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RESEARCH ARTICLE

The influence of green credit on China's industrial structure upgrade: evidence from industrial sector panel data exploration

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Abstract

The green credit is one of the effective tools to save energy and reduce pollution, which mainly applies in industry. Thus, this paper explores the impact of green credit on the upgrading of China's industrial structure from the perspective of industrial sectors, by means of a dynamic panel model with the dada from 2005 to 2016. The upgrading of industrial structure is divided into three dimensions to be analyzed—rationalization of industrial structure (RIS), advancement of industrial structure (AIS), and greenization of industrial structure (GIS). The empirical results are also explained by four influence mechanisms—resource allocation, technological innovation, credit catalysis, and policy guidance mechanism. This paper finds that on the national level, green credit has a positive impact on the upgrading of China's industrial structure and plays a significant role in promoting the greenization and advancement of industrial structure. However, on the regional level, the effect of green credit is more complex. First, green credit has a significant positive effect on the GIS in the eastern, central, and western regions of China, which suggests that green credit is conductive to the cleaner production of industry across the country. Second, green credit also has a positive impact on the AIS in these three regions, but the effect is only significant in the eastern region. Third, in terms of the RIS, the effect of green credit is positive but not significant in the eastern and central regions. However, it is negative, not significant as well, in the western region, which can be explained from the perspective of the resource allocation and technological innovation mechanism. In addition, there is a significant positive correlation between the previous period and the current value of RIS, AIS, and GIS, which indicates that there is a significant positive inertia dynamic feature in the upgrading of China's industrial structure.

Keywords Green credit · Industrial structure · Resource allocation mechanism · Technological innovation mechanism

Introduction

As the lifeblood of the national economy, the industrial sector is the foundation of a country, and its scale of development and degree of modernization are crucial to the economic development of a country or region. Under the "new normal," China's economy is transforming from rapid development to high-quality and green development. Now, the transformation and upgrading of industrial structure becomes the main battlefield of the conversion of China's economic growth mode. Furthermore, the upgrading of industrial structure is inseparable from financial support. China's financial system is dominated by indirect financing. More specifically, bank credit accounts for a high proportion of the social financing system. In the financing scale of China's listed enterprises, external financing accounts for as much as 80%, and the external financing of Chinese enterprises mainly comes from bank loans (He et al. 2019c). Thus, credit funds are the main ways of financing for Chinese

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enterprises. However, banks and other financial institutions in China have "preferred" heavy-polluting industrial enterprises with heavy asset mortgage for a long time (Liu and Wen 2019; Dong et al. 2020), which has caused difficulties of obtaining loans for cleaner production enterprises. This phenomenon has seriously hindered the upgrading of China's industrial structure.

In this context, the China Banking Regulatory Commission, People's Bank of China, and State Environmental Protection Administration jointly proposed the "Opinions on Implementing Environmental Protection Policies and Regulations to Prevent Credit Risks" in 2007, which means that green credit is used as an economic measure to promote energy conservation and emission reduction. Green credit requires banks and other financial institutions to adhere to the principles of environmental protection and energy conservation to lend to companies with differentiated interest rates. Therefore, green credit, as a type of bank credit funds, helps promote the green development by directly supporting cleaner production enterprises and guiding the transformation of polluting enterprises. The "China Green Finance Development Report (2018)" issued by the People's Bank of China showed that the green credit balance of 21 major banking institutions in China increased from 5.2 trillion yuan to 9.66 trillion yuan from 2013 to the end of 2018. According to the "Social Responsibility Report of China's Banking Industry in 2019" released by the China Banking Association, the green credit balance of 21 major banks has exceeded 10 trillion yuan at the end of 2019.

Few studies have investigated the relationship between green credit and the upgrading of industrial structure. This article tries to examine whether the expansion of China's green credit scale has promoted the upgrading of China's industrial structure or not from three dimensions: rationalization, advancement, and greenization. Is there any heterogeneity in the impact of green credit on these three dimensions? Based on the provincial panel data from 2005 to 2016, this study uses a dynamic panel data model to study the impact of green credit on the upgrading of industrial structure from three dimensions, and provide an empirical evidence for the government to promote the upgrading of industrial structure. Referring to *Statistical Yearbook of China's Industrial Economy*, the industrial structure conducted in this article is composed of 35 industrial industries, covering data from the industries of manufacturing, mining, and electric power, thermal power gas and water production and supply, etc. (see Appendix 1).

Literature review and theoretical analysis

Literature review

The existing literatures have made rich achievements in the influencing factors of industrial structure upgrading and green credit, but only a few scholars have studied the impact of green credit on industrial upgrading.

Research on influencing factors of industrial structure upgrading

The research on the factors affecting the upgrading of industrial structure can be divided into two categories from the perspective of supply and demand. In terms of supply, recent literatures mainly focus on environmental regulation, technological progress, capital market and FDI, etc., among which, the impact of environmental regulation on the upgrading of industrial structure is relatively complex. Some scholars believe that environmental regulation can force enterprises to make technological progress and promote the upgrading of industrial structure (Acemogilu et al. 2012; Song and Wang 2013; Yu and Wang 2021; Zhang, 2019). A few scholars claim that environmental regulation will increase the production cost of enterprises and squeeze out a part of innovation investment, which is not conducive to the upgrading of industrial structure (Rubashkina, et al. 2015; Zhong et al. 2015); others consider that the impact of environmental regulation on the upgrading of industrial structure presents a "J" curve (Tong et al. 2016). Most of the existing literature believes that technological progress has a positive effect on the upgrading of industrial structure (Antonelli 2006; Zhang et al. 2019a, b; Wu and Liu 2021). Moreover, the technological progress rate of heavy industry, relative to light industry, is the main driving force of industrial structure upgrading (Yang, et al. 2016). In terms of capital market, Wang et al. (2019a, b) have examined that indirect financing channels have a significant positive effect on the upgrading of industrial structure, while the impact of direct financing channels is weak and negative. Jiang et al. (2020) have found that outward foreign direct investment (OFDI) is conductive to the upgrading of China's industrial structure, and the effect of OFDI becomes more significant with the increasing level of financial development.

There is relatively less literature on the upgrading of industrial structure from the perspective of demand, and the existing articles mainly consider the impact of consumption and export on the upgrading of industrial structure. Fujita and James (1989) investigated the industrialization process of South Korea from 1973 to 1983 and found that it was the demand for industrial products at home and abroad that drove the development of industrialization rapidly in South Korea during the sample period. Dai (2012) hold that industrial export trade is conducive to promoting the rationalization of industrial structure through VAR model. Wang (2013) studied the changing trend of China's industrial structure from the perspective of demand, and found that export-oriented industries can quickly transform excess heavy industrial capacity to promote the upgrading of industrial structure, and the expansion of household consumption had a positive effect on the adjustment of industrial structure and could adjust the ratio between heavy industry and light industry (Wang et al. 2013). Li J. et al. (2020) found that consumer finance could promote the upgrading of industrial structure through two-step systematic GMM estimation, and its positive effect on the rationalization of industrial structure is greater than the advancement of industrial structure.

Research on green credit

The existing literature on green credit mainly focuses on the qualitative and theoretical analysis of operation mechanism, policy system, and challenges during policy implementation (Aizawa and Yang, 2010; Evangelinos and Nikolaou 2009; Goss and Roberts 2011; Verma 2012; Weber 2012; Zhang et al. 2011), while quantitative and empirical studies did not gradually appear until the recent years and these studies focus on that whether green credit can reduce pollution, affect the investment and financing of both heavy pollution enterprises and green enterprises, promote innovation, or improve green economic growth.

