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Research article

Financing constraints change of China's green industries

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Abstract: Adequate funding is a crucial factor for the sustainable development of green industries. However, most green firms have suffered from financing constraints due to the negative externalities and information asymmetry of green finance. This study analyzes the driving factors of financing constraints index (FCI) of green industries from 2010 to 2019 using shift-share analysis. At the regional level, this study decomposes the change in FCI into three factors: national FCI change effect (NC), regional FCI change effect (RC), and regional FCI structure effect (RS). At the industry level, the study decomposes the change in FCI of green sub-industries into three factors: total industries FCI change effect (TIC), green industries FCI structure effect (GIS), and green sub-industries FCI structure effect (GSIS). The results show that the financing constraints on Chinese listed companies are getting stronger with each passing year. In particular, the financing constraints on green industries start to become larger than those of non-green industries after 2015. The decomposition results show that NC for each province is positive and relatively similar from 2010 to 2019. Nearly half of the provinces have positive RC values and there are more provinces with positive RS effects than those with negative RS effects. Most provinces are dominated by NC and RS effects. From the three green sub-industries, we observe that the TIC of all three sub-industries is positive, and GIS is positive in most years, while GSIS presents different characteristics. This study provides policy implications for alleviating financing constraints in green industries.

Keywords: financing constraints; green industries; green sub-industries; shift-share analysis; regional analysis; driving factors
Mathematics Subject Classification: 91B82, 91G50

1. Introduction

At present, the development of green industries is receiving more and more attention from countries. The global shortage of natural resources is becoming increasingly serious, and natural resources have become the key factor restricting the sustainable development of a country, coupled with the long-term and irreversible nature of environmental and ecological restoration, all of which have become the incentives for the development of green industries [1]. In addition, the competitiveness of a country is mainly reflected in the industrial competitiveness of an open economy. As the concepts of green products and green consumption gradually take root in people's hearts, bringing rapid growth of green demand, all countries will compete to develop various green industries. With the requirement of global green development, the green race is likely to change the current international competitiveness pattern. Every country has its own unique green competitiveness, so each country needs to promote domestic green industries strategically. For China, developing green industries also means actively fulfilling its international carbon reduction commitments [2,3]. At the 75th UN General Assembly in 2021, China announced that it aims to peak carbon dioxide emissions by 2030 and achieve carbon neutrality by 2060. As the world's largest energy consumer, China's fulfillment of such an ambitious commitment is essential for advancing the world's response to climate change.

Adequate funding is a crucial factor for the sustainable development of green industries [4,5]. First, most green industries represented by wind power, photovoltaic power, and hydropower require complete supporting infrastructure, and such investments are often characterized by large quantities and long cycles. Second, the development of green industries relies on the R&D and application of green technology, while innovation often needs to be driven by factors such as capital, technology, and talent [6,7]. In 2017, China Urban Green Financial Development Report showed that the green industries need at least two trillion Chinese yuan per year in the next five years, which is approximately the amount of investment above 3% of GDP, but government funds alone are far from enough, and the proportion of social capital investment must account for 85% to 90% [8].

Green industries are more difficult to finance than other short-term high-yield industries due to their characteristics. First, green industries have dual positive externalities, i.e., positive environmental externalities and positive externalities of green technological innovation, which decrease the likelihood of investment in green industrial development [9]. Under this premise, corporate interest in a green economy depends on good and consistent public policies, but due to the current inadequate emission right trading market mechanism in China represented by pollution rights trading, investors are unable to convert social utility into private gain in the market [10]. Second, green industries are characterized by long investment cycles, large capital requirements, and insignificant returns, which cannot attract high-risk investors. Third, green industrial development is highly policy-dependent, and the credibility of policies and the strictness of their implementation will affect the development of green industries [11,12].

For China's green industries, the impact of financing constraints is even more widespread and

profound. Since 2018, the environmental protection industry has been at the first sign of "financing difficulties" due to shrinking financing channels, soaring funding costs, and increasing credit risk in the context of "deleveraging". Then in early 2019, the stock price of the environmental protection industry fell by an average of nearly 35%, a decline greater than all other industries. Data from *the Chamber of Environmental Affairs of the All-China Federation of Industry and Commerce* show that the financing costs of large private environmental protection companies generally rose by more than three percentage points, and many companies are facing the challenge of whether they can continue to survive. It can be seen that the total annual investment in environmental protection in China is far from meeting the financial requirements of controlling environmental pollution, and the lack of funds for the environmental protection industry has become a critical factor in curbing environmental pollution.

To ease enterprises' financing constraints to help the development of green industries, the Chinese central and local governments have issued various policies. In 2014, the State Council issued the "Guiding Opinions on Taking Multiple Measures to Alleviate the Problem of High Financing Costs of Enterprises", emphasizing that a comprehensive solution to the high cost of enterprise financing is vital to stabilize economic growth and promote the transformation of economic structure [13]. Furthermore, the government gave local governments ten recommendations, including cleaning up unreasonable financial service fees, improving the efficiency of loan approval and disbursement, and developing small and medium-sized financial institutions. Subsequently, local governments introduced a series of supporting policies according to regional economic development, financial market perfection, and other factors [14]. Zhejiang, Fujian, and Hunan provinces have successively introduced their plans. The differences in policy intensity, policy credibility, and policy implementation in different regions make the government's influence in reducing financing costs have great regional differences, thus affecting the development of green industries. To further promote the catch-up of the domestic green industries and reduce the development differences among different regions, a clear understanding of the factors that constrain the development of green financing, and its regional distribution differences, is needed [7].

