The Impact of Green Finance on Low-Carbon Transformation of Manufacturing Enterprises: Evidence from Hebei Province

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Abstract. This study analyzes the effect of green finance on the low-carbon transition of manufacturing firms in Hebei Province. The study utilizes data from listed manufacturers in Hebei Province between 2010 and 2022. The findings demonstrate that green finance in Hebei Province efficiently enhances resource utilization efficiency, reduces carbon dioxide emissions, and elevates firms' green total factor productivity. Besides, the study uncovered obstacles confronting firms who aim to switch from customary polluting industries to ecologically sustainable production techniques, including limited access to development capital for transition and difficulties in attracting high-caliber personnel. The study data indicate that green finance has considerably expanded in Hebei Province, particularly in the domain of green securities. The latter exceeds the scale of the majority of regions in China; nevertheless, development across programs reveals some unevenness. The study advises the Hebei provincial government and financial regulators to enhance their encouragement for green finance development and refine existing policies to mitigate shortcomings.

Keywords: Green finance; carbon neutrality; green transformation.

1. Introduction

Today, significant industries worldwide are undergoing rapid expansion. However, this growth has resulted in increasingly severe environmental issues. Therefore, industries must expeditiously transition towards low-carbon and low-pollution development to ensure global economic sustainability. In September 2020, China formally initiated the "dual-carbon" goal in response to environmental and climate changes worldwide. The objective is to attain "carbon peaking" by 2030, when carbon emissions will reach their maximum and start to decline, and "carbon neutrality" by 2060. Reaching the dual-carbon objective necessitates expediting the optimization of industrial and energy structures, raising the share of clean energy usage, and supporting eco-friendly operations in crucial industries and significant regions. As the largest primary energy consumer and carbon emitter worldwide, China is under immense pressure to lessen emissions. China's financial industry has increasingly prioritized green finance, which was proposed by the People's Bank of China in August 2016, as a way of promoting ecological and environmental protection. Green finance refers to numerous aspects like green credit, green investment, and carbon finance. Irrespective of its form, this functions as a financial instrument that advances the lowering of carbon emissions while enabling environmentally friendly growth of enterprises and industries. Hebei Province is located in northern China, in close proximity to the national capital, Beijing. As per predictions, the province will have a GDP of 423.704 billion yuan by 2022, placing it as the 11th biggest economy in the nation. With manufacturing accounting for over 40% of the secondary industry, it plays a vital role in boosting national production and improving the country's overall strength. Hebei Province has played a crucial role in heavy industrial production since the founding of modern China and remains important today. Nevertheless, the nature of this type of production implies that more advanced heavy industries will have a greater impact on the environment. In addition, the distribution of work in the industrial sector in the "Beijing-Tianjin-Hebei" region of China presents a challenge for Hebei Province to break away from its conventional highly polluting industrial growth mode. Currently, as China pursues a "dual-carbon" system, the manufacturing industry in Hebei Province is urgently needed to transition to a decarbonized and sustainable mode of production. This study specifically examines the impact of green finance on the green transformation of Hebei Province's manufacturing industry subsequent to

its introduction in 2016. By applying statistical methods, data from various listed manufacturing firms in Hebei Province between 2010 and 2022 was gathered and ultimately employed to evaluate the extent of environmentally-conscious transformation undergone by the manufacturing industry within Hebei Province. Based on the data analysis results, this study provides conclusions and recommendations for the future green transformation and development of the Hebei manufacturing industry.

2. Literature Review

Amid the growing urgency of environmental concerns, green finance has garnered significant attention in recent years. An array of academic literature has explored the topics of green finance and its impact on the transformation and development of the manufacturing industry, providing numerous methods of assessing this impact. Xiang Yan, Chao Yang, and Renfang Zhang examine the effects of green finance on resource efficiency and economic decarbonization in 2023. Their findings indicate that green financing can effectively reduce carbon intensity by enhancing resource efficiency. Moreover, green financing has a noteworthy influence in stimulating decarbonization in provinces with high carbon intensity [1]. In 2019, Chang Mingyang's analysis posited that green finance contributes to the transformation of the manufacturing industry via resource allocation and signal transmission. Essentially, green finance impels financial resources toward cleaner businesses and provides them with favorable signals. Similarly, Chen Huicai's research concurs with these findings [2]. He separated the allocation of resources into two categories: innovation compensation and risk management. Green finance integrates green financial products and a variety of financial instruments to boost enterprise risk control abilities, effectively managing the risks that arise during technological innovation. It incentivizes companies to prioritize the research and development of primary technologies, resulting in the overall expansion of eco-friendly total factor productivity [3].

