Decoupling Energy Consumption from Economic Growth in Beijing-Tianjin-Hebei Region from 2005 to 2019

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Abstract: As the capital economic circle in China, Beijing-Tianjin-Hebei region has experienced rapid economic development depending on a large amount of fossil fuel energy consumption in decades. Based on Tapio decoupling index, this paper logically analyzes the nexus between economic growth and energy consumption in Beijing-Tianjin-Hebei region from 2005 to 2019. An interesting result is obtained: except for the strong decoupling state in 2012-2013, the relationship between economy and energy consumption showed weak decoupling state for the rest of the research period. In addition, the decoupling elasticity coefficient of weak decoupling varies greatly in different years. The empirical results suggest that adjust economic development mode and transform energy consumption structure are the most necessary means for the future coordinated development of energy-economy-environment in Beijing-Tianjin-Hebei region.

Keywords: Beijing-Tianjin-Hebei region; economic growth; energy consumption; decoupling.

1. Introduction

Energy is the power of economic development and the material basis for human survival and development. Since the implementation of the reform and opening-up policy, China's economy has experienced rapid development. During the past 20 years from 2001 to 2020, China's GDP rose from 11.08631 trillion yuan in 2001 to 101.3567 trillion yuan in 2020, with an average annual growth rate of 8.3% [1]. However, China's obvious economic achievements are mainly supported by a large amount of fossil fuel energy consumption. During the same period, China's energy consumption increased from 1555.47 million tons of standard coal in 2001 to 4980 million tons of standard coal in 2020, with an average annual growth rate of 6.0 percent [2]. Although China is actively developing hydropower, nuclear power, solar energy, Marine energy and other clean energy according to local conditions [3], fossil fuel energy consumption still plays a major role in China's energy consumption with the proportion of 84.1% [4]. Massive consumption of fossil energy will inevitably lead to environmental pollution, affect energy security and harm China's future sustainable development. Therefore, China must change from an extensive economic development model that simply pursues economic development speed and GDP to a new normal economic development model.

Beijing-Tianjin-Hebei region is the "capital economic circle" in China, located in the heart of The Bohai Rim in Northeast China. In 2021, the GDP of Beijing-Tianjin-Hebei region reached 9.6 trillion yuan, accounting for 8.3% of China's total GDP. Among them, Beijing's GDP is 4,026.96 billion yuan, Hebei's 4,039.13 billion yuan, and Tianjin's 1,569.51 billion yuan, with an average annual increase of 6.3%, 6.3% and 5.0% respectively compared with 2013 [5]. Despite the rapid economic development in this region, energy consumption is also supported by fossil energy consumption. In 2019, energy consumption in The Beijing-Tianjin-Hebei region totaled 481.46 million tons of standard coal, accounting for 9.9% of national total energy consumption [6]. Li Guoping, dean of Peking University Capital Development Institute, mentioned that the Beijing-Tianjin-Hebei region has accounted for 11%-12% of China's total carbon emissions in recent years [7], both higher than the proportion of population and GDP in the country at the 2021 Beijing-Tianjin-Hebei Collaborative Development Forum under the Carbon Neutral Vision (The Beijing-Tianjin-Hebei region has 7.81% of population and 8.5% of GDP) [8-9]. A large amount of energy consumption has caused enormous environmental pressure to Beijing-Tianjin-Hebei region and posed a great challenge to the sustainable development and low-carbon green development. It is of great significance to study relationship between economic growth and energy consumption in Beijing-Tianjin-Hebei region. The purpose of the research is to provide targeted guidance and suggestions in order to change the economic development mode, improve the energy consumption structure, reduce carbon emissions, build world-class urban agglomeration, and promote the high-quality development of China's economy in the future.
Up to now, many scholars have used a variety of methods to study the relationship between China's regional energy consumption and economic growth. The methods commonly involve regression equation, correlation analysis, grey correlation analysis, causality, cointegration test, VAR model, decoupling model, etc. When it comes to regression equation, Zhao Jianhui used principal component analysis to extract the main factors affecting China's energy consumption, and then conducted regression analysis, and found that economic development, industrial structure and energy prices are the main factors affecting China's energy consumption [10]. Han Jun and Zhang Huinan used spatial autocorrelation analysis to analyze the spatial correlation between regions, and then used geographically weighted regression model to analyze the spatial difference between regions. They found that under the rapid economic development, the per capita energy consumption level and total energy consumption of different regions were significantly different [11].