Kang et al. (2020) have found that green credit has a positive effect on reducing pollution in South Korean respectively. Li et al. (2018) has also demonstrated that green credit is conductive to improving the environmental quality through cutting down the energy emission. Meanwhile, Zhang et al. (2021) proved that the implementation of green credit significantly decrease carbon dioxide emissions intensity. Ma et al. (2021) and Song et al. (2021) found that green credit can improve energy efficiency. In addition, scholars have discovered that green credit can inhibit the investment and financing of heavy pollution enterprises (Ding 2019; Liu 2006; Wang et al. 2019a, b), and the inhibition effect has kept increasing since the "Green Credit Guidelines" issued in 2012 (Su and Lian 2018; Peng et al. 2021), and meanwhile the green enterprises have received more capital with lower debt financing cost and longer debt financing maturity (Xu and Li 2020). However, Liu (2019b) believes that the development of green finance is not conductive to enhancing the renewable energy investment efficiency, and it has aggravated the under-investment situation for under-invested renewable energy enterprises, although it can curb their overinvestment condition, based on an intermediary effect model. In terms of innovation, Li and Xu (2018) has suggested that green load subsidy can encourage technical innovation of enterprises, as well as enhance the innovation risks. Guo et al. (2019), He et al. (2019c), Hu et al. (2021), Zhang (2021), and Liu et al. (2021) have also found that green credit has a significant positive effect on technological innovation. Nevertheless, Wen et al. (2021) proved that green credit had a significantly negative effect on the R&D intensity of energy-intensive enterprises. With regard to green economic growth, Xie and Liu (2019) has examined that green credit has a positive effect on green economic growth by improving technological progress, based on a GMM model. He et al. (2019a) green credit can improve green economic growth by controlling the environment pollution and adjusting industrial structure.

Research on the impact of green credit on the upgrading of industrial structure

There is relatively less literature on the effect of green credit on industrial structure upgrading, most of which focus on the theoretical point of view (Tan and Fu 2010; Chen and Hu 2011), only quite a few place emphasis on the empirical perspective. Using a dynamic panel model, Xu et al. (2018) has found that green credit can promote the upgrading of China's industrial structure, especially in the eastern and western regions, but the effect in the central region is not significant. Li Y. et al. (2020) used the fixed effect model and discovered that green credit could promote the upgrading of China's industrial structure, based on a provincial panel data from 2000 to 2016. More specifically, this paper has found that green credit can promote the structural upgrading of the secondary industry, but simultaneously restrain the upgrading of the tertiary industry by the regression of subindustry. Hu et al. (2020) has also examined that green credit promotes the upgrading of industrial structure significantly by a fix effect model.

From the above literature review, it can be seen that the gap to the existing literature and the marginal contribution of this paper are as follows: firstly, the above articles mainly study how green credit affect the primary industry and secondary industry transforming to tertiary industry. However, the pollution in China mainly comes from industries like mining and manufacturing, and green credit policy in China mainly targets on these industries as well. Thereby, investigating industry sector can reflect the effect of green credit policy better than studying primary industry to tertiary industry. Secondly, most empirical studies use the interest expenses of six energy-consuming industries as a reversed index to measure green credit, which can only represent part of green credit when studying all the industries—from primary to tertiary industry. This article uses the ratio of interest expenses of all cleaner production industries to the interest expenses of all industrial industries to measure green credit, which is a more direct and accurate index to represent green credit when studying industrial structure. Thirdly, with regard to theoretical mechanism, most of the literature's analysis of the industrial structure is biased towards the adjustment and optimization of a certain dimension, this article explores the impact of green credit on China's industrial structure from three dimensions rationalization, advancement, and greenization and thoroughly sorts out the influence mechanism of green credit on the industrial structure, which is a supplement to the empirical literature on green credit and also enrich the theoretical mechanism of existing literature.

Theoretical analysis on the impact of green credit on industrial structure

Resource allocation mechanism

The flow of funds among industries can promote new industrial increment, which in turn affects the industrial structure; that is, capital flow can promote the change of industrial structure by changing the existing industrial stock. Most of the polluting enterprises are capital-intensive enterprises, which have long been "preferred" by banks and other financial institutions because of their relatively sufficient mortgage assets (Liu 2019), and excessive concentration of credit resources directly leads to overcapacity of these enterprises (Liu 2006). Green credit can reduce the capital inflow of polluting industries by increasing their loan interest rate, reducing the credit line, and cutting down or stopping the credit support for their high-pollution and high-energy-consuming projects. At the same time, green credit gives cleaner production enterprises with high efficiency, more favorable loan interest rate, and higher credit line support, which leads to more funds flowing into cleaner production industry and effectively solve their problems of difficulties on obtaining loans caused by lack of mortgage assets. Through the resource allocation mechanism, green credit can guide more funds from polluting industries into cleaning industries, that is, capital flows from industries with overcapacity and high capital density to industries with low capital density and high capital efficiency, which is conducive to the optimization of resource allocation and the improvement of resource utilization efficiency, thereby boosting the rationalization of industrial sectors.

However, if the intensity of green credit is not strong enough or the enforcement is not in place, and the polluting enterprises try to increase their income by enhancing factor input and offset the rising cost of green credit, then the pollution emissions will increase and the resource utilization efficiency will decline, which will cause the distortion effect of resource allocation. This will have a negative impact on the process of industrial rationalization and greenization (see Fig. 1).

In the industrial sectors, China's high-tech industries are currently included in the scope of cleaning industry; thus, part of the funds flowing into the cleaning industry are directly introduced into the high-tech industry, which has a direct effect on promoting the advancement of China's industrial structure. In addition, for a long time, banks and other financial institutions have "preferred" some polluting enterprises with sufficient mortgage assets, and the cleaning industry has different levels of financing constraints. As a result, enterprises in the cleaning industry have invested most of their funds in high-yield projects, and their R&D investment with long cycles and high risks has been compressed to varying degrees. Green credit alleviates the financing constraints of clean enterprises by means of low interest rate and high credit line, and their R&D investments get more financial support correspondingly, which indirectly promotes the advancement development of industrial structure. Therefore, green credit is conductive to the advancement of industrial structure in both direct and indirect ways through resource allocation mechanism.

Technological innovation mechanism

Technological innovation is vital to the optimization and upgrading of industrial sector, and directly determines the changing form and trend of the industrial internal structure.

In terms of cleaner production industries, if more green credit flows to low-tech industries to encourage them to carry out technological innovation and bring about a rise in factor productivity, the level of RIS will increase, but the degree of AIS will decrease. If more green credit flows to high-tech industries, it will encourage enterprises to carry out technological innovation by alleviating the huge financial pressure and risks they face in the initial stage of innovation, which will promote the development of AIS, but the impact on RIS will be relatively complex. If green credit flows into high-tech industries with high per capita capital and labor productivity, technological innovation can further improve their per capita capital and labor productivity and widen the gap between them and other industries, which will undermine the development of RIS; if green credit flows into high-tech industries with low per capita capital and labor productivity, technological innovation will increase their per capita capital and labor productivity, and narrow the gap between them and other industries, which is helpful to the improvement of RIS.