This study uses shift-share analysis to analyze the drivers of changes in financing constraints on China's green industries from 2010 to 2019. First, this study measures the financing constraints index (FCI) of listed companies and summarizes the characteristics of the FCI for regions and green sub-industries. Second, this study analyzes the drivers of FCI in provinces and green sub-industries from two dimensions: regional and industrial. From the regional level, this study decomposes the amount of FCI changes in each province from 2010 to 2019 into three factors: national FCI change effect (NC), regional FCI change effect (RC), and regional FCI structure effect (RS). At the industry level, this study decomposes the amount of FCI change in green sub-industries from 2010 to 2019 into three factors: total industries FCI change effect (TIC), green industries FCI structure effect (GIS), green sub-industries FCI structure effect (GSIS). Based on the decomposition results, we compare and discuss the characteristics of the drivers of regional and industry FCI changes. The results show that the financing constraints on green industries start to become stronger than those of non-green industries after 2015. Given the decomposition results, it shows that NC for each province is positive and relatively similar from 2010 to 2019. Nearly half of the provinces have positive RC values. We also observe that there are more provinces with positive RS effects than those with negative RS effects, and most provinces are dominated by NC and RS effects. The results from the three green sub-industries show that the TIC of all three sub-industries is positive, and GIS is positive in most years, while GSIS has different characteristics.

The rest of the study is organized as follows: Section 2 reviews the literature on financing constraints on green industries. Section 3 constructs the measurement model of financing constraints index and shift-share analysis for regions and industries and presents the data sources. Section 4, we present the regional and industry decomposition results and discuss them. Section 5 is the conclusion.

2. Literature review

The development of green industries is a core area of international competition in the future. Studies have been conducted to examine the important influencing factors in the development of green industries from the perspective of industrial policy [15], green technology development [16], market demand growth [17], social responsibility disclosure [18,19], and institutional-market-technology interactions [5], but the necessary attention to the importance of financing constraints is lacking.

The financial constraint affects the development of green industries in several ways, such as allocating corporate resources and choosing corporate strategies. First, financing constraints may distort the efficient allocation of resources. It has been found that credit constraints on manufacturing plants distort their asset composition and shift them toward overinvestment of intangible assets that can be used as collateral, thereby increasing emission intensity [20–22]. Similar conclusions are given by Zhang et al. [23], who find substitution effects existed in both fixed asset investment and intangible asset investment on the pollution control investment. Second, financing constraints discourage firms from investing in green innovation. Since green innovation is characterized by greater uncertainty and lower rates of return, financing constraints reduce the likelihood that firms will invest their limited resources in green innovation [24]. Song et al. [25] and Huang et al. [26] demonstrate through empirical studies that when the financing environment in which a firm operates is more relaxed, the firm's ability to innovate green is stronger. Li et al. [27] also find that financial development promotes green technological innovation.

At the macro level, the financing of green industries is influenced by the development of the financial sector [28,29]. Since green technologies are more immature than traditional non-green technologies, there is relatively high-level information asymmetry in the financing process, and financial innovation enhances green innovation in the industry by improving the information screening ability of financial intermediaries [30]. Meanwhile, financial sector development can enable managers to acknowledge the importance of environmental protection and let them take the initiative to improve green innovations [31-33]. Empirical studies have demonstrated that financial development plays a crucial role in the development process of biomass and non-biomass renewable technologies, and this promotion varies with countries' carbon intensity and innovation growth rate [34,35].

Studies have shown that green finance in China has experienced rapid development from 2011 to 2019 and tends to continue to improve [36]. However, China still has a significant financing gap to achieve the goals of "achieving carbon peaking by 2030 and carbon neutrality by 2060". In this context, it is necessary to decompose further the factors influencing the green financing constraints in each region of China to guide future policy formulation better.

3. Methodology and data

3.1. Measurement of financing constraint

The measurement of financing constraints is an important research issue in the field of corporate finance. The idea of quantitative measurement of financing constraints originated from Kaplan and Zingales [37], who qualitatively classify the degree of corporate financing constraints based on the financial status of firms in a limited sample, and then portray the relationship between the degree of financing constraints and variables of company characteristics, i.e., the financing constraints index (FCI). Livdan et al. [38] argue that the index construction method proposed by Whited and Wu [39] fits the financing constraints concept, and it has a better representation of financing constraints. Therefore, this study measures FCI using the method proposed by Whited and Wu [39]. In our study, the FCI is measured using a systematic generalized moment method for the parameter estimation of the investment Euler equation, which is modeled as follows:

$$\mathrm{FCI_{it}} = -0.091 \times CF_{it} - 0.062 \times DDiv_{it} - 0.021 \times Lev_{it} - 0.044 \times Size_{it} + 0.102 \times ISG_{it} - 0.035 \times SG_{it}, \quad (1)$$

where FCI is the financing constraints index. DDiv is the dummy variable of paying dividends. DDiv is 1 when the firm paid for dividends, otherwise DDiv is 0. Size is the natural logarithm of total assets in a given firm, and ISG measures the rate of increase in operating revenue of the given industry. SG is the rate of increase in operating revenue of the given firm. Then, we can calculate the FCI of each listed company by Eq (1). If the FCI is greater, the financing constraints on the firm is tighter.

3.2. Shift-share analysis from the regional and industrial perspectives

Shift-share analysis (SSA) is a method that can analyze the drivers of an indicator from different dimensional perspectives. This method is extensively used in regional economics, which is suitable for decomposing changes in an indicator in a region into the driving factors of global and relative changes. This study uses SSA to explore the drivers of financing constraints on China's green industries. SSA is an index decomposition method widely used in regional studies [40,41], and it is often used in the environmental and energy fields as well [42–44]. This paper aims to explore the drivers of FCI at the regional level and the industry level, so it is appropriate to use the SSA approach. Specifically, we construct two different SSA models to decompose the FCI from regional and industrial perspectives. It is noteworthy that the FCI measured by the Whited and Wu [39] method will let each effect own the following characteristic: a positive effect indicates that this effect tightens the financing constraints.