Hepei Li, Chen Chen, and Muhammad Umair conducted a study on the effect of green finance on the green total factor productivity of Chinese enterprises. The results showed that green finance plays a significant role in enhancing green total factor productivity by promoting energy conservation and reducing emissions [4]. In 2020, Sun Jiuyu evaluated the green total factor productivity of crucial manufacturing industries in Hebei Province. The study discovered that the green total factor productivity of manufacturing businesses linked to chemical energy is frequently lower than that of the general machinery manufacturing sector [5]. Furthermore, several studies have examined the effect of green total factor productivity on companies from a theoretical standpoint.

This study examines the greening of the manufacturing industry in Hebei Province. A review of relevant literature revealed limited research specific to the province; however, some scholars have referenced the topic. In 2021, Wang Kang and other scholars conducted a study on the factors that impact the green transformation of the manufacturing industry in Hebei Province under the environment regulations. Their objective was to investigate the effectiveness of environmental regulations in promoting the shift towards green manufacturing. The study highlights the need for a comprehensive approach to the implementation of environmental regulations to realize the green transformation of the manufacturing industry. The research discovered that human capital, financing capacity, and government behavior greatly affect the green transformation of the manufacturing industry. As a solution, it suggested promoting green transformation by innovating the green economic development model [6]. Zhang Feng and Wang Junling studied China's carbon emissions in 2022, specifically in the manufacturing sector of Hebei province. An entropy weight TOPSIS method was utilized to establish a two-tier model for allocating carbon emission responsibility. The study found that the manufacturing industry scored the highest overall and should shoulder 55.81% of the carbon emission reduction responsibility [7]. Li Shuo and Jiang Hui examined the role of green finance in optimizing the industrial structure of Hebei Province. Multiple indicators, including the growth rate of green finance, the balance of green loans, and the balance of green bonds, were utilized to construct a measurement model that measures the coupling and coordination between green finance

and industrial structure. The study concluded, based on factual data from Hebei Province, that green finance fosters the optimization and upgrading of industrial structure by providing funding for green development and reducing financing costs [8]. In 2023, Zhou Bohan conducted research on the role of green finance in promoting industrial transformation and upgrading in Hebei Province, China. The study examined seven green financial products' impact on industrial transformation and concluded that green finance significantly contributes to enhancing the efficiency of industrial transformation and upgrading. Furthermore, the study conducted a comparison of results utilizing data from Hebei province, showcasing regional disparities in the effect of green finance on industrial transformation when compared to Beijing and Tianjin [9].

This study aims to refine the research scope and concentrate on the manufacturing industry. Specifically, we will examine the influence of green finance on the green transformation of the manufacturing sector in Hebei Province.

3. Analysis of Current Situation of Manufacturing Enterprises

In 2019, based on data from the Economic Yearbook of Hebei Province, manufacturing enterprises in the province emitted 201.42 million tons of carbon dioxide and consumed 144.32 million tons of standard coal. The manufacturing industry in Hebei Province has significantly higher energy consumption and carbon dioxide emissions compared to all other industries operating in the region (see Fig. 1).

