

Scenarios and strategies of Chinese typical three-sector cities towards low carbon economy

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Abstract. Starting from China's low-carbon economic situation, analyze the relationship between the industry's contribution to GDP and AQI, and make a conclusion that carbon emissions will increase linearly with current GDP growth if no interference. The second part describes the status quo of low-carbon economy in China's three-sector. Investigate the situation and trend of GDP of each industry in general, then analyze the corresponding industry contribution to GDP, AQI and interactive in ten typical cities of each industry. Pick up the typical cities, which will pave the way for the following key analysis. Finally, the impact of the development of the corresponding industries in three typical industrial cities on carbon emissions and energy consumption is meticulously analyzed. The low-carbon economy of each typical city has its own uniqueness and is representative of the corresponding industry, so it cannot be generalized. Based on the analyzed data, suggestions and solutions for different industries are put forward.

Keywords: Low carbon economy; GDP; carbon emission; proportion; scenario; strategy.

1. Introduction

The economy of China has grown at an average annual growth rate of 5.5% in the last five years and is ranked the 2nd largest economy in the world. Meanwhile, China's carbon emissions have grown at the fastest pace in the past decades, up to 15% YoY increased in the 1st quarter of 2021. There is an inseparable relationship between GDP growth and carbon emissions. Similar to the data from economic departments analyzed by Paul and Bhattacharya in India from 1980 to 1996, the most fundamental cause of carbon emissions was economic growth [1]. In addition, from the research by Wang et al, energy intensity was essential in reducing carbon emissions, and corresponding economic growth triggered carbon emissions increasing [2].

As the current world's largest emitter of carbon dioxide and the world's second largest economic power, China plays a key role in global climate change mitigation. Relevant policies and commitments are required to enable decarbonization.

This essay provides several contributions to the existing literature. First, I analyze the linkage between GDP growth and carbon emissions from a new perspective, i.e., the relationship between the industry's contribution to GDP and AQI. Second, choose the cities with the average and first proportion of the above two indicators to represent their respective industries, analyze trends, and propose practical solutions and methods based on linear forecasts of future development. Third, uplift from typical cities to an industrial level, based on the characteristics and commonalities of the three-sector, propose solutions that cooperate with each other and interweave. While stabilizing GDP growth, diminish carbon emissions by adjusting the proportion of industries and optimizing the industrial structure to achieve the long-term goal of carbon neutrality.

2. Scenarios of typical Chinese three-sector cities towards low-carbon economy

2.1 Three-sector model of GDP

The long-term relationship between carbon emission and GDP is aligned in country's level, but, if broken down, it is significantly different among three-sector cities in China, mainly influenced by different economic structure and development mode of the cities.

2.2 Primary sector

With the world's largest primary sector, China currently estimated at 12.23 trillion RMB according to the data from China government [3]. 9% of China's total GDP is represented by its primary sector. However, low efficiency of this sector is the major obstacle to boost its contribution to the total GDP. According to the statistics from National Bureau of statistics in 1st quarter of 2021 [4], the primary sector is 1.1332 trillion RMB, accounting for 4.55% of the country economy with 8.1% actual year-on-year growth. The average proportion of primary sector in ten representative cities is 28.48%. From AQI perspective which represent carbon emissions, the average value of the above ten cities is 66 in 2019, varying from 45 to 109. The statistic shows that AQI index of the ten cities with high proportion of primary sector is relatively low in China. Qiqihar is a city dominated by traditional primary sector industries, with proportion of GDP 29.94% and AQI 60 in average, typical in cities with primary industries as the mainstay.

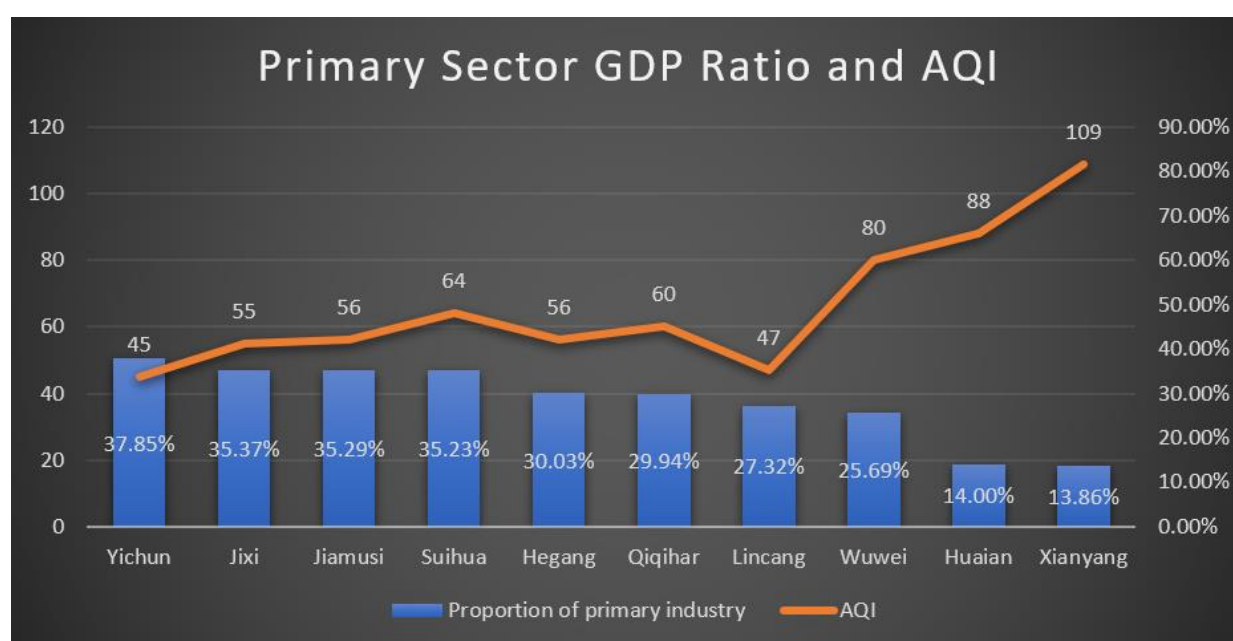


Fig 1. Proportion of primary sector and AQI in 10 cities.