3.2.1. Shift-share analysis from the regional perspective

From the regional perspective, we construct a decomposition model of FCI of green industries for each province. The FCI growth rate of green industries for province i has the following constant Eq (2):

$$g_i = y + (y_i - y) + (g_i - y_i), \quad (2)$$

where g_i is FCI growth rate of green industries in province i. y and y_i are national and provincial FCI growth rates, respectively. After multiplying both sides of Eq (1) by FCI in green industries of

province i at the beginning of the period, we can obtain the classical three-component SSA decomposition of the change in FCI of green industries for province i as follows:

$$\Delta GFCI_i = GFCI_i \times g_i = GFCI_i \times y + GFCI_i \times (y_i - y) + GFCI_i \times (g_i - y_i), \tag{3}$$

where Eq (3) decomposes the change in FCI of green industries in province i, which is $\Delta GFCI_i$, into three drivers. The three drivers are in turn as follows:

$$NC_i = GFCI_i \times y. \tag{4}$$

The first component in Eq (4) is the National Financing Constraints Index Change Effect (NC), which is the product of the national FCI growth rate (y) and the FCI of green industries in province i ($GFCI_i$). NC reflects the change in FCI of green industries in province i if it grows at the national FCI growth rate.

$$RC_i = GFCI_i \times (y_i - y). \tag{5}$$

The second component in Eq (5) is the Regional Financing Constraints Index Change Effect (RC), which is to measure the effect of the difference between national and regional FCI growth rates ($y_i - y$) on the effect of the regional green industries FCI ($GFCI_i$). RC is positive if the FCI growth rate in province i is higher than that in the nation one, making ($y_i - y$) greater than 0. It means that RC tightens the financing constraints on green industries in province i.

$$RS_i = GFCI_i \times (g_i - y_i). \tag{6}$$

The third component in Eq (6) is the Regional Financing Constraints Index Structure Effect (RS), which measures how the difference in the growth rate of FCI between the regional industry-wide and regional green industries affects FCI of green industries in the province i. A positive RS indicates that FCI growth rate of green industries in province i is higher than that of all industries in province i. It means that RS makes the financing constraints on green industries in province i tighter.

From the regional perspective, by using the classical three-component SSA model above, we decompose the change in FCI of green industries in province i into the following three drivers in Eq (7), each with its meaning explained:

$$\Delta GFCI_i = GFCI_i \times g_i = NC_i + RC_i + RS_i. \tag{7}$$

3.2.2. Shift-share analysis from the industrial perspective

To analyze the drivers of changes in financing constraints for each sub-industry in green industries, we construct a decomposition model of FCI of green sub-industries from the industrial perspective. The following constant Eq (8) exists for sub-industry k of green industries:

$$gs_k = y + (G - y) + (gs_k - G), \tag{8}$$

where gs_k is FCI growth rate of green sub-industry k of the whole country. y and G are FCI growth rates of the entire country and of green industries, respectively. After multiplying both sides of Eq (8) by the FCI at the beginning of the period for sub-industry k, the classical three-component decomposition of the change in FCI of green sub-industry k is obtained as follows:

$$GSFCI_k = GSFCI_k \times gs_k$$

$$= GSFCI_k \times y + GSFCI_k \times (G - y) + GSFCI_k \times (gs_k - G)$$
$$= TIC_k + GIS_k + GSIS_k. \tag{9}$$

From the industrial perspective, we decompose the change in financing constraints on green sub-industries into three effects: Total Industries Financing Constraints Index Change Effect (TIC), Green Industries Financing Constraints Index Structure Effect (GIS), and Green Sub-Industries Financing Constraints Index Structure Effect ($GSIS$). The three effects are three components in Eq (9), and they are explained as follows: (1) TIC is the change in FCI of green sub-industries if it changes at the national FCI growth rate. (2) GIS is the change in FCI of green sub-industries caused by the difference in the FCI growth rate of green industries and all industries. A positive GIS indicates that the FCI growth rate of green industries is higher than that of all industries and therefore brings about the growth of FCI of green sub-industries, i.e., GIS strengthens the financing constraints on green sub-industries. (3) $GSIS$ is the change in FCI of green sub-industries due to the difference in FCI growth rate between green sub-industries and green industries. A positive $GSIS$ indicates that the FCI growth rate of green sub-industry k is greater than that of green industries, i.e., $GSIS$ strengthens the financing constraints on green sub-industry k.

3.3. Data

The first step in conducting our study is to clarify the scope of green industries. For green industries, there is currently no unified definition among scholars, governments, and institutions. In February 2019, China's National Development and Reform Commission, Ministry of Industry and Information Technology, Ministry of Natural Resources, Ministry of Ecology and Environment, National Energy Administration and other departments jointly issued the "Green Industries Guidance Catalog (2019)" which provides an approach to clarify green industries [45]. We comprehensively consider the definition of green industries in the guidance catalog and define two major categories of listed companies, namely new energy and environment, as the green industries for this study's research. Specifically, based on the Shenyin & Wanguo Securities (SWS) industry classification criteria widely used in China, we define the following SWS industry categories as green industries and the SWS industry classification codes are in parentheses: energy metals (240600), electric passenger vehicles (280501), hydroelectric power (410102), photovoltaic power (410106), wind power (410107), nuclear power (410108), other energy generation (410109), photovoltaic equipment (630500), wind power equipment (630600), batteries (630700), environmental protection (760000), which includes environmental management (760000) and environmental protection equipment II (760200). Environmental protection (760000) is the only primary industry among all these industries, while the others are categorized as secondary and tertiary industries. In this study, we divide the industries into three main green sub-industries: (1) Clean Energy: hydroelectric power, photovoltaic power, wind power, nuclear power, other energy generation, photovoltaic equipment, wind power equipment; (2) Electric Vehicles & Batteries: electric passenger vehicles, energy metals, batteries; (3) Environmental Services & Equipment: environmental management, environmental protection equipment II. The analysis from the regional perspective will use the above range of green industries. According to these three categories, the analysis from the industrial perspective will follow and show the three main sub-industries in green industries.