As for correlation analysis, Zhu Jian and Li Weihua used correlation analysis to study the relationship between economic growth and total energy consumption, energy consumption elasticity coefficient and energy consumption per unit GDP of Jiangsu province and Xinjiang Province respectively, and found that the economic development of Jiangsu province and Xinjiang Province has a strong dependence on energy consumption. According to the coordinated development of energy and economy, different cities in the province are divided into 4 grades [12-13].

As for grey correlation analysis, Shao Minlan analyzed the correlation between economic growth and energy consumption from two aspects of economic growth and energy consumption variety structure, economic growth and energy consumption industrial structure by constructing grey correlation model, and found that the grey correlation between energy consumption and economic growth is different in different industries [14]. Du Junhui et al. used grey correlation analysis to study the relationship between energy consumption and economic growth in Hebei Province, and found that there was a significant grey correlation between economic growth and energy consumption in Hebei Province [15].

In the aspect of causality and co-integration test, Jian Xin, Zhang Lihua and Xu Weilan et al. used co-integration test and Granger causality to study the relationship between energy consumption and economic growth in Zhejiang province, Shandong Province and Jiangsu Province respectively, and concluded that energy consumption and economic growth are mutually two-way causality [16-18]. Guo Ke and Wang Liqun used co-integration analysis and state space model to study the relationship between energy consumption and economic growth in the Beijing-Tianjin-Hebei region. In addition to the mutual causal relationship between the two, they also found that the economic development in this region has a direct demand for higher energy consumption [19].

In the aspect of VAR model, Zhang Zirong used VAR model to study the relationship between Energy consumption and GDP in China and found that energy consumption has always been positively correlated to economic development [20]. Fan Yaxuan used VAR model to study the energy consumption in Hebei Province and found that the current energy consumption in Hebei province far exceeds the national average level, with coal as the main energy consumption and clean energy consumption accounting for a small proportion [21].

In terms of decoupling model, Liu Huimin used Tapio decoupling model to study the decoupling relationship between China's economic growth and energy consumption, and found that there was a repeated process of decoupling [22]. Ling Liwen et al. used Tapio decoupling model to analyze the decoupling state between industrial waste and economic growth in Guangdong Province and found that there were significant temporal and spatial differences in the decoupling state [23]. Hu Huimin et al. used Tapio decoupling model to study the decoupling between economic development of transportation industry and carbon emission of transportation energy in the Yangtze River Economic Belt, and found that the decoupling of carbon emission of transportation in the Yangtze River Economic Belt is mainly "weak decoupling" [24]. Sun Han et al. used Tapio decoupling model and LEAP system to forecast and analyze the decoupling between output value of various sectors and energy consumption in China under baseline and prospect scenarios. The research shows that the decoupling state of output value of China's three major industries from 2020 to 2030 is different from that of energy consumption [25].

Given the extent of literature, there are few studies on the decoupling relationship between energy consumption and economic growth in Beijing-Tianjin-Hebei region. Therefore, the main contribution of this paper is that the Tapio decoupling theory is adopted to study the relationship between economic growth and energy consumption in Beijing-Tianjin-Hebei region from 2005 to 2019. Moreover, the research work can provide the targeted solution of improving regional low-carbon development in economy and energy consumption.

2. Decoupling theory

Decoupling has become a new research hotspot in recent years as a measure of the coupling relationship between human economic activities and energy consumption or environmental pollution. Decoupling theory is the basic theory proposed by the Organization for Economic Cooperation and Development (OECD) to "destroy the link between economic growth and resource consumption or environmental degradation" [26]. The economic growth of a country or region usually leads to resource consumption and environmental pollution. However, after taking some measures, with the same amount of economic growth, the resource consumption and environmental pollution are reduced, which is called decoupling [27].