2.3 Secondary sector

40.5% of GDP is contributed by China's secondary sector which dominates the carbon emission in China. Energy production and conservation by secondary industry are identified as the cause for highest carbon emission. The consumption demand for secondary industry output also causes indirect carbon emission. In addition, secondary sector is the major source of indirect emissions for other sectors. The GDP created by the secondary industry was 9.2623 trillion RMB, with a year-on-year real growth of 24.4%, accounting for 37.15% of the total GDP. In the central and western areas, the proportion of the secondary industry is still on the rise even the rise is limited. The average proportion of secondary sector in ten representative cities is 57.13%. From AQI perspective, the average value of the above ten cities is 104 in 2019, varying from 92 to 113. The statistic shows that AQI index of the ten cities with high proportion of secondary sector is relatively high in China. Tangshan city, located in the east of Hebei Province, is very famous for its secondary industry, with proportion of GDP 52.27% but AQI 106 in average. As a traditional industrial city, Tangshan is very suitable to investigate the potential relationship between its industrial structure and city's AQI.

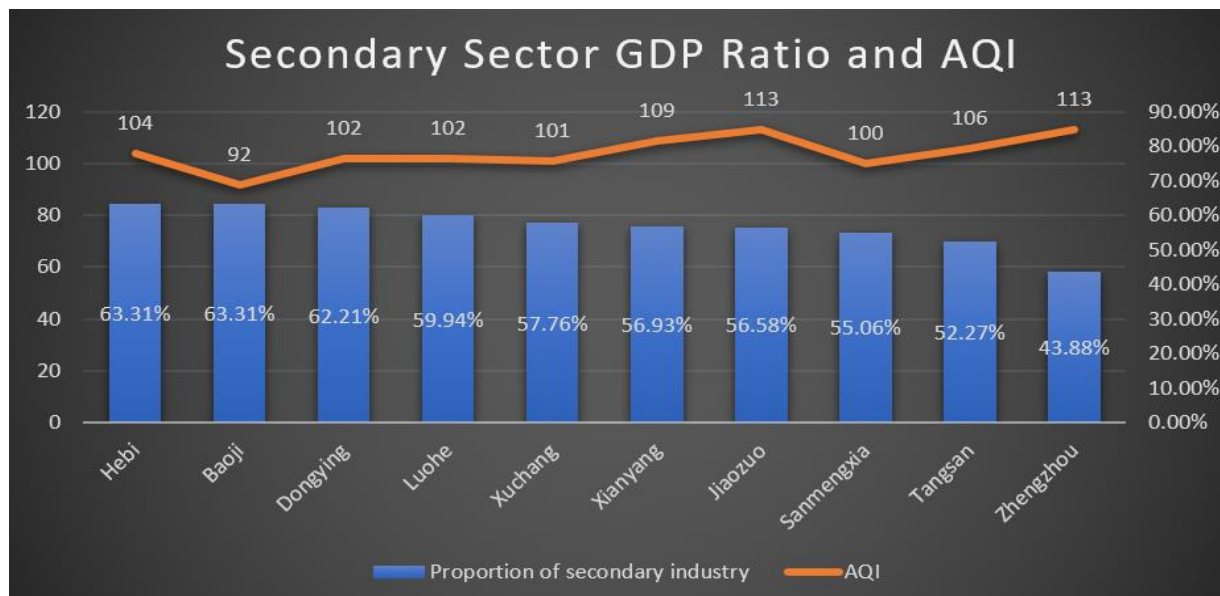


Fig 2. Proportion of secondary sector and AQI in 10 cities.

2.4 Tertiary sector

Tertiary sector development increased in the past decades, close to 44 percent of total output in China [5]. With the industrial transformation, the importance of China's tertiary industry is further increasing. The incremental value of tertiary sector officially exceeded that of the secondary sector in 2013, and gradually widened the gap. Until the 1st quarter of 2021, the GDP of the Tertiary sector has reached for nearly 60% of the total GDP. Nowadays, tertiary sector proportion has generally been increasing, especially in some first tier cities. The average proportion of tertiary sector in ten representative cities is 64.82%. From AQI perspective, the average value of the above ten cities is 80 in 2019, varying from 53 to 97. In China, most of the cities dominated by tertiary industry are large and medium-sized cities whose air quality of these cities are not optimistic. Beijing, as the capital of China, has vigorously developed the tertiary industry in decades. The proportion of tertiary industry is up to 83.70% and AQI is 97 in average. Although the above two indicators are above average values of ten tertiary sector cities, Beijing, as the leader of the tertiary industry, takes an important role in low-carbon economy development.