To analyze the factors influencing the financing constraints on green industries, we also need to measure the FCI of each listed company, each province, and industry. This study calculates the FCI of Chinese listed companies in the Shanghai and Shenzhen stock markets from 2010 to 2019. We employ listed companies' financial data, such as net cash flow from operating activities, total assets, cash dividends before tax per share, total long-term liabilities, and operating income growth rate to measure FCI. Listed companies' financial data and SWS industry classification data are obtained from CSMAR, WIND, and Choice databases. In addition, we treat the data of listed companies as follows: (1) excluding the listed companies that have been implemented risk warning (i.e., enterprises with ST stocks) during the sample period; (2) excluding the listed companies that have been delisted; (3) excluding the listed companies in the financial sector; (4) winsorizing main continuous variables at the 1% and 99% levels to mitigate the effect of outliers [46]. The national, provincial, and industrial FCI used in the SSA decomposition is derived from the average of the FCI of listed companies within the corresponding ranges.

It is worth mentioning that some provinces have been missing listed companies in the green industry for an extended period, making it impossible to use SSA to analyze the drivers for these provinces. For this reason, we exclude from the study six regions with long periods of missing green-listed companies, namely Shanxi, Inner Mongolia, Jilin, Hainan, Yunnan, and Qinghai. At the same time, we keep three regions that lack green-listed companies for a short period in Hebei, Shandong, and Anhui. In this case, our regional decomposition study covers 25 provinces in mainland China.

4. Results and discussion

4.1. National, regional and industrial financing constraints index

Figure 1 shows the changes in the financing constraints index (FCI) of green and non-green industries in China from 2010 to 2019. In general, the FCI of green and non-green industries maintains a stable growth trend, and the FCI of green industries starts to exceed the FCI of non-green industries in 2015. It indicates that the financing constraints on Chinese listed companies, in general, become stronger year by year, while the financing constraints on green industries starts to be stronger than that of non-green industries after 2015. Specifically, the FCI of green industries increased from 0.959 in 2010 to 1.032 in 2019, increasing by 0.073. Non-green industries' FCI increased from 0.971 in 2010 to 1.021 in 2019, increasing by 0.049. From 2010 to 2014, the green industries' financing constraints were looser than the non-green industries, and the average annual FCI difference is −0.009. From 2015 to 2019, the green industries' financing constraints become stronger than non-green industries, and their average annual FCI difference is 0.009. We believe that the environmental protection inspectors beginning in 2016 are one of the reasons why the FCI of green industries exceeds the FCI of non-green industries. To be more specific, the environmental protection inspectors starting in 2016 made the high-quality listed companies in the high pollution industry gain excess profits, easing the financing constraints on this large group of non-green industries listed companies, resulting in a higher FCI of green industries than the FCI of non-green industries.

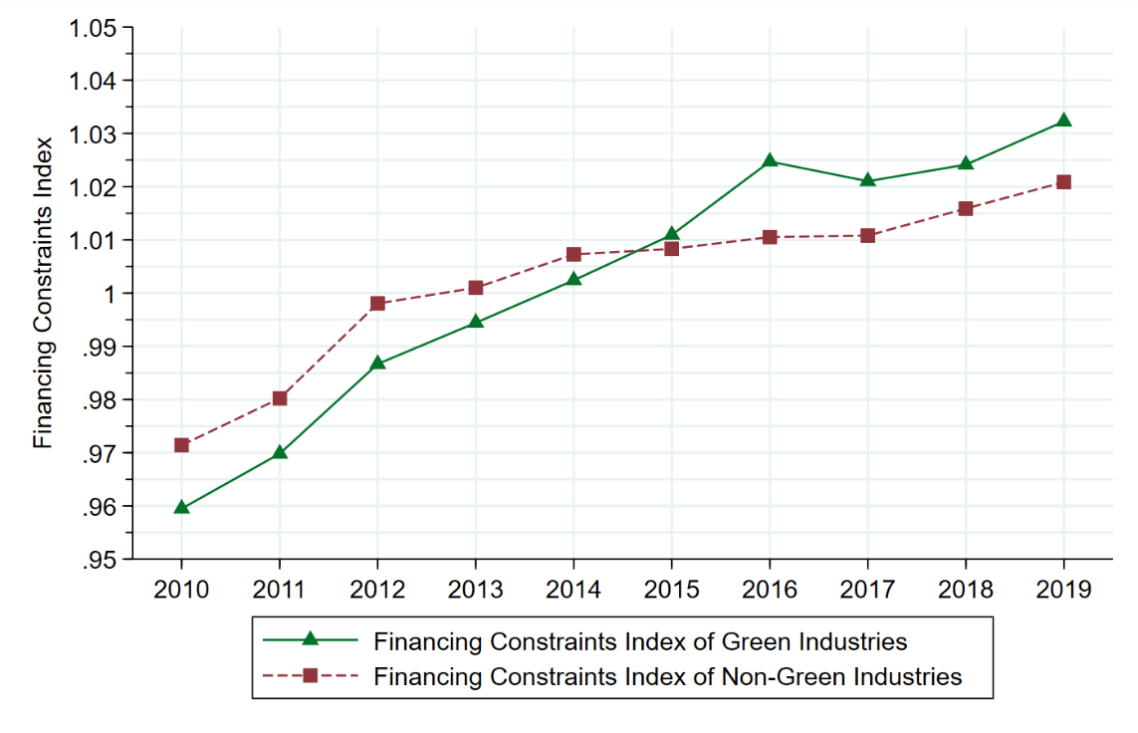

Figure 1. FCI of green industries and non-green industries in China, 2010–2019.