In terms of polluting enterprises, green credit can force them to carry out technology innovation for both environment protection and productivity by increasing their financing cost in the long term. The implementation of green credit has led to the rise of their financing cost and decrease of their profits. In order to solve the problem of high financing cost, polluting enterprises have to improve the level of environmental technology innovation to reduce pollution emissions and energy consumption, so as to alleviate the financing cost of bank credit; meanwhile, polluting enterprises have to increase production technology innovation to improve productivity and enhance economic output per unit factor input, as well. Environmental technology innovation aimed at pollution emission can directly improve RIS by

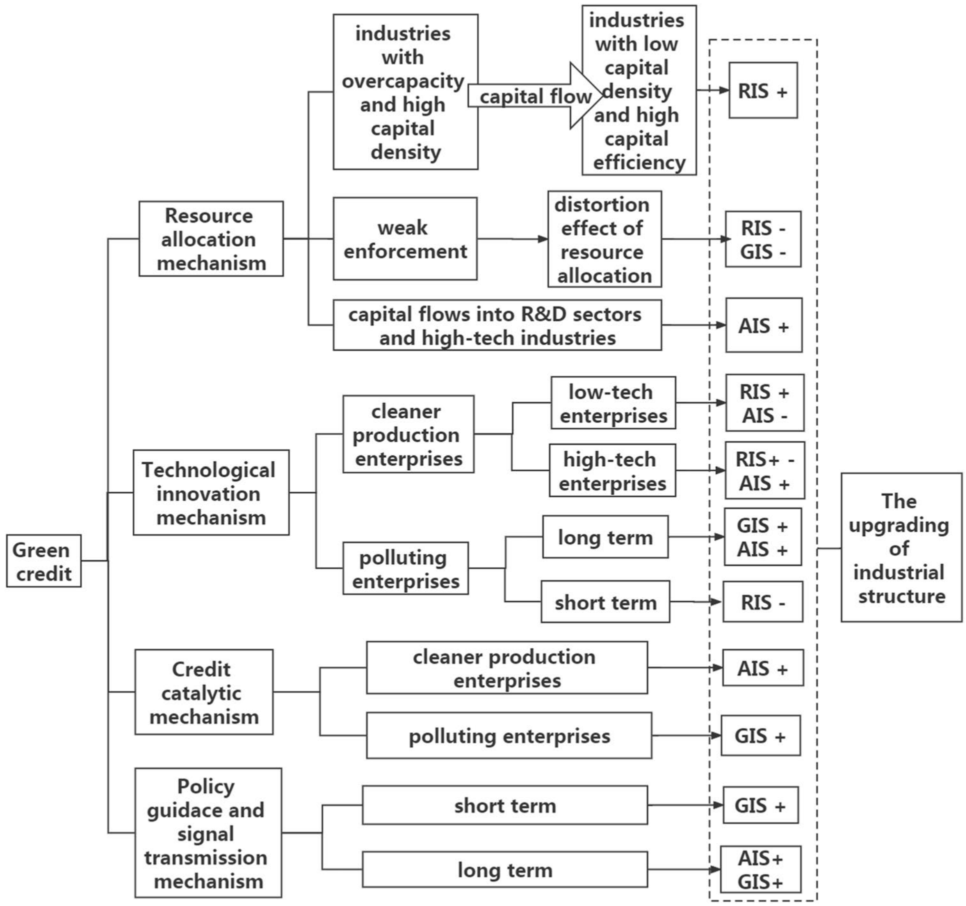

Fig. 1 The influence mechanism of green credit on the upgrading of industrial structure

reducing pollution and energy consumption, while production technology innovation can directly improve the AIS by enhancing the productivity of factor input and developing new products. However, in the short term, the initial rate of return on technological innovation investment is relatively low. Furthermore, the increase of technological investment will greatly raise their production cost, squeeze out part of the production factor input, and reduce their economic output. In other words, resources flow from the department with high productivity to the department with low productivity in the short term, which has a negative impact on the RIS.

Credit catalytic mechanism

The essence of credit catalytic mechanism is to increase the amount of money through credit creation, promote the accumulation of capital in a short time, make full use of the potential resources of enterprises and banks, and improve the using efficiency of enterprise funds, so as to help enterprises launch a new round of production activities or investment projects as soon as possible, in the context of reasonable use of green credit funds as well as good business conditions. Under the credit catalytic mechanism of green credit, these production activities and investment projects are no longer limited to the conventional industrial activities in the past, and usually include pioneering and advanced industrial projects.

For cleaner production enterprises, the financial support of green credit can help them expand their scale of production and investment on technology innovation to improve productivity and boost profits. After the improvement of capital creation ability, cleaner production enterprises can obtain higher credit amount and financing cost with lower interest rate from the new round of green credit, thus forming a virtuous circle. Especially for the highly competitive high-tech electronics industry, efficient capital provides an important guarantee for seizing the initial market share. Therefore, green credit can promote AIS by providing efficient capital supply for high-tech industries.

For polluting enterprises, the penalty effect of green credit forces them to reduce pollution emissions and energy consumption, carry out technological innovation or transform into clean industry, and abandon high pollution and high energy consumption projects, so as to solve the problem of rising financing costs and declining credit lines. Moreover, some high-polluting enterprises may withdraw from its industry due to the implementation of green credit. Therefore, the credit funds saved from polluting enterprises and projects can be invested in cleaner production enterprises and projects in a larger scale, which further promote the virtuous circle of funds. Therefore, green credit forms a virtuous circle of capital through credit catalytic mechanism, stimulating the enthusiasm of polluting enterprises on innovation and emission reduction, which improves GIS.

Policy guidance and signal transmission mechanism

As an important method of national macro-control, government policies should correctly guide the balanced development of various industrial sectors, and promote the sustainable development of China's overall economy. From the "Opinions on Implementing Environmental Protection Policies and Regulations to Prevent Credit Risks" issued in 2007 to the "Green Credit Guidelines" issued in 2012, and then to the "Guiding Opinions on Building a Green Financial System" issued in 2015, the continuous implementation of green credit by the government not only affects the internal capital flow and enterprises' development plan, but also plays a significant role in conveying the national signal of vigorous promotion of green economy to all walks of life.

Due to the policy guidance and signal transmission mechanism of green credit, polluting enterprises that are "punished" can serve as a warning to other enterprises. In order to avoid the punishment by green credit, polluting enterprises can reduce pollution and energy consumption in the short term by reducing investment and production, so that the GIS can be enhanced in the short term. In the long run, polluting enterprises can take measures in advance to increase the investment of environmental technology innovation and production technology innovation of their planned high pollution and high emission projects, and accelerate the industrial transformation, so that AIS and GIS can be improved. For other enterprises, the policy guidance and signal transmission mechanism can encourage them to adjust their internal structure, expand towards cleaner production industry, carry out more clean production projects, and further promote the greenization of China's industrial structure.

Data source, variable definition, and model design

Data sources

The research sample of this paper is panel data of 30 provinces in China from 2005 to 2016. Due to the missing data, Tibet, Hong Kong, Macao, and Taiwan are not included in the analysis of this article. The data of this paper comes from "China Statistical Yearbook," "China Industrial Statistics Yearbook," "China Science and Technology Statistical Yearbook," and "China High-tech Industry Statistical Yearbook." For the missing data, we use interpolation method to complete.

The industry segmentation in this article refers to the industry classification in the "Statistical Yearbook of China's Industrial Economy." Due to the missing data, we refer to the practice of Tong et al. (2016) and retain 35 industrial industries in the "Statistical Yearbook of China's Industrial Economy," excluding 5 industries: mining auxiliary activities, other mining, other manufacturing, comprehensive utilization of waste gas resources, and repair of metal products machinery and equipment; merging automobile manufacturing industry and railway, communication, aerospace and other transportation equipment manufacturing industry into transportation equipment manufacturing industry; dividing the remaining 35 industries into 17 clean industries and 18 pollution-intensive industries (see Appendix 1). Table 1 shows the descriptive statistical analysis of the data.

Variable definition

Explained variable: industrial structure change

Based on the practice of Fu et al. (2016), the industrial structure change is decomposed into the rationalization and the advancement of industrial structure. On this basis, we create a new dimension—greenization of industrial structure—to examine whether green credit helps China's industry develop towards a low-emission and low-pollution model. We empirically test the impact of green credit on the upgrading on China's industrial structure from the above three dimensions.