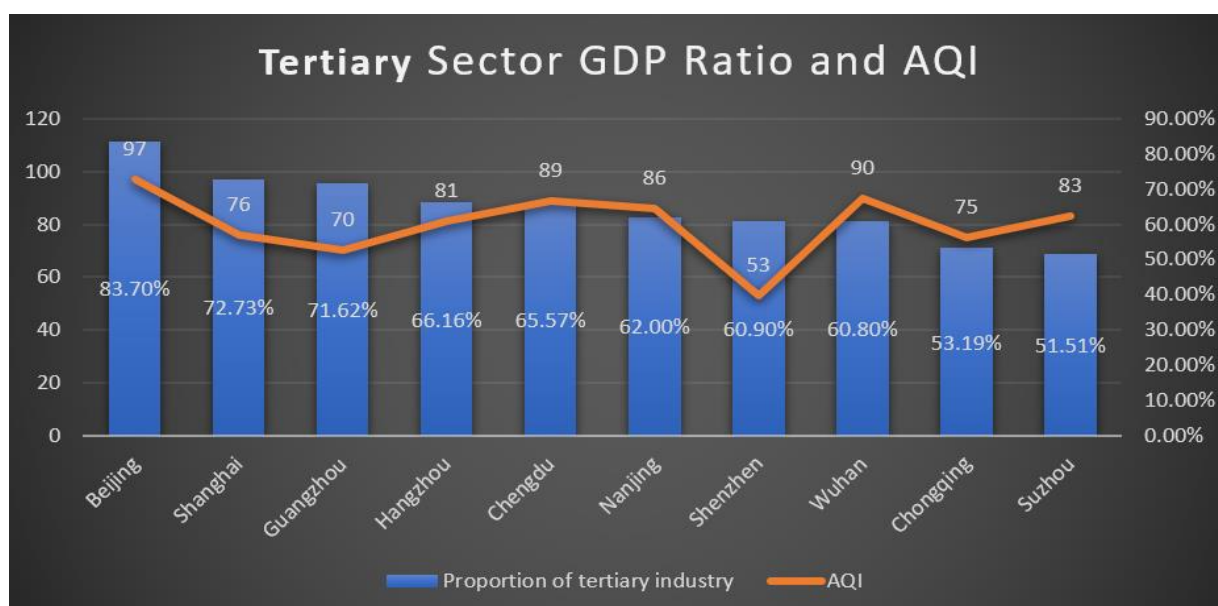


Fig 3. Proportion of tertiary sector and AQI in 10 cities.

3. Strategy of typical Chinese three-sector cities towards low-carbon economy

3.1 Overall situation

Although the carbon emission of China's three sectors is increasing, it also presents obvious differences. First, the carbon emissions of the secondary industry account for the largest proportion of the total carbon emissions. From the last 10 years, the average carbon emissions of the secondary industry accounted for about 70%. Second, in terms of increasing carbon emissions, the tertiary industry has become the top 1 contributor. From the last 10 years, the carbon emission increment of the tertiary industry accounted for nearly 60% of the total.

3.2 Analysis of typical city in primary sector

According to the data on the official website of Qiqihar government [6], the GDP increased from 28.255 billion RMB in 2000 to 120.04 billion RMB in 2020, more than four times growth rate. The GDP contributed by primary sector of the corresponding year increased from 8.19 billion RMB to 38.1 billion RMB. Its proportion hovers between 22% and 32%, however, the increase is not obvious. AQI gradually decreased from 138 in 2013 to 49 in 2020, from high pollution to good air quality.

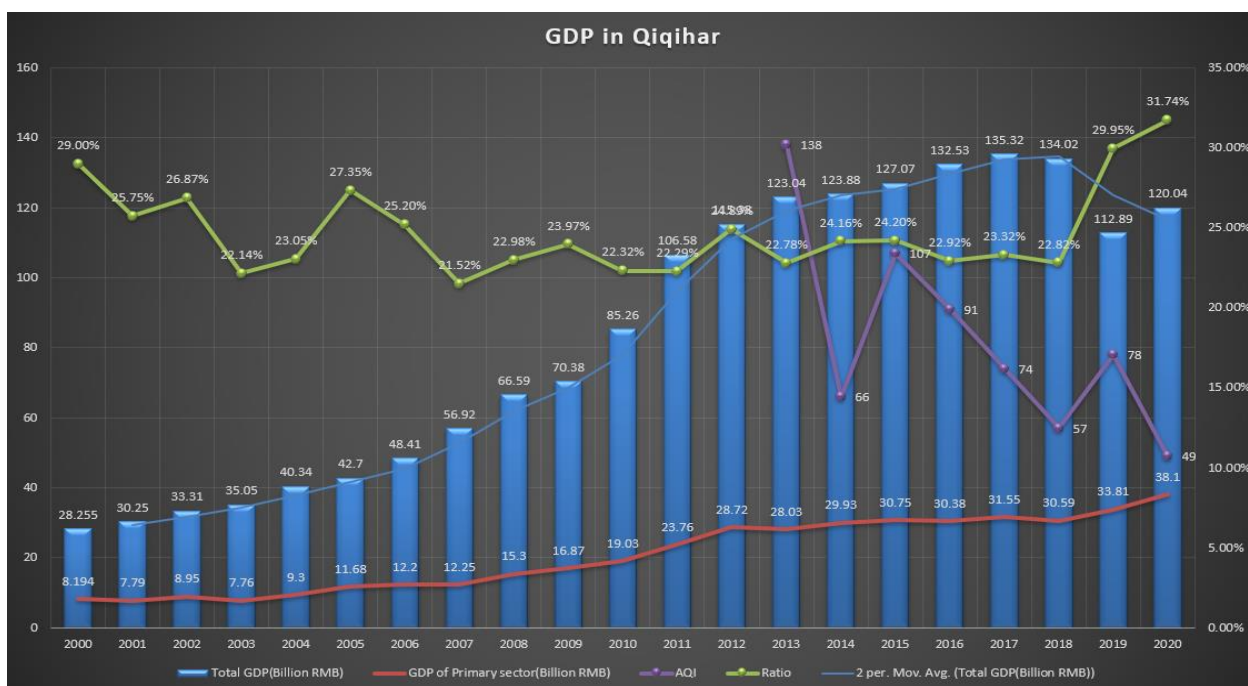


Fig 4. Relationship between proportion of primary sector and AQI.