Figure 2a–c show the FCI changes of green and non-green industries in the East, Central, and West from 2010 to 2019. Overall, the FCI of green and non-green industries in the three regions shows an increasing trend, which means that the financing constraints of green and non-green industries, in general, have become tighter in each region. Specifically, the FCI of green and non-green industries in the eastern region maintains a stable growth trend, and the changing trend is similar to the national situation. The FCI of green industries in the central region fluctuates and rises. In particular, the FCI of green industries in the central region increased rapidly in two periods, 2012–2013 and 2015–2016, and non-green industries' FCI in the central region increased by 0.036 and 0.034 in these two time periods, respectively. The FCI of green industries in the western region increased from 0.965 in 2010 to 1.042 in 2019 while peaking at 1.047 in 2016. Moreover, the FCI of green industries in the West kept rapid growth from 2011–2012 and 2015–2016, during which the FCI of green industries in the West increased by 0.026 and 0.031, respectively.

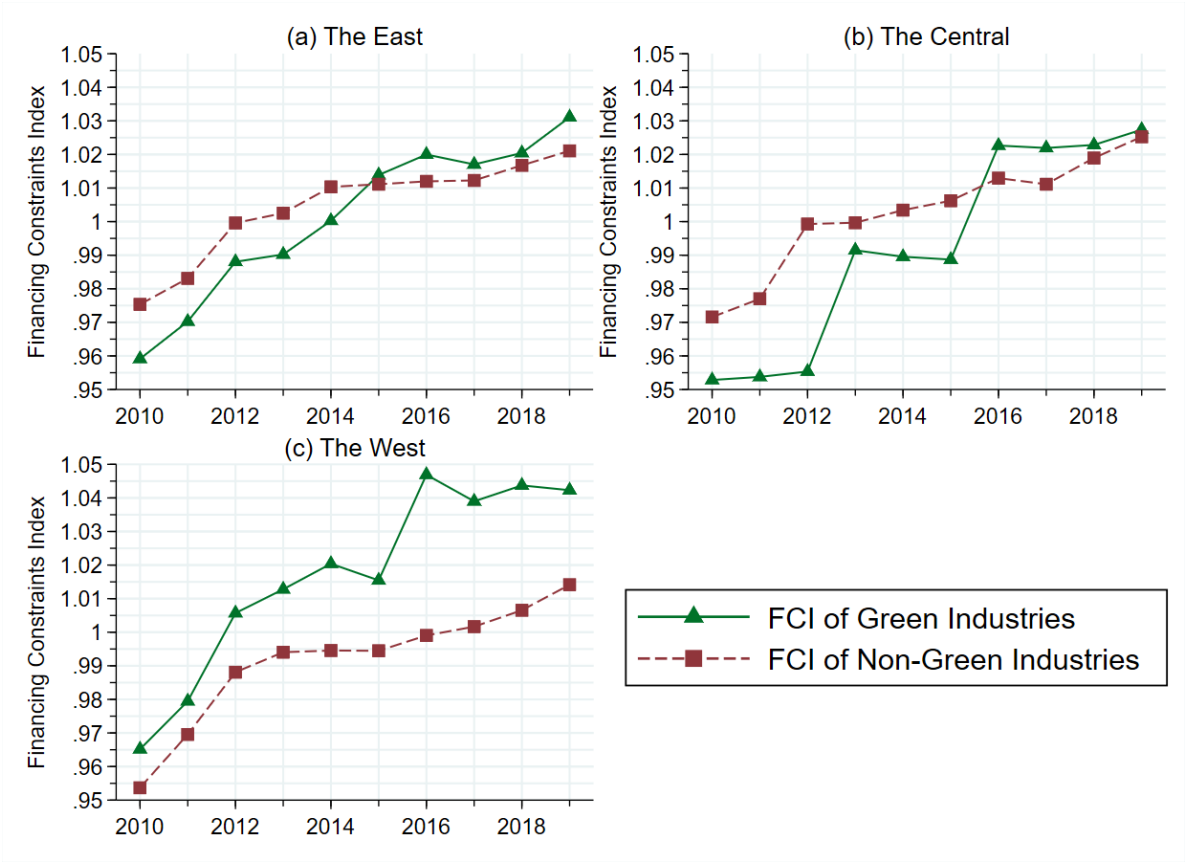

Figure 2. FCI of green industries and non-green industries in different regions, 2010–2019: (**a**) The East; (**b**) The Central; (**c**) The West.

Figure 3 shows the trend of FCI changes in three major green sub-industries in China from 2010 to 2019. Overall, the FCI of China's non-green industries shows a stable growth trend, while the FCI of the three green sub-industries of clean energy, electric vehicles & batteries, and environmental services & equipment shows a fluctuating upward trend. Specifically, the FCI of non-green industries increased from 0.971 in 2010 to 1.021 in 2019. The FCI of clean energy increased from 0.987 in 2010 to 1.045 in 2019, only decreasing from 2016 to 2018. The FCI of electric vehicles & batteries increased from 0.943 in 2010 to 1.021 in 2019. The FCI of environmental services & equipment increased from 0.942 in 2010 to 1.027 in 2019, decreasing only from 2016 to 2017. Both electric vehicles & batteries and environmental services & equipment grew faster from 2010 to 2012, and growth leveled off.