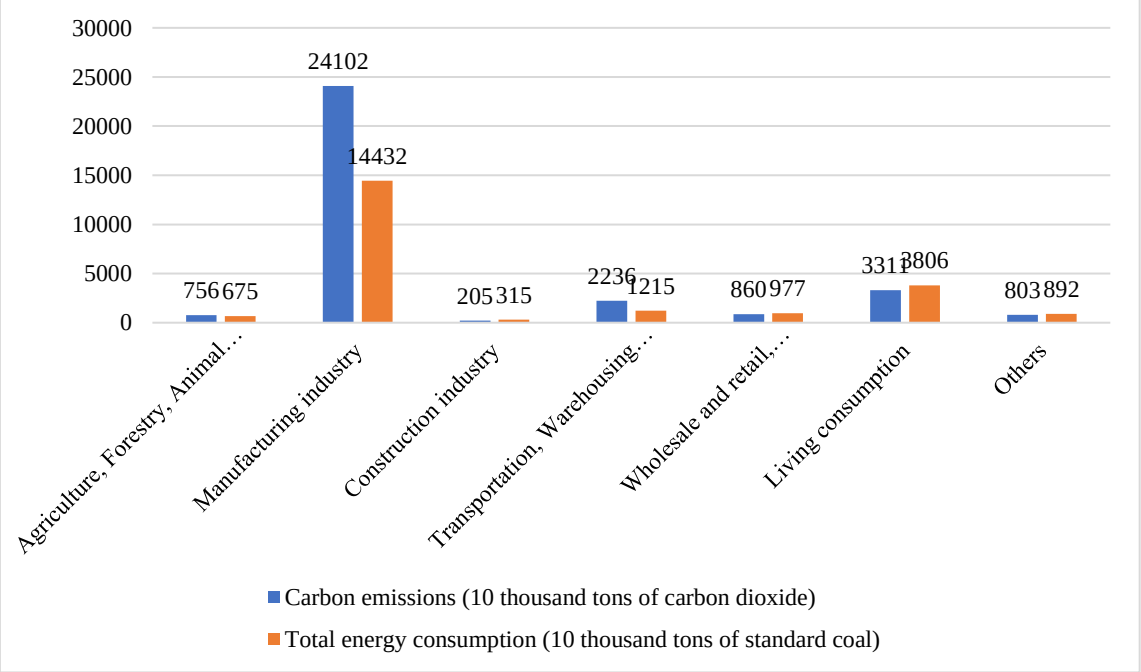


Fig. 1 Total carbon emissons and energy consumption by industry in Hebei Province

If Hebei Province aims to achieve its carbon reduction and green production responsibilities, its success depends on the manufacturing industry. Currently, the three main industries in Hebei Province are distributed in the proportions of 10.4%, 40.2%, and 49.4%. By screening all listed manufacturing enterprises in Hebei Province and dividing them into high-polluting enterprises (primarily fossil fuel production and other industrial categories) and other manufacturing enterprises, we were able to roughly estimate that 49.53% of manufacturing enterprises in Hebei Province are polluting, indicating that half of all manufacturing enterprises in the region fall under the category of high-polluting manufacturing. Annual report data disclosed by enterprises were utilized for this estimation. Previously, other scholars have conducted research on the emission reduction responsibility of sub-sectors within the manufacturing industry. Based on the data obtained from their research, the selected high-polluting manufacturing industry in this study should be responsible for 65.69% of the carbon emission reduction across the entire manufacturing industry [7].