At present, decoupling models are mainly divided into two types, one is the OECD decoupling index model based on initial value and final value, and the other is the Tapio decoupling model based on elastic change of growth [28]. Tapio decoupling model combines relative quantity change and total quantity change to study the
asynchronous change of growth elasticity of economic development and resources and environment in the same period. The decoupling state is subdivided into eight types: weak decoupling, expansion negative decoupling, strong negative decoupling, weak negative decoupling, recession decoupling, strong decoupling, expansion connection and recession connection. Tapio decoupling model established a relatively perfect decoupling index evaluation system, which effectively corrects the possible errors caused by the OECD decoupling index model due to the extreme selection of only the initial value and the final value [22]. Therefore, more scholars prefer to use Tapio decoupling model to study the relationship between economic development and energy consumption.

In this paper, the Tapio decoupling model is used to construct the decoupling analysis model of economic growth and energy consumption in the Beijing-Tianjin-Hebei region. The elastic decoupling analysis is expressed as follows:

\[
\varepsilon_{E,GDP} = \frac{\Delta E / E_{t+1}}{\Delta GDP / GDP_{t+1}} = \frac{E_t - E_{t+1}}{GDP_t - GDP_{t+1}} / \frac{E_{t+1}}{GDP_{t+1}} \tag{1}
\]

Where \(\varepsilon_{E,GDP}\) denotes the decoupling elasticity coefficient, \(E\) is the total energy consumption, \(GDP\) is the gross product, \(E_t\) is the total energy consumption in year \(t\), \(GDP_t\) is the gross product in year \(t\), \(E_{t+1}\) is the total energy consumption in year \(t+1\), \(GDP_{t+1}\) is the gross product in year \(t+1\), \(\Delta E = E_t - E_{t+1}\), \(\Delta GDP = GDP_t - GDP_{t+1}\), \(\Delta E / E_{t+1}\) is the rate of change of \(E\), and \(\Delta GDP / GDP_{t+1}\) is the rate of change of \(GDP\). Based on the difference of decoupling elastic coefficients, the decoupling elastic coefficients are divided into three states: decoupling, negative decoupling and connection, and these three states can be divided into eight different states [22]. Specific indicators are shown in Table 1.

### Table 1. Tapio decoupling elasticity comparison table

<table>
<thead>
<tr>
<th>Decoupling</th>
<th>(\Delta E)</th>
<th>(\Delta GDP)</th>
<th>Elastic (\varepsilon)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decoupling</td>
<td>Weak Decoupling</td>
<td>&gt;0</td>
<td>&gt;0</td>
</tr>
<tr>
<td></td>
<td>Strong Decoupling</td>
<td>&lt;0</td>
<td>&gt;0</td>
</tr>
<tr>
<td></td>
<td>Recessive Decoupling</td>
<td>&lt;0</td>
<td>&lt;0</td>
</tr>
<tr>
<td>Negative Decoupling</td>
<td>Weak Negative Decoupling</td>
<td>&lt;0</td>
<td>&lt;0</td>
</tr>
<tr>
<td></td>
<td>Strong Negative Decoupling</td>
<td>&gt;0</td>
<td>&lt;0</td>
</tr>
<tr>
<td></td>
<td>Expansion Negative Decoupling</td>
<td>&gt;0</td>
<td>&gt;0</td>
</tr>
<tr>
<td>Connection</td>
<td>Expansion Connection</td>
<td>&gt;0</td>
<td>&gt;0</td>
</tr>
<tr>
<td></td>
<td>Recessive Connection</td>
<td>&lt;0</td>
<td>&lt;0</td>
</tr>
</tbody>
</table>

From Table 1, the relationship between economy and energy consumption in Beijing-Tianjin-Hebei shows weak decoupling, strong decoupling, and recession decoupling. Strong decoupling indicates that energy consumption remains unchanged or decreases with the economic growth; weak decoupling means that economic growth is not constrained by energy consumption, but the growth rate of energy consumption is slower than that of economic growth; recession decoupling means that energy consumption decreases faster than that of economic recession. Negative decoupling includes weak negative decoupling, strong negative decoupling and expansion negative decoupling. Among them, strong negative decoupling means that economic recession and energy consumption increases, weak negative decoupling means that energy consumption decreases slower than economic recession, and expansion negative decoupling means that economic growth and energy consumption increases substantially. Connection states include expansion connection and recession connection. The expansion connection means that economic growth and energy consumption increase simultaneously, and the recession connection means that economic growth and energy consumption decrease simultaneously. It can be seen that in different states, strong decoupling is the most ideal decoupling state between economic growth and energy consumption, while strong negative decoupling is the least ideal decoupling state between economic growth and energy consumption.