The change in FCI growth among different sub-industries shows different characteristics. Among them, the FCI growth of non-green industries is 0.049, which is the slowest growth. The FCI growth of 0.085 for environmental services & equipment and 0.078 for electric vehicles & batteries are growing more rapidly. Therefore, around 2015, the FCI of electric vehicles & batteries and environmental services & equipment exceeded the FCI of non-green industries and remained ahead. Meanwhile, the FCI of clean energy is higher than that of non-green industries and the other two green sub-industries.

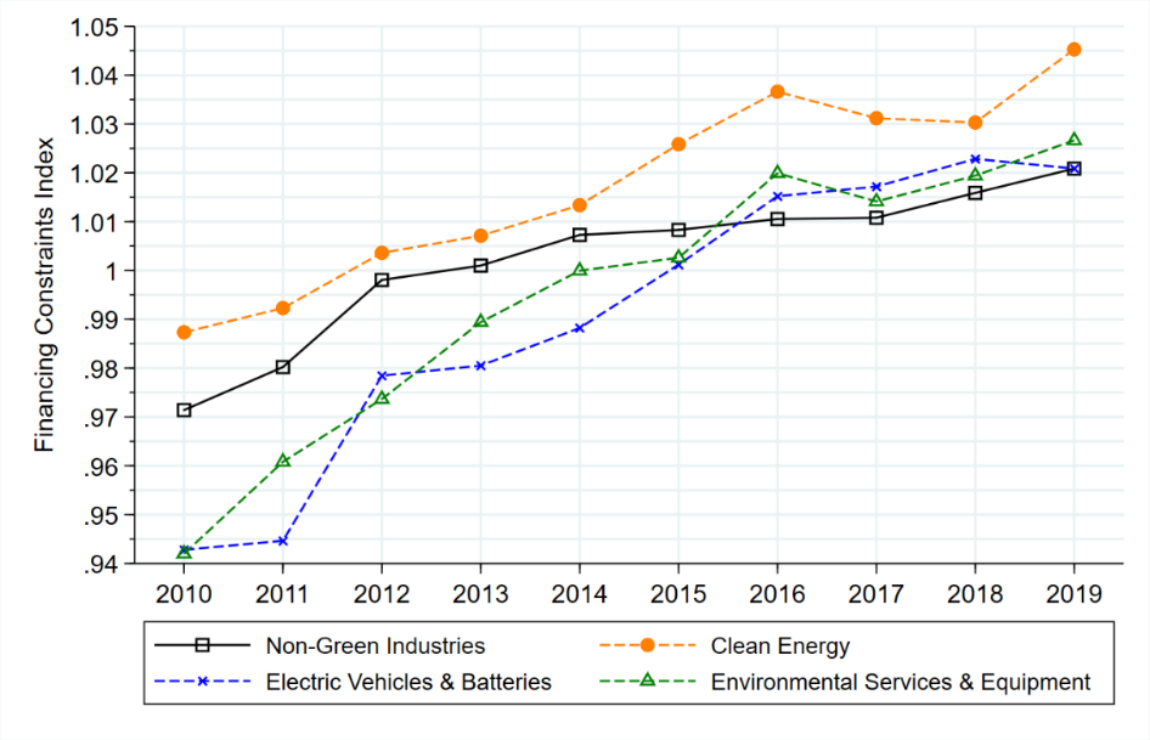

Figure 3. FCI of non-green industries and green sub-industries, 2010–2019.

4.2. National, regional, and industrial financing constraints index

Figure 4a–c show the national FCI change effect (NC), regional FCI change effect (RC), and regional FCI structure effect (RS) for each province within the eastern, central, and western regions from 2010 to 2019. The figure ranks the provinces from highest to lowest according to the amount of change in FCI of green industries, which is the sum of the three effects. Overall, NC is positive for all provinces in the East, Central and West, and both positive and negative values of RC and RS are present. It indicates that NC strengthens financing constraints on green industries, but the effect of RC and RS is not certain. Specifically, all provinces in the national region have positive NC values with slight differences, ranging from 0.04 to 0.06. Both positive and negative RC values exist, and the number of provinces with positive and negative values is similar. 12 out of 22 provinces have positive RC values, and ten provinces have negative RC values, and their absolute values differ significantly. Positive and negative RS values exist, and there are more provinces with positive effects. 14 out of 22 provinces have positive RS values and eight provinces have negative values, and their absolute values differ significantly. In terms of contribution, most of the provinces are dominated by NC and RS, and the overall contribution of RC is smaller. These decomposition results suggest that most provincial FCI changes are mainly driven by two factors: the national factor and provincial green industry structure factor, rather than by national and regional industry-wide FCI differences. We believe this phenomenon is mainly due to the fact that the financing constraints are not very discrete and are relatively even across regions. That is, the policy to alleviate financing constraints should focus on overall national policies and green industry policies within provinces, rather than on overall provincial policies.

From Figure 4, we compare RC and RS to see regional differences among the eastern, central, and western provinces. The influence of RS on the amount of change in green industries' FCI in the

eastern and central regions is much greater than that of RC, and the difference between the influence of RC and RS in the western provinces is smaller. It indicates that the changes in green industries' financing constraints in the eastern and central regions depend mainly on NC and RS, while the western region needs to pay attention to the possible effects of the three effects. Specifically, only Liaoning (−0.0148) and Tianjin (−0.0728) of 8 provinces in the eastern region have negative RS, while the rest of the provinces have positive values. Guangdong (0.0051), Liaoning (0.0027), and Tianjin (0.0022) have positive RC values, while the rest of the provinces have negative values. The absolute value of RC in the eastern region is relatively small, which has less influence on the change in green industries' FCI, and the change in green industries' FCI in most provinces depends on NC and RS. Only Hubei (−0.0373) and Jiangxi (−0.0697) have negative RS in the central region provinces, while the rest are positive. Hunan (0.0046) and Hubei (0.0150) have positive RC values, while the rest are negative. The absolute value of RC is also smaller in the central region, which has less influence on the change in green industries' FCI, and the change in green industries' FCI in most provinces still depends on NC and RS. Most provinces in the western region have positive values of RC and RS, only Ningxia (−0.0208) and Xinjiang (−0.0412) have negative values of RC, and Gansu (−0.0135), Tibet (−0.0141), Guizhou (−0.0142) and Guangxi (−0.0703) have negative RS, while all other provinces have positive values. The influence of RC in the western region is significantly greater than that in the eastern and central regions, and the contribution of RC in Gansu is even higher than that of RS. The change in green industries' FCI in the western provinces depends on the three effects.