The outcome is predictable, with the primary contributing factor being historical legacy. This not only led to impressive industrial development in the region but also inflicted severe environmental damage. During China's founding, Hebei Province undertook the duty of advancing the country's heavy industry. Under the given premise that the industrial division of labor and economic development disparities between North and South China have reached a fixed state, optimizing and upgrading Hebei Province's industrial structure is exceedingly challenging. However, Hebei Province's unique geographical location is a notable advantage. Beijing, the capital of China, is surrounded by several cities in Hebei Province, and the city's siphoning effect is evident as it attracts a considerable number of high-quality talents, technology, capital, and development resources from Hebei Province. This phenomenon poses challenges to the transformation of conventional high-polluting industries in Hebei Province. This aspect is straightforward to comprehend. It used to employ a large number of workers, most of whom were not highly educated and even included part-time farmers. Let us assume there is a company that follows traditional methods in its production. However, the company must now modernize its production processes and transition from polluting to efficient and eco-friendly production methods. This transition will inevitably result in some challenges for the company. First, the process of updating the production line necessitates a substantial amount of funds. Where should the company acquire these resources? The company is faced with a dilemma as local banks are hesitant to provide the necessary credit, and the government subsidies are not substantial enough. This specific issue is where green finance comes in; it provides a solution and is significant in solving this issue. Later on, this research will delve into green finance in detail. Second, how can one leverage new technology to modernize outdated production lines? The reality of Chinese society is that the majority of highly educated individuals are disinclined to pursue skilled labor and instead favor office careers in more prosperous cities where they can address problems. Consequently, businesses encounter difficulties in recruiting educated workers willing to engage in manual labor. One possible resolution entails training current migrant workers; however, entrepreneurs frequently forego this option due to the associated high cost. Third, what will be the primary focus post-green transformation? China boasts the world's most comprehensive industrial categories. The transformation of this company may signify an entry into new markets to compete. High-tech industries generally dominate green production, and neighboring companies have already secured their market position with local policy support. Competing with them now would be unwise. The limitations of the siphon effect are evident. Meanwhile, the industrial division of labor in the Beijing-Tianjin-Hebei region hinders the adjustment of the industrial structure in Hebei Province. As of 2021, the proportion of the three main industries in Beijing is roughly 0.2:17.5:82.3, and in Tianjin, it is 1.4:37.3:61.3. According to the "Beijing-Tianjin-Hebei Industrial Coordinated Development Plan" issued jointly by the governments of Beijing, Tianjin, and Hebei, a development model has been established that assigns research and development responsibilities to Beijing, achievement transformation to Tianjin, and manufacturing to Hebei. The manufacturing industry in Hebei Province requires careful consideration to determine the optimal approach for green transformation and upgrading under this model.

4. Green Finance

The Opinions on Implementing Environmental Protection Policies and Regulations to Prevent Credit Risks, promulgated in 2007, is considered the commencement of China's green finance practice. The formal proposal of the concept of green finance was made in 2016. This study primarily examines the development of green credit, green bonds, and carbon finance in Hebei Province, focusing on the year 2010.

4.1. Green Credit

Firstly, this study evaluates the green credit of Hebei Province by calculating the proportion of interest expenses of high-energy-consuming industrial enterprises. The interest expense data of six

high-energy-consuming industries is compared with the interest expense data of all industries to obtain the interest ratio of high-energy-consuming industrial enterprises. The results are presented in Table 1 and Fig. 2. It is evident that despite the interest expenditure proportion of high-energy-consuming industrial enterprises in total industrial interest expenditure hovering around 0.55 prior to 2019, there was a notable increase thereafter. Furthermore, from 2010 to 2021, the trend in interest expenditure remained positive, indicating that the interest expenditure of high-polluting manufacturing enterprises is on the rise. The potential of green credit in facilitating the transformation of highly polluting firms remains insufficiently demonstrated. Comparing the development status of Hebei Province with that of Beijing and Shandong Province in the latter diagram, there is considerable opportunity for enhancing green credit's impact in Hebei Province. Thus, refining the present model is necessary to increase the efficacy of guiding green development.

Table 1. The proportion of interest expenses of high energy-consuming industrial enterprises from 2010 to 2021

Year	The proportion of interest expenses of high energy-consuming industrial enterprises
2010	0.608865155
2011	0.559369369
2012	0.587179063
2013	0.590525312
2014	0.561640039
2015	0.556563693
2016	0.559259112
2017	0.554402264
2018	0.550113935
2019	0.558039009
2020	0.614797666
2021	0.636524855