### 3. Data

In this paper, GDP data of Beijing-Tianjin-Hebei region from 2005 to 2019 are collected from China National Bureau of Statistics (2005-2019) [29], and the energy consumption data are extracted from China Energy Statistical Yearbook (2006-2020) [30]. The original data are shown in Table 2.

### Table 2. Original data of economic growth and energy consumption in Beijing-Tianjin-Hebei region (2005-2019)

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Energy Consumption (10^4 tons of standard coal)</th>
<th>Total GDP (100 million RMB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>29443</td>
<td>19081.8</td>
</tr>
<tr>
<td>2006</td>
<td>32198</td>
<td>21968.2</td>
</tr>
<tr>
<td>2007</td>
<td>34813</td>
<td>26736.8</td>
</tr>
<tr>
<td>2008</td>
<td>36013</td>
<td>31195.6</td>
</tr>
<tr>
<td>2009</td>
<td>37963</td>
<td>33917.4</td>
</tr>
<tr>
<td>2010</td>
<td>41303</td>
<td>39798.4</td>
</tr>
<tr>
<td>2011</td>
<td>44091</td>
<td>46686</td>
</tr>
<tr>
<td>2012</td>
<td>45366</td>
<td>51145.2</td>
</tr>
<tr>
<td>2013</td>
<td>44270</td>
<td>55339.6</td>
</tr>
<tr>
<td>2014</td>
<td>44206</td>
<td>58775.5</td>
</tr>
<tr>
<td>2015</td>
<td>46159</td>
<td>62057</td>
</tr>
<tr>
<td>2016</td>
<td>46453</td>
<td>66992.5</td>
</tr>
<tr>
<td>2017</td>
<td>47003</td>
<td>72974.5</td>
</tr>
<tr>
<td>2018</td>
<td>47428</td>
<td>78963.5</td>
</tr>
<tr>
<td>2019</td>
<td>48146</td>
<td>84479.2</td>
</tr>
</tbody>
</table>

### 4. Decoupling results and analysis

Taking 2005 as the base year, the decoupling index between economic growth and energy consumption in Beijing-Tianjin-Hebei region can be calculated according to Equation (1), which are shown in Table 3.
4.1 Analysis of variation of decoupling index

As can be seen from Table 3, the relationship between economy and energy consumption in Beijing-Tianjin-Hebei showed weak decoupling state for the research period except for the strong decoupling state in 2012-2013. In addition, the decoupling elasticity coefficients in 2013-2014 and 2015-2016 were less than 0.1, which was very close to strong decoupling. The decoupling elasticity coefficients from 2005 to 2012 and 2013 to 2019 were all in the interval (0, 0.8), and both $\Delta E$ and $\Delta GDP$ were positive. Therefore, economic growth and energy consumption in The Beijing-Tianjin-Hebei region showed weak decoupling in these two periods. The decoupling elasticity coefficient from 2012 to 2013 was within the interval ($-\infty$, 0), with negative $\Delta E$ and positive $\Delta GDP$. Therefore, economic growth and energy consumption in the Beijing-Tianjin-Hebei region showed a strong decoupling state during this period. In Table 3, the change trend of energy consumption change rate, GDP change rate and decoupling elastic are shown in Figure 1.

As shown in Figure 1, the decoupling elasticity coefficients from 2005 to 2008 showed a decreasing trend year by year, which were 0.623, 0.373 and 0.204, respectively. The decoupling elasticity coefficients increased from 2008 to 2009, but showed a decreasing trend in the four years after the increase, which were 0.586, 0.526, 0.393 and 0.365, respectively. The decoupling value during 2012-2013 was −0.366 showing strong decoupling state, during which the energy consumption decreased by 3%, while GDP increased by 8.2% compared with the previous year. Energy consumption in 2013-2014 increased only 260,000 tons of standard coal compared to the previous year with the growth rate of 0.1%, so it is very close to strong decoupling. From 2014 to 2015, the decoupling elasticity coefficient increased sharply and reached 0.75, the highest value in the research period. The decoupling state improved from 2015 to 2019. Although there was no strong decoupling, the elasticity coefficients of decoupling remained at a low level, which were 0.075, 0.135, 0.11 and 0.214, respectively.