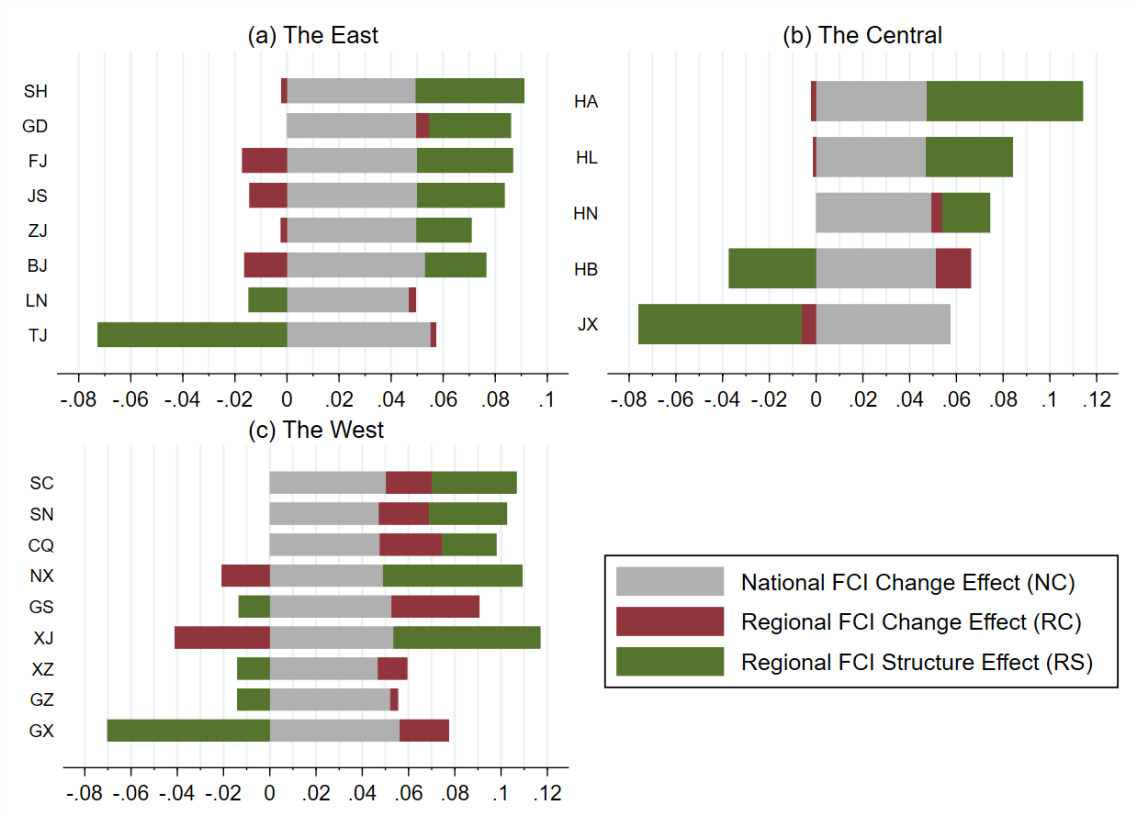

Figure 4. Three driving factors of provincial FCI of green industries, 2010–2019: (**a**) The East; (**b**) The Central; (**c**) The West.

4.3. Decomposition results of financing constraints index of green sub-industries

Figure 5a–c show the decomposition results of driving factors of FCI of three green sub-industries from 2010 to 2019, namely total industries FCI change effect (TIC), green industries FCI structure effect (GIS), and green sub-industries FCI structure effect (GSIS). Overall, TIC is positive for all three green sub-industries and GIS is mostly positive, while the three sub-industries' GSIS have different characteristics. Comparing the three green sub-industries, we find that the three effects of the two green sub-industries, electric vehicles & batteries, and environmental services & equipment, have exactly the same direction and similar magnitude over the years. The differences in the FCI of the three sub-industries are slight, resulting in little difference in their TIC and GIS, and the difference is mainly in the GSIS. For clean energy, the GSIS appears negative seven times, with only positive values for 2014–2015 and 2018–2019. As for electric vehicles & batteries and environmental services & equipment, GSIS showed five positive values and four negative values.