While keeping the proportion of the primary industry relatively stable, GDP shows a strong growth momentum, which proves that the secondary and tertiary industries have greater contributions to the GDP of Qiqihar. However, under the guidance of low-carbon economic policies in the past three years, the primary industry proportion in GDP has increased by nearly 10% and AQI has continued to decrease, indicating that the optimization of the primary industry has a positive effect on AQI.

3.2.1 Forecasted GDP & Carbon emission

Using the linear budget method, we can get that GDP will reach 369.11 billion RMB in 2060, which is about three times of the GDP in 2020. However, the GDP contributed by the primary industry is 83.8 billion RMB, slightly more than twice that of 2020. If the prediction model of future carbon emission of the city is the same as the above national level with linearly increasing GDP, carbon emission will continuously increase to 51.67 million tons by 2060, 1.7 times of 2019, while it is 35.77 million tons in 2030. Obviously, it is impossible to reach the long-term goal of carbon neutrality in 2060.

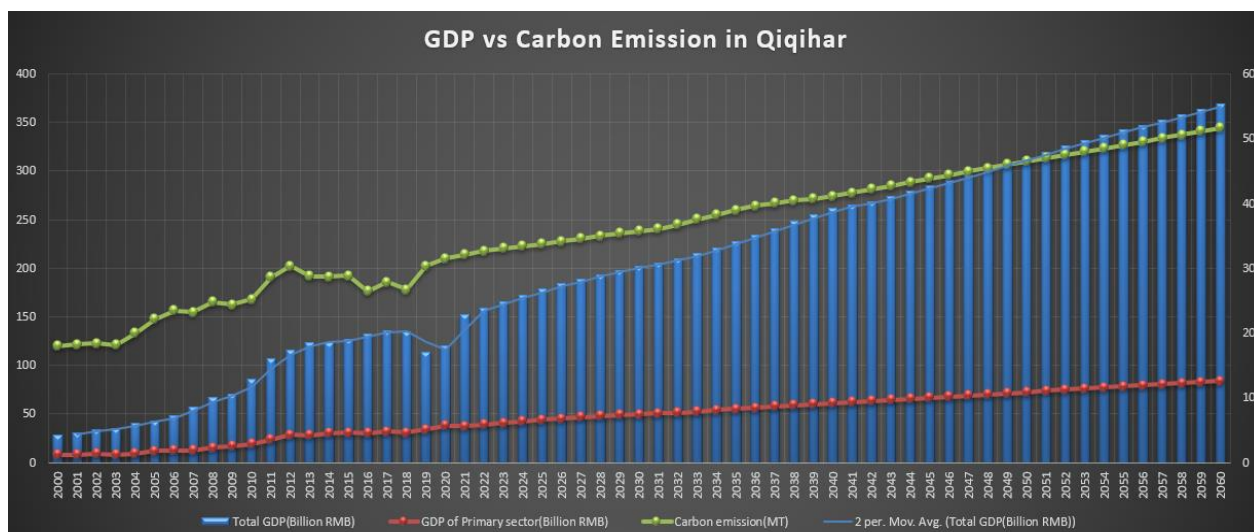


Fig 5. GDP vs Carbon emission in Qiqihar.

3.2.2 Proportion of primary sector trend

Forecast the future development trend from the perspective of the primary industry proportion in GDP, the proportion in Qiqihar's total GDP was 29.9% in 2020, and it will be about 22.7% by 2060. The overall situation remained stable with a slight downward trend.