4.2 Analysis of the reasons for the great variation of decoupling elasticity coefficient in several special periods

Although the decoupling state of economic growth and energy consumption in Beijing-Tianjin-Hebei region was relatively stable from 2005 to 2019 except for strong decoupling in 2012-2013, the decoupling elasticity coefficient varied greatly in different periods. In particular, the three periods of 2008-2009, 2012-2013 and 2014-2015 showed the most dramatic changes. The following reasons for the great variation of decoupling elasticity coefficients in these three periods are described in detail.

4.2.1 Analysis of reasons for the increase of decoupling elasticity coefficient in 2008-2009

In 2008, after the outbreak of the global financial crisis, to cope with the crisis, Chinese government launched "four trillion plan", to invest four trillion yuan to expand domestic demand and stimulate economic growth by the end of 2010. Beijing-Tianjin-Hebei region has already stopped production of energy-intensive, highly polluting enterprises and back into the production, leading to the consumption of energy increase demand. This is also the main reason why the elasticity coefficient of decoupling between energy consumption and economic growth in the Beijing-Tianjin-Hebei region rebounded in 2008-2009. With the resolution of the financial crisis, the decoupling elasticity coefficient from 2010 to 2012 decreased to a relatively low level of 0.393 and 0.365 respectively, and the GDP growth rate in both years reached 17.3%.

4.2.2 Analysis of the causes of strong decoupling in 2012-2013

In 2013, the energy consumption in Beijing, Tianjin and Hebei was 67.24, 78.82 and 296.64 million tons of standard coal, decreasing 4.54, 3.26 and 5.86 million tons of standard coal, respectively, compared with 2012 [30].

### Table 3. Decoupling analysis results of economic growth and energy consumption in Beijing-Tianjin-Hebei region (2005-2019)

<table>
<thead>
<tr>
<th>Year</th>
<th>$\Delta E/E_{t-1}$</th>
<th>$\Delta GDP/GDP_{t-1}$</th>
<th>Decoupling Elastic</th>
<th>Decoupling State</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005-2006</td>
<td>0.094</td>
<td>0.151</td>
<td>0.623</td>
<td>Weak Decoupling</td>
</tr>
<tr>
<td>2006-2007</td>
<td>0.081</td>
<td>0.217</td>
<td>0.373</td>
<td>Weak Decoupling</td>
</tr>
<tr>
<td>2007-2008</td>
<td>0.034</td>
<td>0.167</td>
<td>0.204</td>
<td>Decoupling</td>
</tr>
<tr>
<td>2008-2009</td>
<td>0.051</td>
<td>0.087</td>
<td>0.586</td>
<td>Weak Decoupling</td>
</tr>
<tr>
<td>2009-2010</td>
<td>0.091</td>
<td>0.173</td>
<td>0.526</td>
<td>Decoupling</td>
</tr>
<tr>
<td>2010-2011</td>
<td>0.068</td>
<td>0.173</td>
<td>0.393</td>
<td>Weak Decoupling</td>
</tr>
<tr>
<td>2011-2012</td>
<td>0.035</td>
<td>0.096</td>
<td>0.365</td>
<td>Decoupling</td>
</tr>
<tr>
<td>2012-2013</td>
<td>−0.03</td>
<td>0.082</td>
<td>−0.366</td>
<td>Strong Decoupling</td>
</tr>
<tr>
<td>2013-2014</td>
<td>0.001</td>
<td>0.062</td>
<td>0.016</td>
<td>Decoupling</td>
</tr>
<tr>
<td>2014-2015</td>
<td>0.042</td>
<td>0.056</td>
<td>0.075</td>
<td>Weak Decoupling</td>
</tr>
<tr>
<td>2015-2016</td>
<td>0.006</td>
<td>0.08</td>
<td>0.075</td>
<td>Decoupling</td>
</tr>
<tr>
<td>2016-2017</td>
<td>0.012</td>
<td>0.089</td>
<td>0.135</td>
<td>weak Decoupling</td>
</tr>
<tr>
<td>2017-2018</td>
<td>0.009</td>
<td>0.082</td>
<td>0.11</td>
<td>Decoupling</td>
</tr>
<tr>
<td>2018-2019</td>
<td>0.015</td>
<td>0.07</td>
<td>0.214</td>
<td>Weak Decoupling</td>
</tr>
</tbody>
</table>