The rationalization of industrial structure (RIS) can reflect the coordination degree and resource utilization efficiency among industries, and measure the coupling degree between input structure of production factors and output structure. Referring to the practice of Gan et al. (2011) etc., we use the Theil index to measure the rationalization degree of industrial structure. The closer the Theil index is to 0, the stronger rationalization of industrial structure will be; otherwise, the weaker the rationalization. The calculation formula is as follows:

$$RIS = \sum_{i=1}^{n} \left(\frac{Y_i}{Y}\right) ln\left(\frac{Y_i}{L_i} / \frac{Y}{L}\right) \quad (1)$$

where Y, L, n, and i refers to output value, employment, number of industries, and the industry, respectively. Y_i/Y is the output structure, Y_i/L_i refers to the productivity of industry i, and Y/L represents the total productivity of industry.

The advancement of industrial structure (AIS) is an essential measure of upgrading of industrial structure. Referring to the practices of Xiao and Li (2013), the ratio of high-tech industrial output value to total industrial output value is used to calculate the advancement degree of industrial

Table 1 Descriptive statistical analysis of each variable

Variables	Observation	Mean	Standard deviation	Minimum	Maximum
Advancement	360	0.089	0.080	0.002	0.370
Rationalization	360	0.202	0.173	0.040	1.345
Greenization	360	0.374	0.161	0.080	0.724
Green credit	360	0.228	0.132	0.003	0.636
Financial scale	360	0.051	0.029	0.006	0.171
Government intervention	360	0.215	0.094	0.079	0.627
Energy consumption	360	3.213	1.506	0.993	8.284
Marketization	360	1.691	2.363	0.126	14.98
International trade	360	0.084	0.088	0.001	0.430
Innovation	360	0.006	0.003	0	0.016
Urbanization	360	0.524	0.140	0.269	0.896

structure. The output value of high-tech industries is measured by the main business income of high-tech industries in each region from "Statistical Yearbook of China's High-tech Industries,"[1] and the total industrial output value is measured by the total sale output value of 35 industries from "China Industrial Statistical Yearbook."

The greenization of industrial structure (GIS) is an actual measure of the cleanliness of industrial structure, and this paper uses the ratio of the sales value of 17 industrial cleaning industries to the total sales value of 35 industrial industries to measure it.

Core explanatory variable: green credit

Some articles use the "bank loan" in industrial pollution control investment, or the percentage of green credit and the proportion of environmental protection project loans in the "Social Responsibility Report" to measure green credit. The former has no longer been updated since 2010, while the latter only counts the situation of green credit at the national level without the data of various regions and industries. Thus, these two measurement methods are rarely used. The mainstream measurement of green credit (GC) is applying the interest expense of six high energy–consuming industries as a reverse indicator (Xie and Liu 2019; Li Y. et al. 2020). Since this paper only focus of industrial sector, we are able to discriminate all cleaning industries and polluting industries. Therefore, we use the ratio of the total interest expense of 17 industrial cleaning industries to the total interest expense of 35 industrial industries to represent green credit, which is a more accurate and direct method to measure green credit.

Control variables

Referring to Dai (2012), Lan and Chen (2013), Xu et al. (2018), Li Y. et al. (2020), and other studies, the following variables are selected as control variables: the relative scale of the financial industry, which is measured by the ratio of the added value of the regional financial industry to the GDP; the level of independent innovation of industry, which is measured by the ratio of the internal expenditure of R&D funds of industrial enterprises above designated size in the region to the sales output value of industries above designated size in the region; the level of industrial international trade, which is measured by the ratio of the delivered value of industrial export in each region to the regional industrial sales value; the degree of industrial marketization, which is measured by the ratio of the average number of employees employed by private industrial enterprises to the average number of workers employed by state-owned industrial enterprises; the government intervention, which is measured by the ratio of the local general public budget expenditures to the regional GDP; energy consumption, which is measured by the per capita energy consumption; the degree of urbanization, which is measured by the proportion of urban population at the end of the year. Detailed variable definition and abbreviation can be referred in Table 2.

Model setting

The development and changes of economic variables have a certain sort of inertia, and the current results of the variables are often affected, to some extent, by the results of the previous period. In the dynamic panel data model, the lagged term of the dependent variable is usually put into the model as an independent variable. Therefore, in order to test whether green credit has a positive impact on the upgrading

[1] According to the "Statistical Yearbook of China's High-tech Industries," high-tech industries are composed of 6 industries, including manufacture of medicines, manufacture of aircrafts and spacecrafts and related equipment, manufacture of electronic equipment and communication equipment, manufacture of computers and office equipment, manufacture of medical equipments and measuring instrument, and manufacture of electronic chemicals.

Table 2 Variables and definition

Variable name	Variable symbol	Variable definition
Advancement	AIS	Ratio of high-tech industrial output value to total industrial output value
Rationalization	RIS	Theil index is used to measure RIS
Greenization	GIS	Ratio of sales value of cleaning industrial industries to the sales value of all industrial industries
Green credit	GC	Ratio of total interest expense of cleaning industrial industries to the interest expense of all industrial industries
Financial scale	FS	Ratio of the added value of the regional financial industry to the GDP
Government intervention	GI	Ratio of the local general public budget expenditures to the regional GDP
Energy consumption	EC	Per capita energy consumption
Marketization	Market	Ratio of the average number of employees employed by private industrial enterprises to the average number of workers employed by state-owned industrial enterprises
International trade	IT	Ratio of the delivered value of industrial export to the regional industrial sales value
Innovation	R&D	Ratio of the internal expenditure of R&D funds of industrial enterprises to the sales output value of industries
Urbanization	Urban	Proportion of urban population at the end of the year

of industrial structure, this paper establishes the following dynamic panel data model:

$$RIS_{it} = \alpha + \beta_1 RIS_{it-1} + \beta_2 GC_{it} + \Phi X_{it} + \mu_{it} + \varepsilon_{it} \quad (2)$$

$$AIS_{it} = \alpha + \beta_1 AIS_{it} - 1 + \beta_2 GC_{it} + \Phi X_{it} + \mu_{it} + \varepsilon_{it} \quad (3)$$

$$GIS_{it} = \alpha + \beta_1 GIS_{it-1} + \beta_2 GC_{it} + \Phi X_{it} + \mu_{it} + \varepsilon_{it} \quad (4)$$

where i represents the region, t is the year, and μ_{it} represents the individual heterogeneity that does not change with time. RIS_{it-1}, AIS_{it-1}, and GIS_{it-1} represent the lagging phase of rationalization, advancement and greenization of industrial structure respectively. GC_{it} is the core explanatory variable—green credit; X_{it} is the control variable; and ε_{it} is the random disturbance term.

In order to effectively solve the endogenous problem of the model and reduce the influence of measurement error and time-invariant missing variables on the model, this paper adopts the generalized moment estimation (GMM) proposed by Arellano and Bond. GMM includes system generalized moment estimation (SYS-GMM) and difference generalized moment estimation (DIF-GMM). With limited samples, the SYS-GMM is more efficient and less biased than the DIF-GMM. Thus, the SYS-GMM is used in the benchmark regression of this paper, while DIF-GMM is applied in the robustness test. Furthermore, GMM estimation can be divided into one-step and two-step method. The weight matrix estimated by the two-step method of GMM depends on the parameters and the standard deviation is biased downwards, which not only does not bring obvious efficiency improvement but also makes the estimators unreliable. However, the estimator of the one-step method is consistent, despite the decrease in efficiency. Therefore, we only use one-step GMM to estimate in this paper.