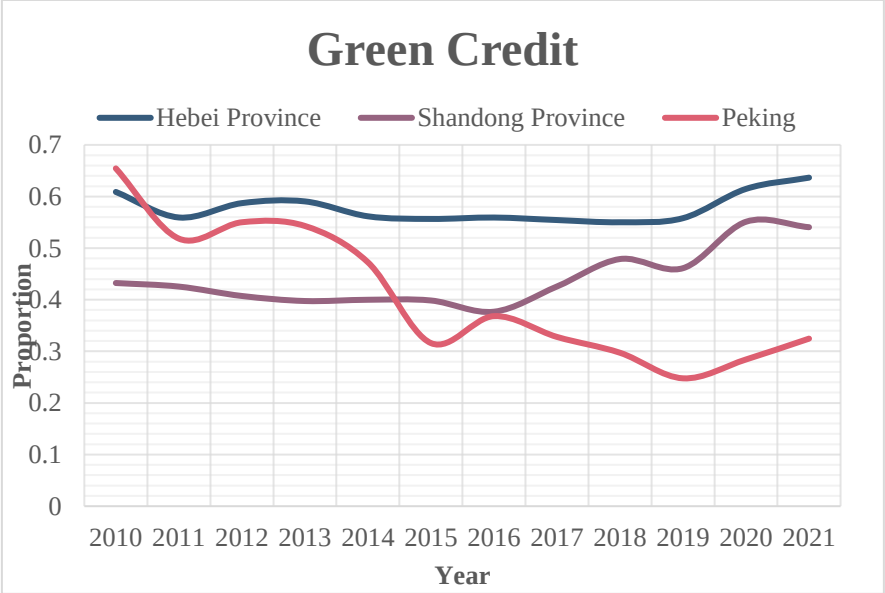


Fig. 2 Comparison of the changing trend of the proportion of interest expenditure of high energy-consuming industrial enterprises in Hebei Province, Shandong Province and Beijing from 2010 to 2021

4.2. Green Securities

This underscores the importance of green investments in the region. The study assesses the current market capitalization of high-polluting enterprises while comparing the total market capitalization of

six energy-intensive industries to that of all A-share listed enterprises in Hebei Province. The results indicate that the total market capitalization of high-energy-consuming listed enterprises in Hebei Province is less than half of that recorded in 2010. Similarly, when comparing it to Shandong Province and Tianjin Municipality, Fig. 3 reveals that Hebei Province excels in the development of green securities compared to most provinces in China. However, due to policy and industrial arrangements, there is still a gap compared to certain regions.

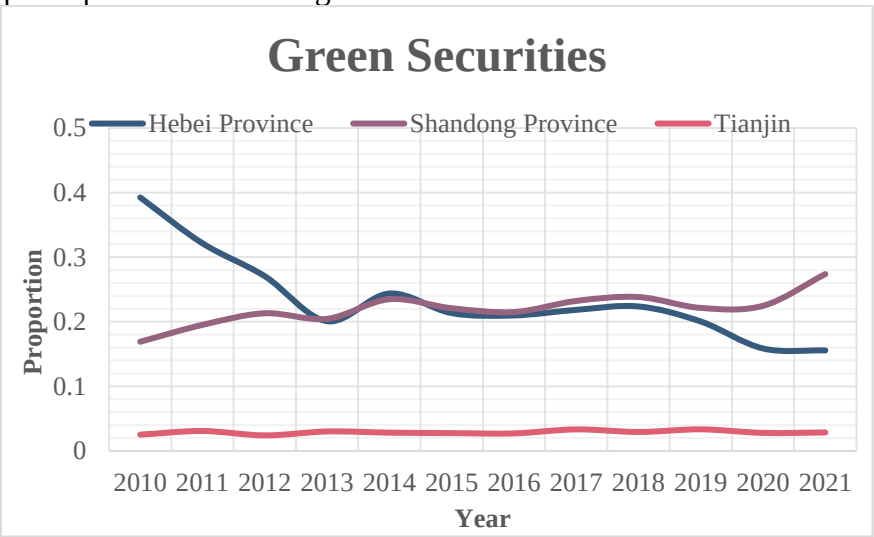


Fig. 3 The changing trend of the market value proportion of high-polluting enterprises in Hebei Province, Shandong Province and Tianjin

4.3. Carbon Finance

The third measurement dimension is carbon finance. It gauges the development of carbon finance in Hebei Province using the total carbon emissions and GDP. Carbon finance determines if carbon dioxide emissions increase at the same rate as the economy. If the rate of carbon dioxide emissions is lower than the economic growth rate during GDP development, it signifies simultaneous economic and green development. According to Fig. 4, the carbon finance reference ratio in Hebei Province dropped from 0.0279 to 0.0062 between 2010 and 2021, representing a 77.78% total decrease. This outcome shows that Hebei Province has exerted significant efforts in curbing carbon emissions and promoting green development, resulting in favorable outcomes.