**Figure 1.** Change rates of energy consumption and GDP and decoupling elasticity coefficient in Beijing-Tianjin-Hebei Region (2005-2019)
The main reason is that serious environmental pollution forced the government to take measures to interfere with the production of high energy consumption and high pollution enterprises. In 2013, smog pollution in the Beijing-Tianjin-Hebei region reached an unprecedented level, with the average annual PM2.5 and PM10 concentrations exceeding the standard in all cities at prefectural level and above, with the average annual PM2.5 concentration at 106 micrograms per cubic meter and the average PM10 concentration at 181 micrograms per cubic meter. The proportion of days with air quality meeting the standard was 37.5% on average, far lower than 64.2% in the Yangtze River Delta and 76.3% in the Pearl River Delta [31]. In order to reduce the concentration of smog, the governments of Beijing, Tianjin and Hebei, under the leadership of the central government, have carried out coordinated efforts to control smog, increased the promotion of clean and renewable energy, such as liquefied petroleum gas and solar energy, and controlled the total coal consumption. Beijing is required to cut 13 million tons of raw coal, Tianjin 10 million tons, and Hebei province 40 million tons by the end of 2017 [32], which also keeps the growth rate of energy consumption in the Beijing-Tianjin-Hebei region at a relatively low level after 2012.

4.2.3 Analysis of the reasons for the sharp increase of decoupling elasticity coefficient during 2014-2015

The decoupling elasticity coefficient from 2014 to 2015 was 0.75, which was close to the expansion connection state. This was not because of the significant increase in energy consumption, but because of the GDP growth rate during this period declined and reached the lowest value from 2005 to 2019. As a result, energy consumption growth rate is close to GDP growth rate. In August 2015, a major explosion occurred in Ruihai Company's dangerous goods warehouse in Tianjin Binhai New Area, which was the main reason for the slowdown of GDP growth. Tianjin Binhai New Area is the international shipping center and international logistics center in northern China, as well as the largest port in northern China, which occupies an important position in foreign trade. In 2015, the total GDP of Tianjin was 1,08795 trillion yuan, with a growth rate of only 2.2% compared with 2014, which was the lowest GDP growth rate of Tianjin during the study period from 2005 to 2019 [29]. In 2014, the total import and export of goods in Tianjin was 160846.57 million US dollars. In 2015, the total import and export volume of Tianjin goods was 11,4282.8 million US dollars, down 28.9% compared with 2014 [33]. Therefore, the explosion accident caused huge economic losses to Tianjin, and then had a certain impact on the overall development of the Beijing-Tianjin-Hebei region.

4.3 Analysis on the causes of weak decoupling in Beijing-Tianjin-Hebei region for many years

4.3.1 Economic growth plays a more significant role in decoupling

As can be seen from Table 3, although the total energy consumption in the Beijing-Tianjin-Hebei region showed an upward trend from 2005 to 2019, the growth rate of total energy consumption was much lower than that of GDP. It can be calculated from Table 3 that the average annual growth rate of energy consumption in Beijing-Tianjin-Hebei region was 3.6% from 2005 to 2019, while the average annual growth rate of GDP in Beijing-Tianjin-Hebei region was 11.3% during the same period. This difference is more obvious during the period of 2012-2019. The average annual growth rate of energy consumption and GDP is 0.8% and 7.4% respectively. Therefore, the economic growth plays a more significant contribution in driving decoupling on the whole, which is one of the reasons why economic growth and energy consumption in the Beijing-Tianjin-Hebei region have remained weak decoupling for many years.