Results and discussion of empirical analysis

National estimated results

Table 3 shows the estimated results of the national sample. The *F*-test values of three mixed OLS models indicate that the model has individual heterogeneity. The Hausman test of fixed effect model and random effect model are significant at 1% statistical level, which shows that fixed effect model is better than random effect model. In order to solve endogenous problems better, we choose to use GMM dynamic panel model, instead of fixed effect model, as our benchmark model. The results of AR (2) in Table 3 suggest that there is no second-order autocorrelation in the difference of the disturbance term, so the original hypothesis "The disturbance term has no autocorrelation" is accepted; Hensen's results show that the original hypothesis "All instrumental variables are valid" cannot be rejected; that is, the model does not have the problem of over-identification. According to the research results of Roodman (2009), when the one period lagging coefficient of the explained variable in the GMM model is between that in the mixed OLS (upper bound) and that in the fixed effect model (lower bound), the instrumental variable setting of the GMM model is reasonable. In Table 3, the coefficients of L.AIS, L.RIS, and L.GIS in GMM estimation are between the corresponding coefficients of the mixed OLS (upper bound) and fixed effect model (lower bound), indicating that the model setting in this paper is reasonable and the result of one-step SYS-GMM is reliable.

At the national level, green credit has a positive impact on the transformation of China's industrial structure as a whole, and its impact on RIS, GIS, and AIS increases in turn.

The coefficient of green credit on the rationalization of national industrial structure is negative, illustrating that the more green credit, the smaller the rationalization index,

Table 3 Results of the impact of green credit on China's industrial structure

	Advancement (AIS)			Rationalization (RIS)			Greenization (GIS)		
	OLS	FE	GMM	OLS	FE	GMM	OLS	FE	GMM
L.AIS	0.920***	0.748***	0.867***						
	(34.72)	(15.53)	(9.93)						
L.RIS				0.911***	0.552***	0.885***			
				(26.51)	(27.60)	(27.51)			
L.GIS							0.902***	0.791***	0.901***
							(42.32)	(17.96)	(26.81)
GC	0.034***	0.024	0.113***	−0.091**	−0.018	−0.068	0.107***	0.073**	0.093**
	(3.95)	(1.00)	(4.30)	(−1.99)	(−0.42)	(−1.21)	(4.66)	(2.16)	(2.66)
Constant	0.000	−0.046***	0.010	0.003	0.300***	0.004	0.008	−0.067***	0.019*
	(0.07)	(−3.74)	(1.08)	(0.18)	(4.30)	(0.19)	(1.11)	(−3.96)	(2.00)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	330	330	330	330	330	330	330	330	330
Hausman		33.03***			31.39***			32.49***	
R-squared	0.985	0.871		0.899	0.597	0.994	0.985	0.848	1.000
adj_R2	0.985	0.844		0.985	0.844	0.125	0.985	0.844	0.308
F	4158	295.8		4158	295.8		4158	295.8	
AR(2)			0.19			0.125			0.308
Hensen			1.000			0.994			1.000

L.RIS, L.AIS, and L.GIS respectively indicate the lagging first order of RIS, AIS, and GIS; *t*-statistics is in the brackets; ***, **, * represent the significance at level of 1%, 5%, and 10%, respectively; GMM refers to one-step SYS-GMM

which indicates the higher rationalization degree; that is, green credit has a positive impact on RIS, but the effect is not statistically significant. As the whole, green credit transfers resources from polluting enterprises with overcapacity to clean industries with high production efficiency and difficulty in obtaining loans through resource allocation mechanism. Moreover, green credit improves the productivity of low-tech clean enterprises through technological innovation mechanism, which has a positive effect on the rationalization. However, due to the consideration of profitability and investment risk, banks are relatively conservative during the implementation of green credit, which makes the above positive effect cannot be fully highlighted.

Green credit has a positive correlation with the advancement of national industrial structure, and it is significant at the statistical level of 1%, which indicates that green credit can significantly promote AIS. In addition, the impact of green credit on GIS is positive as well, which is significant at the statistical level of 5%; that is, green credit can significantly promote the greenization level of national industrial structure. Besides, there is a very significant positive correlation between the previous period and the current value of RIS, AIS, and GIS, which is significant at the level of 1%, indicating that there is a significant positive inertia dynamic feature in the upgrading process of China's industrial structure. Moreover, the inertia of advancement, rationalization, and greenization increases in turn.

Estimated results by regions

According to State Statistical Bureau, this paper divided three areas of eastern, central, and western regions in China (see Appendix 2) to study the regional heterogeneity on the effect of green credit on industrial structure.

Eastern results

As shown in Table 4, the estimated results of the eastern region indicate that green credit has a positive impact on the overall change of industrial structure in the eastern region of China, and its impact on the rationalization, advancement, and greenization of industrial structure increases in turn.

Green credit significantly promoted AIS and GIS in the eastern region at the statistical level of 1%. A major feature of the eastern region was that high-tech industries accounted for a relatively high proportion of industrial sector. In 2015, the proportion of high-tech industries in Shanghai had reached 55.56%, and in Guangdong, Jiangsu, and Beijing, the proportion had achieved more than 40%, even in other eastern provinces the proportion was also above 20%. Green credit enables high-tech enterprises to obtain more funds with lower interest cost through the mechanism of technological innovation, alleviates the capital pressure at the initial stage of enterprise innovation, and reduces the cycle of enterprise technological innovation. In addition, through the credit catalytic mechanism, enterprises

Table 4 Estimation of dynamic panel data model

Variable/region	East			Central			West		
	Model 2 RIS	Model 3 AIS	Model 4 GIS	Model 2 RIS	Model 3 AIS	Model 4 GIS	Model 2 RIS	Model 3 AIS	Model 4 GIS
L.RIS	0.660***			0.818***			0.904***		
	(4.68)			(6.88)			(17.28)		
L.AIS		1.013***			1.017***			0.799***	
		(24.88)			(13.59)			(11.37)	
L.GIS			0.701***			0.952***			0.841***
			(4.93)			(31.87)			(22.56)
GC	−0.036	0.101***	0.114***	−0.781	0.023	0.138***	0.080	0.018	0.089*
	(−0.20)	(3.29)	(2.57)	(−1.25)	(1.56)	(3.50)	(0.58)	(0.54)	(2.03)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AR(2)	0.349	0.329	0.062	0.773	0.476	0.863	0.654	0.615	0.877
Hensen	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

L.RIS, L.AIS, and L.GIS respectively indicate the lagging first order of RIS, AIS, and GIS; *t*-statistics is in the brackets; ***, **, * represent the significance at level of 1%, 5%, and 10%, respectively

are encouraged to carry out more innovative and advanced industrial projects. Thus, the advancement degree of industrial structure can be improved. By the policy guidance and signal transmission mechanism, the proportion of high pollution and energy-intensive industries, such as petroleum processing, metal smelting, and chemical manufacturing in the eastern region, has dropped significantly after the release of Green Credit Guidelines in 2012, and the proportion of cleaner production industries has increased year by year. In addition, green credit has enabled enterprises to increase investment in environmental technology innovation by technology innovation mechanism, which has further led to a reduction in pollution and energy consumption in the eastern region. Therefore, the greenization degree of the eastern industrial structure naturally rises.

The influence coefficient of green credit on RIS is negative, indicating that the more green credit, the higher the rationalization degree. In other words, green credit has a positive impact on the rationalization of industrial structure, but it is not statistically significant. The reasons may be as follows: on the one hand, green credit helps the eastern clean industry to obtain more financial support through the resource allocation mechanism, and the efficiency of resource allocation is also improved, thereby green credit has a positive effect on the rationalization degree. However, since the eastern region is dominated by clean industry, the efficiency of resource allocation and labor productivity have been at a high level for a long time, so the increase in green credit has not significantly improved the RIS in the eastern region. On the other hand, there are some high-tech clean enterprises with relatively high per capita capital in the eastern region, and green credit can further enhance their per capita capital through technological innovation mechanism, so the gap between these high-tech clean enterprises and other enterprises keep on increasing, which is not conducive to the improvement of rationalization.