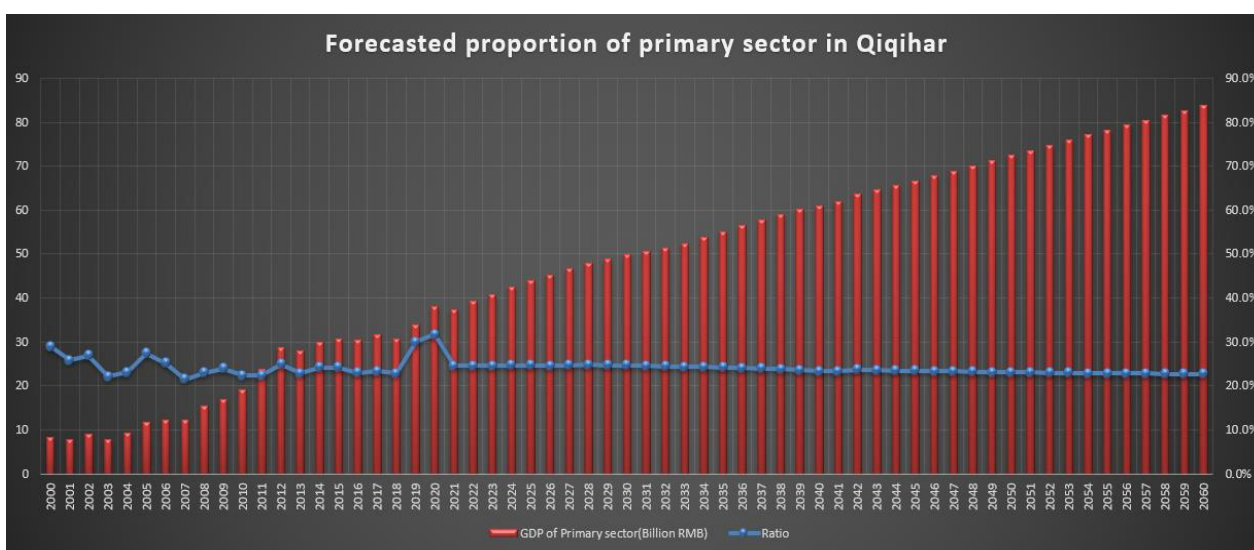


Fig 6. Forecasted proportion of primary sector in Qiqihar.

3.2.3 Analysis and strategy to achieve ultimate low-carbon economy target

From the above data, it can be obtained that the optimization of the primary industry will not have a decisive effect in achieving the goal of carbon neutrality by 2060. For the export trade perspective, the export scale expansion of the primary industry is the most essential driver of the carbon emission [7]. But, since the export structure of the primary industry has not changed much, its impact is relatively small. Because of the fact that China's primary industry technology is not advanced, the carbon emission from the non-clean energy consumption would enhance the growth of carbon emission in relevant trade. However, with the development of the city's secondary industry, various energy sources have been over-exploited. Soil erosion, excessive logging and the discharge of heavy pollutants lead to the destruction of the ecological environment, which have a negative impact on the development of the primary industry [8].

In combination with the low-carbon strategy of Qiqihar Municipal government [6], the following suggestions are put forward. First, maintain investment in primary industry and develop green industry to promote sustainable growth of the industrial economy. Improve agricultural product

quality to meet the current national requirements for rural economic development and industrial construction [9]. Second, main source of carbon emission is due to land/forest usage change [10]. Agriculture emits greenhouse gases and can trap them reversely during the change. It means that the agriculture exacerbates the problem of climate change by emitting different greenhouse gases, then it also compensates climate by absorbing such gases. Therefore, it's essential to establish a circular agriculture mode, which is based on the recycling of renewable energy and turns limited land into infinite value. Third, build an ecological environment protection mechanism to save water resources and other nonrenewable resources, and implement the development of recyclable system [11]. Integrate the transformation and development of water resources utilization and protection. Develop small and medium-sized hydropower stations to supplement power supply. For remote rural areas, wind turbines and photovoltaic arrays are used as generators to generate electricity, and surface water tanks and open wells are used as the different reservoirs of the pumped storage system, respectively, to establish a small off-grid wind-solar-pumped storage system. The joint operation system [12] can realize the stable supply of clean energy in remote areas.

3.3 Analysis of typical city in secondary sector

Based on the data on the official website of Tangshan government [13], the GDP increased from 91.5 billion RMB in 2000 to 721.09 billion RMB in 2020, more than seven times growth rate. The GDP contributed by secondary sector of the corresponding year increased from 46.168 billion RMB to 383.674 billion RMB. Its increase was slightly higher than that of GDP. Its proportion continued to grow from 50.45% in 2000 to 60.08% at peak in 2011, and then dropped to 53.21% in 2020 due to the impact of industrial adjustment and low-carbon economy. AQI gradually decreased from 171 in 2013 to 77 in 2020, from severe pollution to moderate pollution correspondingly.



Fig 7. Relationship between proportion of secondary sector and AQI.

The secondary industry proportion in Tangshan increased rapidly from 2000 to the peak in 2011. During the following four years declination, GDP suffered a certain impact. From 2015, GDP began to grow rapidly because of the contribution of other industries, especially the tertiary industry. With the mindset of low-carbon economy and corresponding industrial adjustment, the air quality continues to improve.

3.3.1 Forecasted GDP & Carbon emission

Using the linear budget method, we can get that GDP will reach 1988.78 billion RMB in 2060, which is less than 2.78 times of the GDP in 2020. However, the GDP contributed by the secondary industry is 1089.92 billion RMB, very close to three times that of 2020. If the prediction model of

future carbon emission of the city is the same as the above national level with linearly increasing GDP, carbon emission will continuously increase to 969.86 million tons by 2060, 2.34 times of 2019. To achieve carbon neutrality in 2060, the secondary industry, which contributes the most to carbon emissions, must make corresponding adjustments.