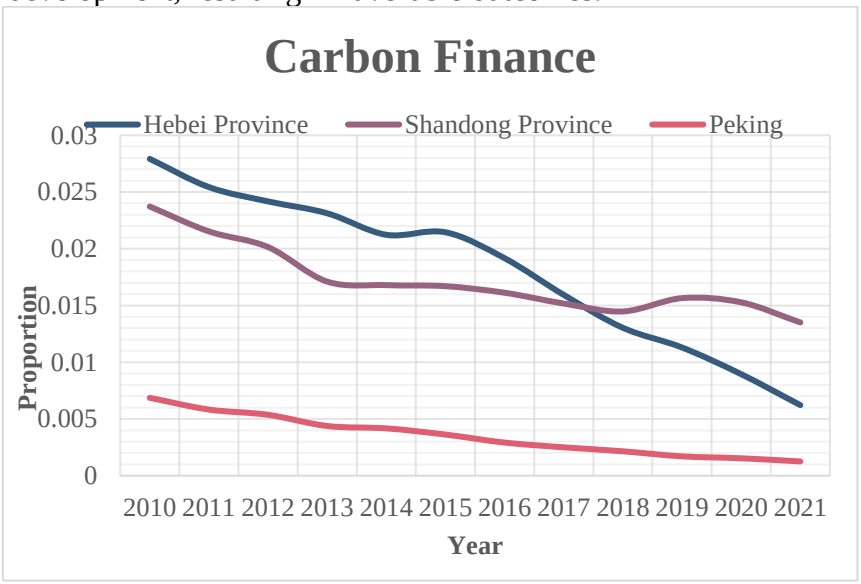


Fig. 4 Trends of carbon finance intensity in Hebei, Shandong and Beijing (CO2 emissions /GDP)

4.4. Evaluation of Enterprises' Green Transformation Under Green Finance Environment

After analyzing the recent progress of green finance in Hebei Province, we can examine its influence on the green transformation of businesses in the area. This research follows the methodology established by Loughran and McDonald in 2011, using information from the annual reports of public corporations to evaluate their level of eco-friendly transformation [10]. Compared to content analysis, utilizing natural language processing technology enables precise identification of unstructured text data across large samples, thereby reducing misinterpretation rates and improving consensus in judgment. This study selects the annual reports of listed enterprises for observation because the green transformation is a critical strategic information that companies disclose in their open corporate annual reports. Moreover, the annual reports of listed enterprises are mandatory information with strict formatting and language norms. This improves retrieval efficiency of the research keywords. Therefore, this study measures the extent of green transformation in high-feasibility enterprises by quantifying the frequency of green transformation-related terms in their annual reports.

In this study, we selected 113 keywords related to the green transformation of enterprises, focusing on aspects such as publicity, ideology, technology, innovation, management, and supervision. We calculated the frequency of each keyword in the annual report disclosed by listed enterprises, added 1 to the frequency of occurrence of each word, and then took the natural logarithm of the resulting data to measure the degree of green transformation of the enterprise. The results are displayed as a scatter plot, with a trend line drawn from the data. Figure 5 illustrates the outcome.

Since 2010, the green transformation index of all publicly traded companies in Hebei Province has consistently increased from 2.44 in 2010 to 5.46 in 2022. Although each individual enterprise's index does not experience stable growth, it is still following the upward trend. Notably, the difference in green transformation levels among enterprises has progressively expanded in the past 13 years. Based on the summary above, this study posits that variations in primary business categories among enterprises have caused the observed change. Consequently, we can conclude that green finance in Hebei Province has positively influenced the adoption of sustainable practices by businesses between 2010 and 2022.