There is a very significant positive correlation between the previous and the current value of RIS, AIS, and GIS, and they are all significant at the 1% level, which suggests that there is a significant positive inertia dynamic characteristic in the upgrading process of industrial structure in eastern China, and the inertia of advancement is the largest.

Central results

From Table 4, we can see the regression results of the central region show that green credit also has a positive impact on the overall industrial structure change.

Green credit has a significantly positive impact on GIS of central China at 1% significance level. At the beginning of this century, the heavy-polluting industrial enterprises in the east began to migrate to the central region gradually. The industrial sector in the central region mainly consists of metal smelting and rolling processing industry, electric and thermal power production and supply industry, and chemical raw materials and chemical products manufacturing industry, which not only bring economic benefits to the central region, but also cause environmental problems of high pollution and high emission. With the in-depth implementation of green credit policy, industrial enterprises in central China are also actively seeking transformation and upgrading under the influence of policy guidance and signal transmission mechanism. Meanwhile, green credit has forced these polluting enterprises to enhance environmental technology innovation by increasing their financing cost, so as to reduce pollution and energy consumption. Since 2012, the proportion of heavy-polluting industrial enterprises in central China, mainly from Anhui, Jiangxi, Hubei, and Hunan province, has declined year by year, and the industrial pollution emissions have shown an obvious downward trend in recent years; thus, the greenization level of industrial structure is significantly improved.

Green credit has a positive effect on AIS of central China, but it is not statistically significant. Although the industries in the central region at the beginning of this century were mainly heavy-polluting industries, green credit still promoted the development of high-tech clean industries through technological innovation mechanisms and credit catalytic mechanisms. Since 2012, the proportion of high-tech industry in the central provinces has gradually increased. In 2015, the proportion of high-tech industries in Anhui Province was the highest at 33.91%, followed by Jilin at 33.16%. Although there is a gap compared with the eastern region, the proportion of high-tech industries in the central provinces has kept on increasing, and the regression result of AIS is significant at the statistical level of 15%. However, as green credit promotes the development of high-tech clean enterprises through technological innovation mechanism, it also promotes the development of low-tech clean enterprises in central China, which weakens the advancement level. Furthermore, since the cycle of advancement is longer than that of greenization, the effect of AIS comes out slower as well. Thus, although green credit has a positive impact on AIS of central China, it is not statistically significant.

The impact of green credit on RIS of the central region is positive, but not significant. The reason may be as follows. Green credit transfers resources from polluting enterprises with overcapacity to clean industries with high production efficiency and difficulty in obtaining loans, through the resource allocation mechanism. Meanwhile, green credit also helps to improve the productivity of low-tech clean enterprises through the technological innovation mechanism. The above two channels make green credit affects RIS positively. However, the banks in central China hold a relatively conservative implementation of green credit, due to the consideration of its own profitability and investment risk (Bing et al. 2011). In addition, the time cycle of productivity improvement, brought by technological innovation mechanism, lasts long, resulting in the fact that the positive effect of green credit on rationalization cannot be fully highlighted.

Western results

The regression results of the western region from Table 4 show that the overall impact of green credit on the industrial structure in western China is relatively weak, compared with the eastern and central regions. Moreover, unlike other regions, the coefficient of green credit on the western RIS is positive, suggesting that the stronger green credit, the lower rationalization degree of industrial structure. There may be four reasons: firstly, the western industry is dominated by heavy industry. In 2016, the sales value of heavy industry in the western region accounted for 73.06% of the total industrial sales value, coming from mining industry, power, thermal power and water production and supply industry, ferrous and non-ferrous metal smelting industry, and non-metallic mineral products industry, which are mainly polluting industries. Too much polluting heavy industry and too little clean industry make it difficult to fully exert the optimizing effect of resource allocation. Secondly, the implementation of green credit in the western region is weaker than the central region (Bing et al. 2011). Since most of the sales value in the western region came from polluting industry, strict implementation of green credit would lead to a rapid decline of the western economy. With the consideration of both political achievements and local economic development, the implementation of green credit in the western provinces would be weak. This has brought about a distorting effect of resource allocation, under the resource allocation mechanism, which is greater than the optimization effect, resulting in a reduction in the degree of rationalization. Thirdly, green credit can squeeze out the output of polluting enterprises in the short term through technological innovation mechanisms, which causes resources to flow from sectors with high production efficiency to sectors with low production efficiency, thereby reducing the degree of rationalization of the western industries. Fourthly, the western region is in a shortage of talents, and the coupling between the labor structure and the demand of developing high-tech industry is low. With the continuous implementation of green credit, the contradiction between the shortage of senior talents and the industries that urgently need to be upgraded cannot be reconciled, resulting in a reduction in the degree of rationalization of the industrial structure.

Similar to the central region, green credit has a positive but not significant impact on AIS of the western region. The reason may be that the western region has abundant natural resources, and enterprises tend to rely on the developing model of resource-intensive heavy industries (Li and Xu 2018), which inhibits the incentives of the technological innovation mechanism and makes the technological innovation mechanism of green credit unable to be fully utilized. In addition, there is a shortage of high-tech talents in the western region, so it is more difficult to develop high-tech industries than that in the central region, and the cycle is longer as well. As a result, the effect of green credit on the advancement of the western industrial structure is not significant.

Green credit has a positive impact on RIS of the western region, which is significant at 10% statistical level. This is mainly because green credit can suppress pollutant emissions in the long and short term through policy guidance and signaling mechanisms, and reduce pollutant emissions through environmental technological innovation; thus, it can promote the GIS in the west.

To sum up, green credit has a significant positive impact on the GIS in China, and it is positively correlated with the level of AIS, but the impact on the rationalization of the industrial structure is more complex and not significant.

Robustness test

In order to verify the empirical results of the impact of green credit on the upgrading of China's industrial structure, this

Table 5 Robustness test results

	Static panel model estimation			DIF-GMM (one-step) estimation		
	RIS	AIS	GIS	RIS	AIS	GIS
GC	−0.155	0.081***	0.204**	0.122	−0.091**	−0.209**
	(−1.01)	(3.74)	(2.10)	(1.33)	(−2.13)	(−2.35)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	360	360	360	360	360	360
R-squared	0.201	0.688	0.495			
Number of region	30	30	30	30	30	30
adj_R2	0.484	0.484	0.484			
F	10.93	10.93	10.93			
AR (2)				0.336	0.311	0.22
Hensen				0.998	0.556	0.247

t-statistics is in the brackets; ***, **, * represent the significance at level of 1%, 5%, and 10%, respectively

paper apply two methods to examine the robustness. First, we use a static panel model—fixed-effect model to test the national RIS, AIS, and GIS. In addition, based on one-step DIF-GMM, the interest expenses of six energy-consuming industries are used as a reversed index to measure green credit to test the robustness of national results. As shown in Table 5, the results of these two methods show that green credit have a positive impact on national RIS, AIS, and GIS, and the effects on AIS and GIS are significant, which are the same as the benchmark regression, indicating that the regression results of this article are robust. Besides, in terms of the regional empirical results, these two methods also have similar conclusions Tables 6 and 7.

Conclusions

Based on a provincial panel data from 2005 to 2016, this paper employs a dynamic panel data model to study the effect of green credit on the upgrading of China's industrial structure, and find that, at the national level, green credit has a positive impact on the upgrading of China's industrial structure and plays a significant role in promoting the greenization and advancement of industrial structure. However, on the regional level, the effect of green credit is more complex.