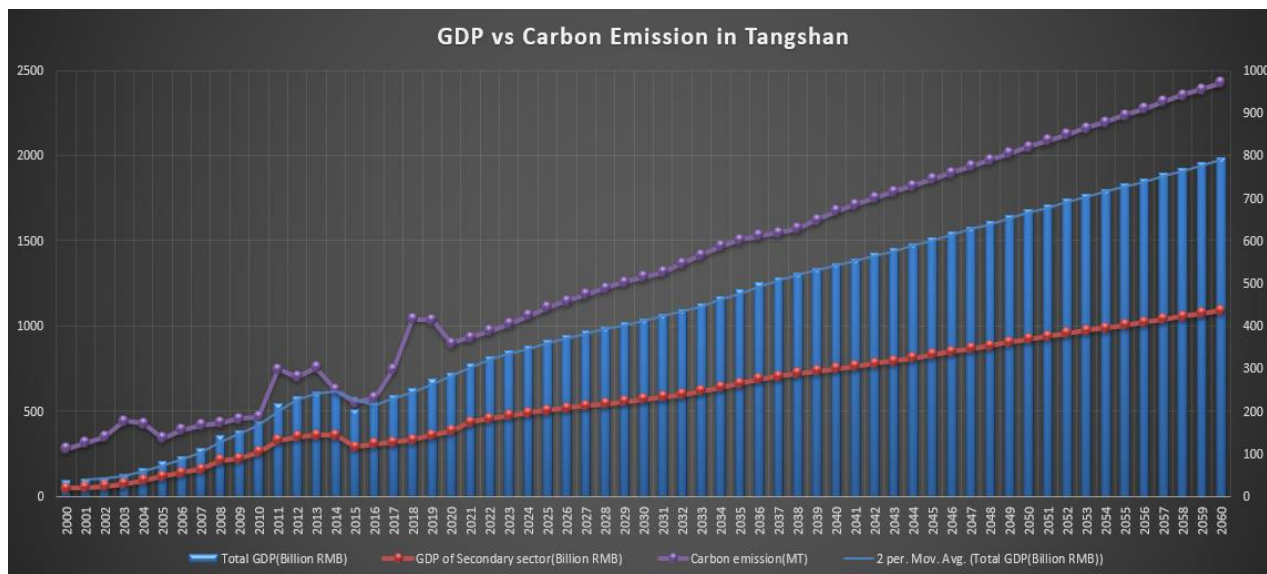


Fig 8. GDP vs Carbon emission in Tangshan.

3.3.2 Proportion of secondary sector trend

Looking at this issue from another perspective, we can find that secondary industry contribution to GDP has slowly increased from 53.21% in 2020 to 54.8% in 2060. It can be seen that if the GDP growth trend remains unchanged, the secondary industry in Tangshan needs to maintain a stable trend according to the current trend.

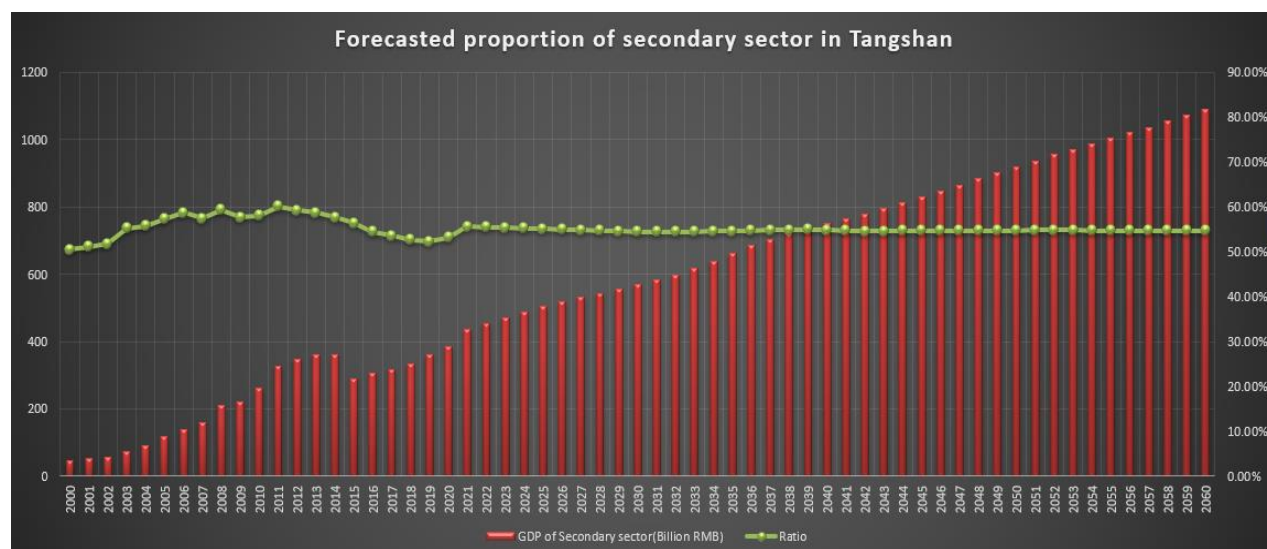


Fig 9. Forecasted proportion of secondary sector in Tangshan.

3.3.3 Analysis and strategy to achieve ultimate low-carbon economy target

Industrial growth is strongly dependent on energy consumption, but also has a negative effect on carbon emissions. It is necessary to adjust the contribution of the whole secondary industry to carbon emissions by improving the secondary industry with high energy consumption [14]. As a traditional industrial town and a resource consuming city, the industrial structure in Tangshan has formed a development pattern dominated by heavy industry and supplemented by light industry. However, its carbon neutrality road is full of challenges.

According to the analysis results of the above data, the secondary industry needs to be significantly adjusted and optimized [13]: First, refer to the experience of Shanghai in the 1990s, actively adjust the secondary industry structure by making a higher priority to the development of the tertiary industry and stabilize the primary industry. In practice, it can be divided into 3 stages [15]. The first stage focuses on economic development, considering energy conservation and environmental protection in parallel. The second stage is that economic development and environmental protection are equally important. The third stage is to highlight the importance of energy conservation and emission reduction, converting goals into actions.

