoupling of industrial economic growth from industrial environmental pollution.

**Funding**

This research was funded by “The seventh batch of distinguished experts in Guangxi”, “Guangxi Natural Science Foundation, grant number 2020GXNSFAA159065”, “Opening Fund of Key Laboratory of Environment Change and Resources Use in Beibu Gulf, Ministry of Education (Nanning Normal University), Guangxi Key Laboratory of Earth Surface Processes and Intelligent Simulation (Nanning Normal University), grant number GTEU-KLOP-K1701”, and “Nanning Normal University Youth Research Fund”.

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