Green credit has a significant positive effect on the greenization of industrial structure in the eastern, central, and western regions of China, which suggests that green credit is conductive to the green production of industry. Likewise, green credit has a positive impact on the advancement level in the three regions, but the effect is only significant in the eastern region. Furthermore, in terms of the RIS, the effect of green credit is positive, but not significant, in the eastern and central regions, but negative, not significant as well, in the western region, which can be explained from the perspective of the resource allocation mechanism, technological innovation mechanism, and talent shortage. We can see that there are large regional differences on the effect of green credit, and the overall influence of green credit on the industrial structure of the eastern, central, and western regions gradually weakened. In addition, there is a significant positive correlation between the previous period value and current value of RIS, AIS, and GIS, which indicates that there is a significant positive inertia dynamic feature in the upgrading of China's industrial structure.

On the basis of the above discussion, we draw the following policy implications: first, improve the green credit related system, and formulate alternative industrial development plans in accordance with the actual conditions of each province. The top-level design of green credit has been introduced, but the detailed rules of the bottom-level system are seriously insufficient. The government can establish a green evaluation system based on carbon emission trading mechanisms, water rights, sewage discharge, and other mechanisms, clarify and regulate the implementation scope of green credit projects, and strengthen statistical monitoring of relevant information of various industries and enterprises. Second, alternative industry development plans should be made by the government in order to make up for the removed polluting enterprises in time. Otherwise, strict implementation of green credit will bring about a rapid decline in local economy and rising unemployment, especially in the western provinces. As the central and western regions have more abundant renewable resources than the eastern region (Wang et al. 2020), the government can guide the local industrial industries to develop in the direction of renewable energy. Third, strengthen policy guidance. Since green projects are often characterized by long cycles and slow results, most financial institutions are inactively investing in such projects. Thus, the government should further strengthen the guidance. In terms of environmental protection technology innovation, the government should increase rewards and incentive policies to improve the awareness and the ability of independent innovation of industrial enterprises. Fourth, banks and other financial institutions should strive to improve their own driving force for green development, establish an assessment system for the environmental responsibility of the enterprises or projects they invest in, set up a green financial department internally, and reform the assessment system and incentive mechanisms; meanwhile, accelerate the innovative development of green insurance, green bonds, and green industry funds.

Appendix 1

Table 6 According to *Statistical Yearbook of China's Industrial Economy,* the industrial structure conducted in this article is composed of 35 industries, and the classification refers to Tong et al. (2016):

Number	Industry	Classification
1	Non-ferrous metal mining and dressing	Pollution-intensive industry
2	Ferrous metal mining and dressing	Pollution-intensive industry
3	Electric power, heat production, and supply	Pollution-intensive industry
4	Paper-making and paper products	Pollution-intensive industry
5	Non-metallic mineral manufacturing	Pollution-intensive industry
6	Coal mining and washing	Pollution-intensive industry
7	Ferrous metal smelting and rolling processing	Pollution-intensive industry
8	Non-metallic mining and dressing	Pollution-intensive industry
9	Chemical fiber manufacturing	Pollution-intensive industry
10	Chemical raw materials and chemical products manufacturing	Pollution-intensive industry
11	Non-ferrous metal smelting and rolling processing	Pollution-intensive industry
12	Water production and supply	Pollution-intensive industry
13	Petroleum processing, coking, and nuclear fuel processing	Pollution-intensive industry
14	Beverage manufacturing	Pollution-intensive industry
15	Gas production and supply	Pollution-intensive industry
16	Textile	Pollution-intensive industry
17	Agricultural and sideline food processing	Pollution-intensive industry
18	Food manufacturing	Pollution-intensive industry
19	Electrical machinery and equipment manufacturing	Cleaner production industry
20	Cultural, educational, and sporting goods manufacturing	Cleaner production industry
21	Printing and recording media reproduction	Cleaner production industry
22	Communication equipment, computer, and other electronic equipment manufacturing	Cleaner production industry
23	Textile and clothing, shoes, and hat manufacturing	Cleaner production industry
24	General equipment manufacturing	Cleaner production industry
25	Tobacco manufacturing	Cleaner production industry
26	Transportation equipment manufacturing	Cleaner production industry
27	Instrumentation and cultural and office machinery manufacturing	Cleaner production industry
28	Special equipment manufacturing	Cleaner production industry
29	Metal products	Cleaner production industry
30	Leather, fur, feathers (velvet), and their products	Cleaner production industry
31	Oil and gas extraction	Cleaner production industry
32	Wood processing and wood, bamboo, rattan, palm, and grass products	Cleaner production industry
33	Rubber and plastic products	Cleaner production industry
34	Pharmaceutical manufacturing	Cleaner production industry
35	Furniture manufacturing	Cleaner production industry

Appendix 2

Table 7 According to State Statistical Bureau, this paper classfied three areas of "central, east and west" in China foranalysis purpose

Region	Province
Eastern region	Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan
Central region	Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Hebei, Hubei, Hunan
Western region	Neimenggu, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shanxi, Gansu, Qinghai, Ningxia, Xinjiang

Note: Provinces distribution in three regions of China

Author contribution Professor Jixian Liu and Associates Professor Xiaodong Lai contributed to the study conception and design. Material preparation, data collection, and analysis were performed by PhD. Ms. Qingqing Cheng. The first draft of the manuscript was written by Ms. Qingqing Cheng. Yuqing Liu and Zhijiang Yang commented on previous versions of the manuscript and do some data analysis. Associate professor Xiaodong Lai read and approved the final manuscript.

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Declarations

Ethical approval and consent to participate Not applicable.

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References

Acemoglu D, Aghion P, Bursztyn L, Hemous D (2012) The environment and directed technical change. Am Econ Rev 102(1):131–166

Aizawa M, Yang C (2010) Green credit, green stimulus, green revolution? China's mobilization of banks for environmental cleanup. J Environ Dev 19(2):119–144

Antonelli C (2006) Localized technological change and factor markets: constraints and inducements to innovation. Struct Chang Econ Dyn 17(2):224–247

Bing Z, Yang Y, Bi J (2011) Tracking the implementation of green credit policy in china: top-down perspective and bottom-up reform. J Environ Manage 92(4):1321–1327

Chen W, HU, D., (2011) An analysis of the functional mechanism and effect of green credit on industrial upgrading. Journal of Jiangxi University of Finance and Economics 4:12–20 ((**In Chinese**))

Dai K (2012) Driving factors of China's industrial structure: 1985–2010. Modern Economic Science 34(6):14–22 ((**In Chinese**))

Ding J (2019) Green credit policy, credit resources allocation and strategic response of enterprises. Econ Rev 4:62–75 ((**In Chinese**))

Dong Q, Wen S, Liu X (2020) Credit allocation, pollution, and sustainable growth: theory and evidence from China. Emerg Mark Financ Trade 56(12):2793–2811

Evangelinos KI, Nikolaou IE (2009) Environmental accounting and the banking sector: a framework for measuring environmental-financial risks. Int J Serv Sci 2(3–4):366–380

Fu Y, Ye X, Wang Z (2016) Structure changes in manufacturing industry and efficiency improvement in economic growth. Econ Res 8:86–100 ((**In Chinese**))

Fujita N, James WE (1989) Export promotion and the "heavy industrialization" of Korea. Dev Econ 27:3

Gan C, Zheng R, Yu D (2011) An empirical study on the effects of industrial structure on economic growth and fluctuations in China. Econ Res 5:4–16 ((**In Chinese**))

Goss A, Roberts GS (2011) The impact of corporate social responsibility on the cost of bank loans. J Bank Finance 35(7):1794–1810

Guo Q, Zhou M, Liu N, Wang Y (2019) Spatial effects of environmental regulation and green credits on green technology innovation under low-carbon economy background conditions. Int J Environ Res Public Health 16(17):3027

He L, Zhang L, Zhong Z, Wang D, Wang F (2019a) Green credit, renewable energy investment and green economy development: empirical analysis based on 150 listed companies of China. J Clean Prod 208:363–372