Second, industrial diversification mode, transforming resource mining and traditional heavy industry into high-tech industry and service industry. The proportion of high-tech industry in the manufacturing industry needs to be increased [16]. Further reducing the use of traditional fossil energy can enhance the inhibition of carbon emissions. Increasing new energy R&D and improving energy efficiency is the future road of Tangshan's secondary industry.

Third, use wind energy, solar energy and tidal energy to replace the traditional coal-based energy, and vigorously develop the new secondary industry supported by renewable energy [17]. In China's energy structure, coal accounts for about 70%, but this proportion must decline due to the introduction of new energy [18]. In addition, new energy, as a renewable resource, will inevitably reduce the budget of energy consumption enterprises in the long run. Therefore, the government can issue policies to control traditional energy usage and allocate public budget funds to support new energy development enterprises, especially at the initial stage.

Fourth, utilize the advantages of the secondary industry, combined with the development of new energy, to accelerate the development of the tertiary industry, increase its proportion in GDP, and pave Tangshan's own low-carbon economy road [14].

3.4 Analysis of typical city in tertiary sector

Data on the official website of Beijing government indicated that [19], the GDP increased from 327.78 billion RMB in 2000 to 3610.26 billion RMB in 2020, almost eleven times growth rate. The GDP contributed by tertiary sector of the corresponding year increased from 217.49 billion RMB to 3027.86 billion RMB, an incredible fourteen times growth rate. Its proportion maintained a very stable growth rate, from 66.4% in 2000 to 83.9% in 2020, accounting for the biggest proportion of GDP. AQI gradually varied from 187 in 2015 to 56 in 2020. The air quality has improved significantly, especially in the past 3 years. The highest proportion and sustained growth of the tertiary industry show Beijing's attitude and determination to vigorously develop the tertiary industry as the capital. After many years of heavy pollution, Beijing's AQI has dropped significantly recent years, which fully proves the positive role of developing the tertiary industry in the low-carbon economy.



Fig 10. Relationship between proportion of tertiary sector and AQI.

3.4.1 Forecasted GDP & Carbon emission

Using the linear budget method, we can get that GDP will reach 11237.38 billion RMB in 2060, which is over three times of the GDP in 2020. In addition, the GDP contributed by the tertiary industry is 9621.28 billion RMB, also beyond three times that of 2020. If the prediction model of future carbon emission of the city is the same as the above national level with linearly increasing GDP, carbon emission will drop to 87.65 million tons by 2030 then float up and down until 79.17 million tons of 2060, starting from 88.16 million tons in 2019. Although the current tendency is that the overall carbon emissions of Beijing are declining, there is still a certain gap from the ultimate goal of national carbon neutrality by 2060.

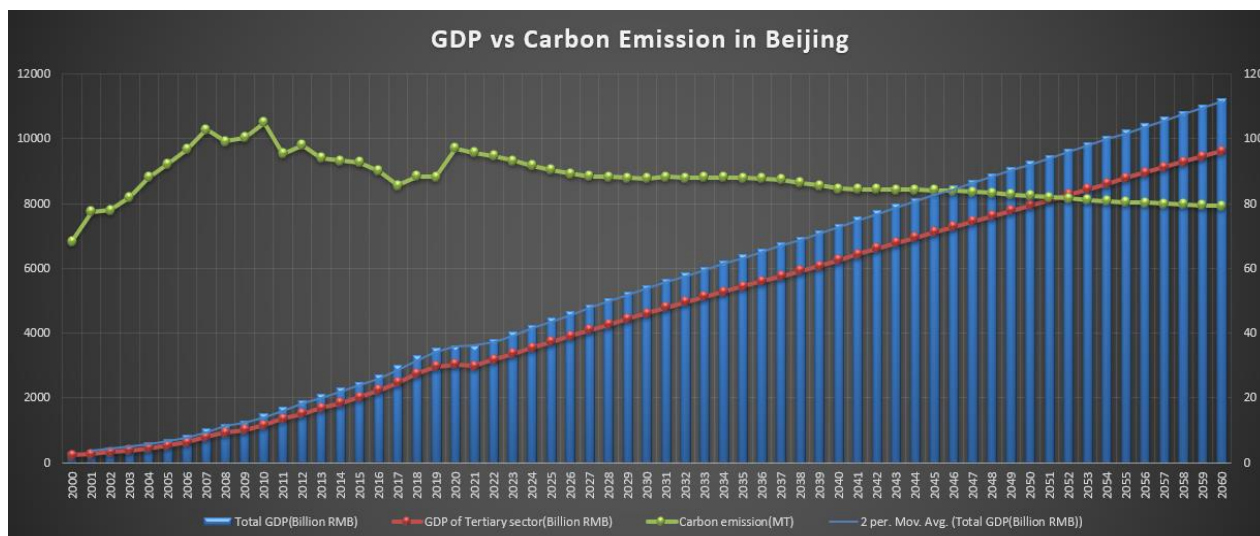


Fig 11. GDP vs Carbon Emission in Beijing.

3.4.2 Proportion of tertiary sector trend

From the analysis of tertiary industry contributed to Beijing's GDP, we are not surprised by the similar trend and conclusion. The tertiary industry proportion slowly increased from 83.9% in 2020 to 85.6% in 2060. The stable proportion is consistent with the current national policy of focusing on the development of the tertiary industry in super large cities.