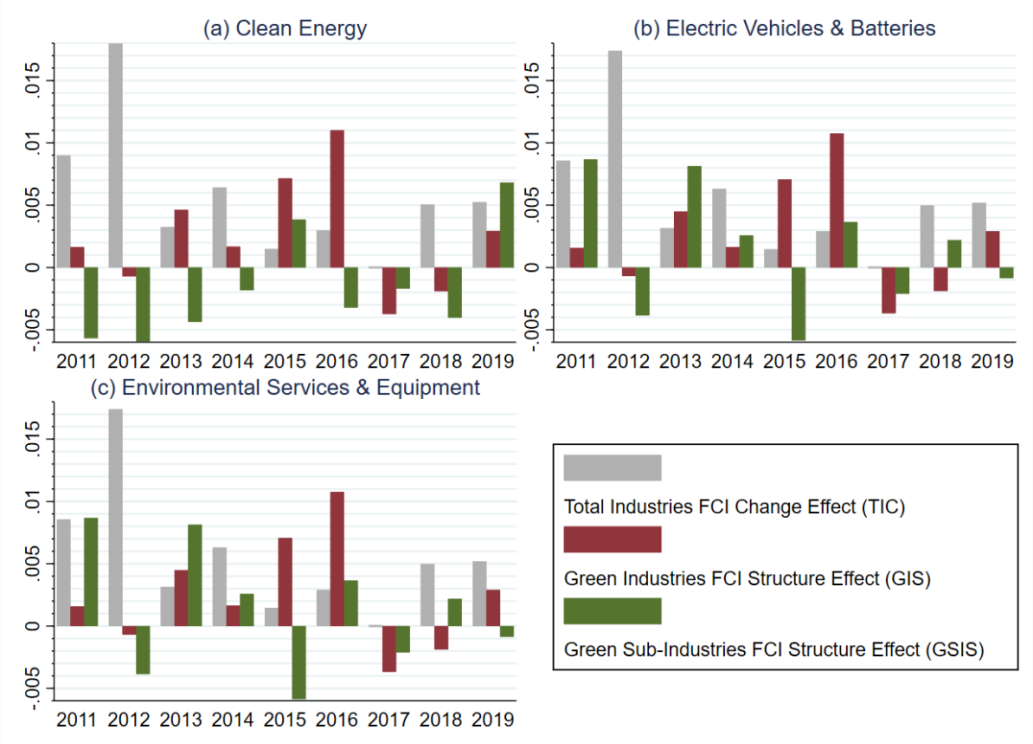

Figure 5. Three driving factors of FCI of green sub-industries, 2010–2019: (**a**) Clean Energy; (**b**) Electric Vehicles & Batteries; (**c**) Environmental Services & Equipment.

5. Conclusions

This study measures the financing constraints index (FCI) of Chinese listed companies and summarizes the characteristics of FCI of different regions and green sub-industries. Based on the results of FCI, this study decomposes the change in FCI of each province into three factors: National FCI Change Effect (NC), Regional FCI Change Effect (RC), and Regional FCI Structure Effect (RS). Then, this study decomposes the change in FCI of green sub-industries into three factors: Total

Industries FCI Change Effect (TIC), Green Industries FCI Structure Effect (GIS), and Green Sub-Industries FCI Structure Effect (GSIS). With the decomposition results, we discuss the characteristics of the drivers of regional and industrial FCI. The main findings of this study are as follows:

(1) Nationally, the financing constraints on Chinese listed companies are generally getting stronger year by year. The growth of FCI of green industries is larger than that of non-green industries from 2010 to 2019, while the financing constraints on green industries start to become stronger than that of non-green industries after 2015. Looking at the three regions, the financing constraints on green industries in the West are consistently stronger than those in the East and Central from 2010 to 2019. The green industries' FCI in both eastern and central regions exceeded the non-green industries' FCI around 2015, while the green industries' FCI in the western region has been consistently greater than the non-green industries' FCI from 2010 to 2019, with the gap increasing.

(2) From the industrial perspective, three green sub-industries discussed, which are clean energy, electric vehicles & batteries, and environmental services & equipment, have seen fluctuating and increasing trends in financing constraints. Among them, the FCI of the latter two sub-industries grows faster. At the same time, financing constraints on clean energy are basically stronger than those of non-green industries and the other two green sub-industries.

(3) Given the decomposition results, we find that NC for each province is positive and relatively similar from 2010 to 2019. Nearly half of the provinces have positive RC values, and the others have negative ones. There are more provinces with positive RS effects than those with negative RS effects. Most provinces are dominated by NC and RS. The comparison of each region shows that the extent influenced by RS is much greater than the extent affected by RC in the eastern and central regions, while the difference between the influence of RC and RS effect is smaller in the western provinces.

(4) Looking at the three green sub-industries, the values of TIC of all three sub-industries are positive, GIS is positive in most years, while GSIS has different characteristics. All three effects of the two sub-industries, electric vehicles & batteries, and environmental services & equipment, have the same positive/negative direction and similar magnitude of impact in all years. The difference between clean energy and the other two green sub-industries discussed is mainly GSIS.

The importance of green financing for the development of green industries has now been widely recognized. In order to further promote the development of green financing, this paper proposes as follows: firstly, various government departments should coordinate more, formulate unified regulatory standards, promote the transparency of information and improve the efficiency of the green financial market system. Secondly, local governments should carefully analyze the local situation and be more willing to introduce incentive policies targeting on green financing. Meanwhile, related departments should promote the integration of green financing with industrial development, green poverty alleviation, ecological restoration, and some other goals. Furthermore, the government should encourage banks and other financial institutions to strengthen the innovation of green credit products and support the development of start-ups and SMEs focusing on the green industry.

There exist some limitations in this study. First, there are representativeness issues for listed companies. This study uses the relatively comprehensive data available for listed companies in China and measures the FCI of companies while conducting regional and industry analysis. However, this is not representative enough of all firms in the region and industry. A more accurate study can be conducted in the future if more comprehensive financial data of enterprises within each region and industry in China become available. Second, the index decomposition method used in this study does not strictly obtain causal effects, although SSA is one of the classic models in regional analysis. Similar

to other index decomposition methods, like LMDI, SSA only obtains aggregate decomposition results. Although we can obtain the drivers using this approach, it is still not an accurate causal effect. Third, similar to other index decomposition methods, this study only discussed the drivers in the constructed model, while many other factors may also contribute to the financing constraints on green industries.

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Conflict of interest

All authors declare no conflict of interest in this paper.

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