He L, Liu R, Zhong Z, Wang D, Xia Y (2019b) Can green financial development promote renewable energy investment efficiency? A consideration of bank credit. Renew Energy 143:974–984

He LY, Liang X, Yang XL, Zhong ZQ (2019c) Can green credit promote the technological innovation of environmental protection enterprises? Financ Econ Res 34(5):109–121 ((**in Chinese**))

Lan Q, Chen C (2013) Does new-type urbanization promote the upgrading of industrial structure. J Financ Res 39(12):57–71 ((**In Chinese**))

Li J, Xu B (2018) Curse or blessing: how does natural resource abundance affect green. Economic Growth in China. Econ Res 53(09):153–169 ((**In Chinese**))

Li J, Xie Y, Tian F (2020) A study on the effect of consumer finance on industrial structure adjustment. Macroecon Res 5:18–27 ((**In Chinese**))

Li Y, Hu H, Li H (2020) Empirical analysis of the impact of green credit on the upgrading of China's industrial structure: based on Chinese Provincial Panel Data. Econ Issues 1:37–42 ((**In Chinese**))

Li Z, Liao G, Wang Z, Huang Z (2018) Green loan and subsidy for promoting clean production innovation. J Clean Prod 187:421–431

Liu JY, Xia Y, Fan Y, Lin SM, Wu J (2017) Assessment of a green credit policy aimed at energy-intensive industries in China based on a financial CGE model. J Clean Prod 163:293–302

Liu S, Xu R, Chen X (2021) Does green credit affect the green innovation performance of high-polluting and energy-intensive enterprises? Evidence from a quasi-natural experiment. Environ Sci Pollut Res 31:26378–26392

Liu X (2006) On the production capacity surplus, firms coexistence and credit rationing. J Financ Res 3:166–173 ((**In Chinese**))

Liu X, Wen S (2019) Should financial institutions be environmentally responsible in China? Facts, theory and evidence. Econ Res 54(03):38–54 ((**in Chinese**))

Jiang M, Luo S, Zhou G (2020) Financial development, OFDI spillovers and upgrading of industrial structure. Technol Forecast Soc Change 155:119974

Hu G, Wang X, Wang Y (2021) Can the green credit policy stimulate green innovation in heavily polluting enterprises? Evidence from a quasi-natural experiment in China. Energy Econ 98(3):105134

Hu Y, Jiang H, Zhong Z (2020) Impact of green credit on industrial structure in China: theoretical mechanism and empirical analysis. Environ Sci Pollut Res 1–14

Kang H, Jung SY, Lee H (2020) The impact of Green Credit Policy on manufacturers' efforts to reduce suppliers' pollution. J Clean Prod 248:119271

Ma X, Ma W, Zhang L et al (2021) The impact of green credit policy on energy efficient utilization in China. Environ Sci Pollut Res 28(6):52514–52528

Peng B, Yan W, Elahi E, Wan A (2021) Does the green credit policy affect the scale of corporate debt financing? Evidence from listed companies in heavy pollution industries in China. Environ Sci Pollut Res 1–13

Roodman D (2009) A note on the theme of too many instruments. Oxford Bull Econ Stat 71(1):135–158

Rubashkina Y, Galeotti M, Verdolini E (2015) Environmental regulation and competitiveness: empirical evidence on the Porter Hypothesis from European manufacturing sectors. Energy Policy 83:288–300

Song M, Wang S (2013) Analysis of environmental regulation, technological progression and economic growth from the perspective of statistical tests. Econ Res 48(03):122–134 ((**In Chinese**))

Song, M., Xie, Q., and Shen, Z., 2021. Impact of green credit on high-efficiency utilization of energy in China considering environmental constraints. Energy Policy, 153(22).

Su D, Lian L (2018) Does green credit policy affect corporate financing and investment? Evidence from publicly listed firms in pollution-intensive industries. Financ Res 12:123–137 ((**In Chinese**))

Tan X, Fu M (2010) Thinking of promoting the green credit policy under the background of the industrial structure adjustment. Econ Res Guid 29:94–97 ((**In Chinese**))

Tong J, Liu W, Xue J (2016) Environmental regulation, factor input structure and industrial transformation. Econ Res 51(7):43–57

Verma MK (2012) Green banking: a unique corporate social responsibility of India Banks. Int J Res Commerce Manag 3(1):110–114

Wang C, Wang Y, Tong X, Ulgiati S, Liang S, Xu M, Wei W, Li X, Jin M, Mao J (2020) Mapping potentials and bridging regional gaps of renewable resources in China. Renew Sustain Energy Rev 134:110337

Wang C, Zhang X, Vilela AL, Liu C, Stanley HE (2019a) Industrial structure upgrading and the impact of the capital market from 1998 to 2015: a spatial econometric analysis in Chinese regions. Physica A 513:189–201

Wang E, Liu X, Wu J, Cai D (2019b) Green credit, debt maturity, and corporate investment—evidence from China. Sustainability 11(3):583

Wang Y, Gan C, Wang W (2013) The analysis of demand motive for the evolution of industrial structure: study based on non-competitive input-output model. J Financ Res 39(10):60–75 ((**In Chinese**))

Weber O (2012) Environmental credit risk management in banks and financial service institutions. Bus Strateg Environ 21(4):248–263

Wen H, Lee CC, Zhou F (2021) Green credit policy, credit allocation efficiency and upgrade of energy-intensive enterprises. Energy Econ 94:105099

Wu N, Liu Z (2021) Higher education development, technological innovation and industrial structure upgrade. Technol Forecast Social Change 162:120400

Xiao Z, Li S (2013) Dynamic impacts of environmental regulation on industrial upgrading path. Econ Theory Bus Manag 6:102–112 ((**In Chinese**))

Xie T, Liu J (2019) How does green credit affect China's green economy growth. China Popul Resour Environ 29(9):83–90 ((**In Chinese**))

Xu S, Zhao X, Yao S (2018) Analysis of the effect of green credit on the up-grading of industrial structure. J Shanghai Univ Financ Econ 20(02):59–72 ((**In Chinese**))

Xu X, Li J (2020) Asymmetric impacts of the policy and development of green credit on the debt financing cost and maturity of different types of enterprises in China. J Clean Prod 264:121574

Yang Z, Wang W, Wu H (2016) Migrant workers' education-occupation matching and wage effect in China. J Financ Res 42(11):44–59 ((**In Chinese**))

Yu X, Wang P (2021) Economic effects analysis of environmental regulation policy in the process of industrial structure upgrading: evidence from Chinese provincial panel data. Sci Total Environ 753:142004

Zhang B, Yang Y, Bi J (2011) Tracking the implementation of green credit policy in China: top-down perspective and bottom-up reform. J Environ Manage 92(4):1321–1327

Zhang D (2021) Green credit regulation, induced R&D and green productivity: revisiting the porter hypothesis. Int Rev Financ Anal 75:101723

Zhang Q, Lei F, Wei Q (2019a) Synergy between technological innovation and industrial upgrading: internal mechanism and empirical test. J Humanit 8:65–75

Zhang, G., Zhang, P., Zhang, Z.G. and Li, J., 2019. Impact of environmental regulations on industrial structure upgrading: an empirical study on Beijing-Tianjin-Hebei region in China. *Journal of Cleaner Production*, *238*, p.117848.

Zhang, W., Hong, M., Li, J., and Li, F., 2021. An examination of green credit promoting carbon dioxide emissions reduction: a provincial panel analysis of China. *Sustainability*, *13*.

Zhong MC, Li MJ, Du WJ (2015) Can environmental regulation force industrial structure adjustment: an empirical analysis based on provincial panel data. China Popul Resour Environ 25(8):107–115 ((**In Chinese**))