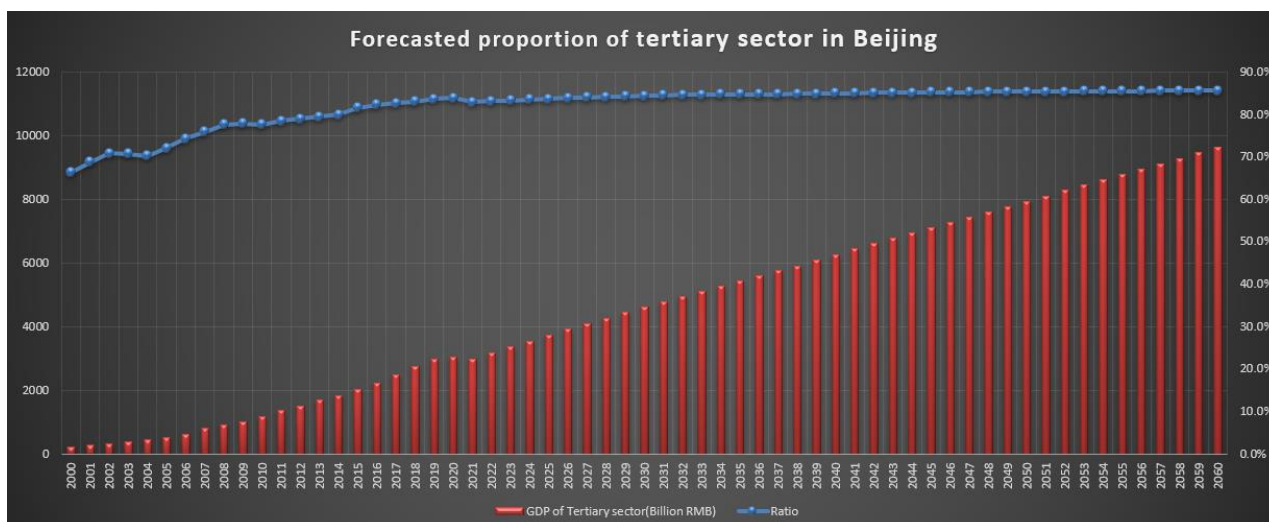


Fig 12. Forecasted proportion of tertiary sector in Beijing.

3.4.3 Analysis and strategy to achieve ultimate low-carbon economy target

The tertiary industry contributes a lot to Beijing's GDP, and the above prediction model based on the appeal data is unacceptable. How to maximize its tertiary industry function in low-carbon

economy is the next most important research topic. In modern society, the dominated factors of carbon emissions are economic development and technological advancement, indicated by Cheng et al. [20], Xu et al. [21], Siddiqi [22] and other researchers. Moreover, the rapid growth of population is also an important factor affecting carbon emissions. The research on the carbon emissions of Fujian Province from 2000 to 2009 shows that the population growth has significantly increased the carbon emissions [23]. The researches by Xu and Liu [24], Shi [25] echo the above finding and discover potential link between total population and carbon emissions.

The production and consumption of energy play a decisive role in Beijing's GDP and carbon emissions. In the first two stages of Beijing's energy consumption [26], the economy transforms from high-speed growth to a normal state of development. The tertiary industry is also subject to corresponding fluctuations. From 2020 onwards, according to the requirements and long-term goals of the Chinese government and the Beijing Municipal Government, the consumption of energy by the tertiary industry, which plays an absolutely dominant role, will determine the future growth trend of GDP and whether it can achieve carbon neutrality as scheduled.

First, as the capital and a key development city, Beijing needs to designate energy conservation and emission reduction policies and corresponding regulations for the tertiary industry. The energy structure also needs to be adjusted accordingly. Instead of relying on regional energy sources, Beijing must strengthen the development of non-coal energy and its own energy sources. Second, in addition to some large state-owned enterprises, emission control enterprises also include many government institutions, universities, hospitals, etc., to tap their emission reduction potential [27]. Third, the main energy consumption of the tertiary industry is electricity, and its accumulated emission reduction potentials are significant. In the era of big data, the improvement of ICT industry efficiency in the tertiary industry has a leverage effect on promoting carbon emission reduction in other industries. Fourth, the introduction of new energy and new technology, such as the promotion of new energy vehicles, will also play a positive role in carbon emissions. The government should increase subsidies for residents' travel and energy consumption, and promote the use of energy-saving appliances and green travel. In addition, with the increasing population, the publicity of social environmental awareness needs to be strengthened. Fifth, Innovation should have a positive influence on carbon emissions. It means that, investing more capital, e.g., technology of energy conservation, is an effective approach to diminish carbon emissions. Give full rein to Beijing's technological advantages, establish a technical service system, promote technological progress in all industries, and play a leading role in the tertiary industry to the low-carbon economy [28].

4. Summary

From the above analysis data, Qiqihar, Tangshan and Beijing are typical representatives of primary industry, secondary industry and tertiary industry respectively. While maintaining stable GDP growth, it is hard to achieve the long-term goal of carbon neutral economy by simply controlling carbon emissions through the adjustment of related industries. In low-carbon economy, industrial restructuring is of great significance. While maintaining stable GDP growth, we should actively take the responsibility of environmental protection, adjust industrial institutions and develop low-carbon industries. One of the key points of industrial adjustment is to diminish energy consumption and use clean energy to keep sustainable economic development [29].

From the above analysis, we can see that the improvement of the primary industry efficiency needs to be further strengthened. It is a great challenge for the secondary industry to develop emerging industries through new science and technology and appropriately reduce the proportion of the secondary industry. From major cities to the national level, balancing the proportion of the three industries, learning from foreign cutting-edge technologies and rich experience, and focusing on tertiary industry development is the most efficient way to the future low-carbon economy.

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