4.3.2 Industrial restructuring in the Beijing-Tianjin-Hebei region

In China’s “11th Five-Year Plan”, development concepts, such as promoting the optimization and upgrading of industrial structure and building a resource-saving and environment-friendly society, were proposed to promote the adjustment of industrial structure. Meanwhile, the National Development and Reform Commission formulated the “Regional Planning of Beijing-Tianjin-Hebei Metropolitan Area”, which is also one of the important plans of the 11th Five-Year Plan. According to the plan, Beijing-Tianjin-Hebei region will develop “8+2” model, i.e. the two municipalities directly under the Central government of Beijing and Tianjin and the eight prefecture-level cities of Shijiazhuang, Baoding, Qinhuangdao, Langfang, Tangshan, Zhangjiakou, Chengde and Cangzhou in Hebei province. Under this model, Beijing, Tianjin and Hebei have a clear industrial development orientation. Beijing focuses on the development of the tertiary industry with service industry and high-tech industry, gives full play to its talent advantages, and gradually transfers low-end manufacturing and heavy pollution enterprises to other cities. On the basis of traditional processing and manufacturing, Tianjin vigorously develops advanced manufacturing industries such as new energy vehicles and modern medicine, vigorously supports the development and construction of Binhai New Area, and builds Tianjin Port into a modern international port. Hebei serves as a supporting base for the high-tech industries of Beijing and Tianjin, and at the same time takes advantage of its geographical advantages to develop agriculture to ensure the grain supply of Beijing and Tianjin. This collaborative development mode has made the tertiary industry in Beijing and Tianjin develop rapidly in recent years. In
In the first few years of the agreement, when the total of energy consumption is bound to slow. This was evident in the Tianjin-Hebei region, as one of China's major industrial areas, must control carbon emissions, so the growth rate of energy consumption is bound to slow. This was evident in the first few years of the agreement, when the total energy consumption in the Beijing-Tianjin-Hebei region increased by 9.4%, 8.1% and 3.4% from 2006 to 2008, showing a downward trend for three consecutive years.

4.3.3 Binding by international treaties

With the global warming, more and more people realized the harm caused by industrial activities to the earth's natural environment. The global carbon emission control mechanism represented by the Kyoto Protocol officially came into effect on February 16, 2005, which is the first time in human history to limit global greenhouse gas emissions in the form of regulations. In 2005, China was the largest emitter of carbon dioxide in the world. If China does not undertake the responsibility of reducing greenhouse gas emissions for a long time, it will come under increasing pressure in the United Nations Framework Convention on Climate Change, which will affect its international reputation and status. Beijing-Tianjin-Hebei region, as one of China's major industrial areas, must control carbon emissions, so the growth rate of energy consumption is bound to slow. This was evident in the first few years of the agreement, when the total energy consumption in the Beijing-Tianjin-Hebei region increased by 9.4%, 8.1% and 3.4% from 2006 to 2008, showing a downward trend for three consecutive years.

5. Policy Suggestions and Conclusions

5.1 Policy Suggestions

Based on the decoupling analysis of economic growth and energy consumption in Beijing-Tianjin-Hebei region from 2005 to 2019, this paper provides the following targeted suggestions for the region's future development:

5.1.1 Create a green and low-carbon energy consumption model

The governments of Beijing, Tianjin and Hebei should strengthen the publicity of energy conservation and emission reduction, and promote green and low-carbon consumption to citizens. In the aspect of transportation, improve the urban transportation system, increase the number of bus and subway stops in non-central urban areas of Beijing and Tianjin, plan more routes, and lower the charging standard for different numbers of passengers.

As for the management of private cars, in addition to limiting the number of vehicles, cross-departmental cooperation should be strengthened to strictly control the emissions of motor vehicles from the production and circulation links. Improve factory standards, strengthen the supervision of environmental protection departments, and eliminate motor vehicles with high energy consumption and high emissions. At the same time, encourage people to buy new energy vehicles, reduce taxes on new energy vehicles, and give policy support to enterprises producing new energy vehicles.

5.1.2 Adjust the energy consumption structure

First, accelerate the development and utilization of renewable energy, reduce the consumption of fossil energy, especially coal, close down outdated production facilities, and increase the share of renewable energy in energy consumption. Beijing, Tianjin and Hebei should develop different kinds of renewable energy according to their geographical advantages. For example, Zhangjiakou city in Hebei province is located in the windward zone between the North China Plain and the Inner Mongolia Plateau. The government should develop wind energy and improve the construction of wind energy infrastructure in Zhangjiakou city. Second, the government should promote the clean revolution of traditional energy, actively promote clean coal technology, and realize the clean development, production and use of coal. Speed up the production sector to replace coal, oil and other traditional fossil fuels with clean energy such as liquefied petroleum gas and coal-to-natural gas. The quality of coal should also be strictly controlled, and the sale of coal with high ash and inorganic sulfur content should be prohibited to prevent the production of large quantities of gases harmful to human health.