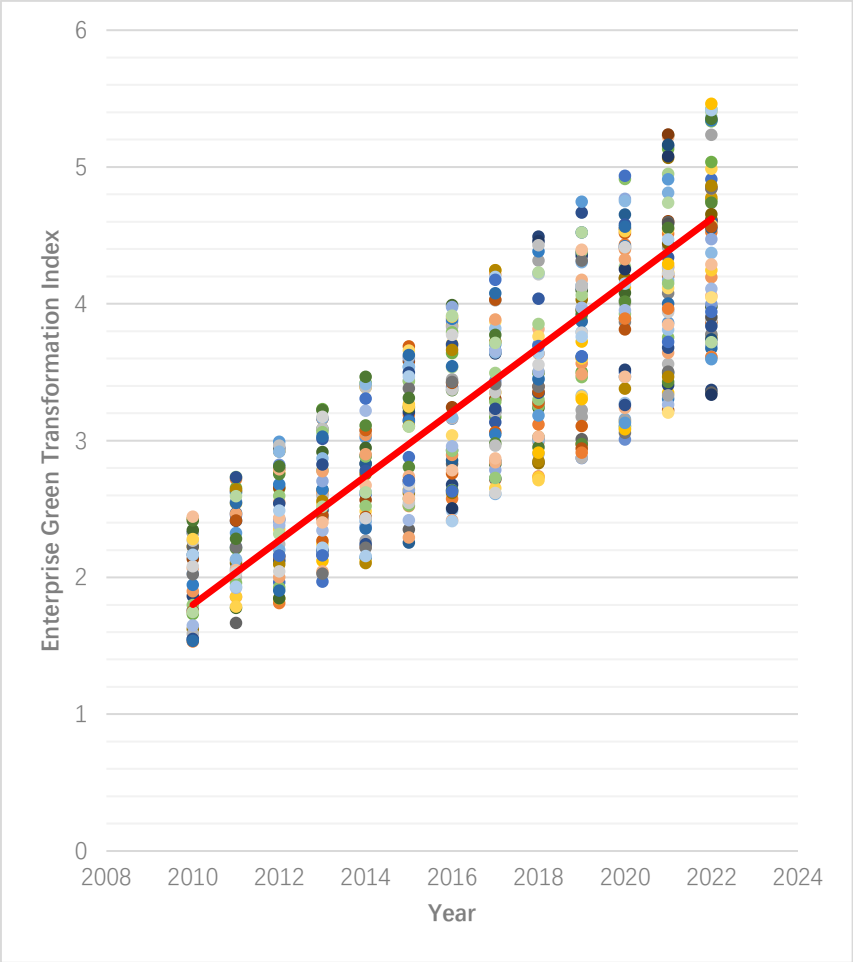


Fig. 5 Green transformation index of listed enterprises in Hebei Province

5. Conclusion

Based on the data, evidence, and research analysis, it can be concluded that between 2010 and 2022, certain aspects of green finance experienced significant development in Hebei Province. Furthermore, the degree of green securities development in Hebei Province surpassed that of most other areas in China. However, the development of various financial projects remains unbalanced. It is crucial to balance different projects and work collaboratively to achieve better results in green financial development. Furthermore, the development of green finance has facilitated the effective transformation of high-polluting enterprises in Hebei Province into environment-friendly enterprises. Based on the research methodology and computation results of this study, the level of green transformation among listed enterprises in Hebei Province has doubled. The discrepancy in the degree of green transformation between various firms is progressively expanding. It was noted that there were three instances in 2018, 2020, and 2022 where there was a discrepancy in the transformation progress of different enterprises. Based on current trends, it is anticipated that businesses will continue to prioritize environmentally-friendly practices in the future, leaving ample room for growth. As a result, companies within Hebei Province are expected to expedite their green transformation efforts over the next few years, ultimately progressing towards carbon neutrality and peak carbon emissions.

For the government and financial regulatory institutions in Hebei Province, it is imperative to enhance support for the growth of green finance. To foster balanced development in all areas of the province, it is necessary to optimize and incline policies in response to current inadequacies. The second strategy is to actively encourage the transformation of other areas of the enterprise, including digital transformation, to drive green transformation. The aim is to establish a scenario in which

different transformations complement and advance each other. Third, it is crucial to conduct a comprehensive analysis of the operations and transformations of businesses in the province. Provide targeted guidance and assistance to firms with limited transformational progress, minimize the gap between varying transformation rates, maintain a clear overview, and prevent "dragging back" or polarization.

Enterprises should take the initiative to respond to the call for green transformation and development. They should actively improve their old, high-energy consumption, and high-pollution production equipment and methods while implementing multiple measures to encourage innovation. Additionally, they should strictly abide by the provisions of the law, actively monitor their emissions of pollutants, waste water, waste gas, and carbon dioxide, and avoid discharging excessive or illegal emissions.

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