5.1.3 Make use of Beijing and Tianjin's scientific and technological advantages to promote the energy technology revolution

Beijing and Tianjin should fully rely on the advantages of universities and research institutes to promote the transformation of traditional energy use technology. The government should increase investment in scientific research institutions, coordinate the application and promotion of energy technologies, demonstration and experiment, and focus on tackling key problems. Optimize the coal processing process, improve the overall performance of coal combustion equipment, and reduce the coal consumption by reducing the proportion of direct combustion of raw coal. Actively promote the research and development of CCUS technology, reduce the carbon emitted by fossil energy combustion, and achieve large-scale low-carbon utilization of fossil energy, in line with the 2030 carbon peak target proposed by the State Council. Improve the matching mechanism between innovation chain and industrial chain to fully utilize the innovation achievements actual industries. At the same time, Beijing, Tianjin and Hebei should also pay attention to exchanges with other countries on clean energy technologies,
actively participate in various forums, and establish multilateral cooperation mechanisms to achieve mutual benefit and win-win results.

5.1.4 Change the economic development model of the Beijing-Tianjin-Hebei region

The Beijing-Tianjin-Hebei region should continue to promote the adjustment of industrial structure. The government should evacuate Beijing’s non-capital functions, orderly transformation of high-energy-consuming industries, increase the proportion of tertiary industry, maintain a reasonable scale of secondary industry, and deeply integrate advanced manufacturing with modern service industry. Beijing, Tianjin and Hebei will jointly explore the coordinated layout of the industrial chain in the region and build industrial clusters. Adhere to the development of Beijing and Tianjin’s emerging industries and Hebei’s traditional energy industry transformation and upgrading. The government should promote the construction of supporting bases for Beijing and Tianjin advanced manufacturing industry in Hebei, strengthen the incubation of scientific and technological achievements and the sustainable development of advanced manufacturing industry, give full play to the radiating and driving role of Beijing and Tianjin excellent scientific and technological achievements, and build an intelligent city group.

5.2 Conclusions

Based on the Tapio decoupling theory, this paper analyzed the decoupling state of economic growth and energy consumption in Beijing-Tianjin-Hebei region from 2005 to 2019, and the following conclusions can be drawn:

1. According to the results of the decoupling elasticity coefficient, it can be clearly found that the decoupling state of economic growth and energy consumption in Beijing-Tianjin-Hebei region from 2005 to 2019 showed overall weak decoupling. The reason for the sustained weak decoupling for many years mainly rely on the strong driving effect of rapid economic growth on decoupling. Through research, it is found that the high-speed economic development of the Beijing-Tianjin-Hebei region mainly benefits from the significant proportion of the tertiary industry in Beijing and Tianjin. In addition, international constraints such as the Kyoto Protocol have also contributed to the weak decoupling of the Beijing-Tianjin-Hebei region over the years.

2. According to the elasticity coefficient of decoupling during the weak decoupling period, it can be clearly found that although the state of weak decoupling has lasted for many years, the elasticity coefficient of weak decoupling varies greatly in different periods. The main reason for the change is the impact of unstable factors such as the international financial crisis and major events in the Beijing-Tianjin-Hebei region.

3. According to the results of the decoupling elasticity coefficient, it can be clearly found that there is a strong decoupling between economic growth and energy consumption in Beijing-Tianjin-Hebei region from 2012 to 2013. The main reason is that severe air pollution in Beijing-Tianjin-Hebei region has prompted the government to introduce policies to cut energy consumption. Based on the above conclusions, the following suggestions are put forward, such as: create a green and low-carbon consumption model, adjust the energy consumption structure, give full play to the scientific and technological advantages of Beijing and Tianjin to improve energy technology, and change the economic development model. Finally, although this paper has made contributions to the study on the decoupling relationship between economic growth and energy consumption in Beijing-Tianjin-Hebei region, there are still some limitations in this study. For example, this paper does not examine the decoupling between economic growth and energy consumption in Beijing, Tianjin and Hebei, respectively. In addition, different energy consumption structures may have different impacts on the decoupling state. In this regard, more complex and subtle methods can be used to study the decoupling relationship between economic growth and energy consumption in the Beijing-Tianjin-Hebei region, which is a possible future research direction.

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