Impact of Green Credit on Energy Consumption Intensity: Empirical Analysis Based on Inter-provincial Panel Data in China

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Abstract. Green credit policy, as one type of social responsibility taken on by financial institutions, is critical in promoting energy saving and emission reduction. To investigate the impact of green credit on energy consumption intensity, this research builds a panel model using data samples from 30 Chinese provinces, cities, and autonomous areas from 2012 to 2020. The findings reveal that green credit policies have a significant inhibitory influence on energy consumption, with the inhibitory effect being more prominent in the eastern and western regions. Local governments and financial institutions should promote the expansion of green credit scale with policy orientation, allocate loan resources rationally, and build a green credit policy system in line with local development laws to give full play to its energy-saving and emission reduction effects.

Keywords: green credit, energy consumption intensity, regional heterogeneity

1 Introduction

The national economy depends heavily on energy, but energy waste can also negatively affect the environment. China has overtaken the rest of the world in terms of total energy consumption, and its energy consumption structure shows an annual decline in the share of fossil fuels like coal, oil, and natural gas consumption and an annual increase in the share of clean energy sources like hydropower and nuclear power. However, the majority of energy usage overall remains from fossil sources. Supporting and promoting the modernization of the energy business is essential to lowering energy consumption and increasing energy efficiency.

Since finance is a crucial tool for supporting resource allocation in the real economy, it is necessary to have financial support in order to modify the total and structure of energy consumption. Financial institutions are required to voluntarily assume social and environmental responsibilities and to carry them out through appropriate rules and regulations. Examples of such measures include a set of policies, institutional arrangements, and the use of loans to support energy conservation and emission reduction. China began enforcing its green credit policy in 2007, and since then, its use has increased significantly. By the end of 2022, the total amount of green loans outstanding in both domestic and foreign currencies would be 22.03 trillion yuan. Theoretically, a major factor in increasing energy efficiency is the establishment of a green credit policy. However, in concrete practice, what kind of impact green credit will have on China's energy consumption intensity and whether this impact is heterogeneous are

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important questions that need to be addressed in current research.

The research on the effect of green credit on green economy has achieved fruitful results(Aizawa and Yang, 2010; Nabeeh, Abdel-Basset and Soliman,2021; Kassi, Li and Gnangoin, 2023)[1]-[3]. The relationship between green credit and energy use has been studied extensively. The first major finding reached was that green credit can greatly lower energy intensity. Zhang, Li, and Zhao (2022) found that green credit has a significant regional spillover impact on both energy intensity and environmental pollution using a dynamic spatial Durbin model. [4]. Su and Lian (2018) examined the effects of green finance policies on the financing and investment behavior of high-polluting firms. According to the study's findings, green credit has an adverse financial and investment incentive effect on major polluters [5]. Second, there is a threshold effect on energy consumption for green credit. Wu, Wu, and Zhao (2021) found that green credit has a negative impact on the manufacturing industry's financing behavior and that this impact lessens over time[6]. By using a smoothed transformation model, Mei, Zhu, and Feng (2018) discovered that the relationship between green credit and energy conservation is non-linear and asymmetrical and that the degree to which changes in green credit have an impact on energy conservation varies significantly depending on the amount of green credit at various threshold levels[7]. Chen and Guo (2018) discovered a significant double threshold effect between credit size and energy consumption as well as an inverted U-shaped relationship between credit size, the level of financial sector competition, and energy consumption using a threshold regression model [8].

From the literature, it is easy to see that the impact of green credit policy implementation is still controversial. There are three possible marginal innovations in this paper: first, using a fixed-effects model as a way to test the implementation effect of green credit policies; second, to analyze regional heterogeneity by classifying different regions in China; third, based on the findings of the theoretical and empirical analyses, practical suggestions are made to promote green and sustainable development in China and to provide experience for other developing countries.

2 Theoretical analysis and research hypothesis

The role of green credit on energy consumption intensity exists in two main impact mechanisms. First, green credit policies aim to construct a credit constraint mechanism for energy-intensive industries. Sa and Lian (2020) suggest that green credit reduces environmental economic losses due to inefficient energy use based on controlling total energy consumption. Either quantitative credit rationing or differentiated high-interest rate policies will create credit constraints on energy-intensive enterprises, raise their financing costs, increase their financing risks, influence their investment and financing, and production decisions, and consequently affect their energy efficiency[9]. Second, green credit promotes the growth of the renewable energy industry. Li et al. (2023) suggest that the development of renewable energy is more dependent on financial support compared to traditional energy sources, mainly due to the inherent characteristics of large financing needs and long investment cycles for renewable energy[10]. Yu (2018) proposes green credit to provide loans and various preferential policies to companies that produce, develop energy-saving technologies, and engage in green manufacturing and circular economy businesses as a way to provide financial support for renewable energy development[11].

Therefore, hypothesis 1 is proposed. Hypothesis 1: On a national level, green credit has positive environmental benefits and can reduce the intensity of energy consumption.

China boasts the world's second-largest economy and is the third-largest country in terms of land area. Green financial development, according to Wang and Li (2022), greatly reduces energy consumption intensity; nevertheless, the energy-saving effect is more significant in central and western China[12]. As a result, hypothesis 2 is offered. Hypothesis 2: Because China has geographical disparities, it is thought that the influence varies by location.

3 Model and data

3.1 Model setting

This paper uses energy consumption intensity as the explanatory variable and green credit size as the core explanatory variable. However, since many factors affect energy consumption intensity, considering only the green credit variable would seriously bias the validity of the empirical results. In order to eliminate their effects on energy consumption intensity, other factors affecting energy consumption intensity are introduced in this work as control variables. A panel data model is then established to investigate the link between green credit and energy consumption intensity as follows:

$$EI_{it}=\alpha_0+\alpha GC_{it} + \beta X_{it} + \delta_i + \varepsilon_{it} \quad (1)$$

Where i and t refer to provinces in China and years from 2012 to 2020, respectively. Ei_{it} denotes energy consumption intensity, GC_{it} denotes the level of green credit for each region, X_{it} denotes the control variable, δ_i is the regional effect, and ε_{it} is the random error term.

3.2 Variables

Explained variable: energy consumption intensity (EI). Using Shi et al.'s (2008)[13] technique, the ratio of total local energy consumption to real regional GDP is used to assess energy consumption intensity, with 2000 serving as the base period.

Core explanatory variable: level of green credit (GC). The interest expense ratio of the six high-energy-consuming industries is used as an inverse indicator to guarantee the consistency and completeness of data at the provincial level.

The control variables: first, the urbanization rate (URL), which is expressed as the ratio of urban population to total population; second, foreign direct investment (FDI), which is expressed as the ratio of FDI to total social fixed asset investment; third, the degree of technological progress (RD), which is expressed as R&D expenditure of industrial enterprises above the scale; and fourth, the economic development level (PGDP), which is expressed as per capita GDP.

3.3 Data

Table 1 Meaning of variables and descriptive statistics

Variable	Mean	Std	Min	Max
EI	1.153	0.779	0.089	4.084
GC	0.481	0.154	0.094	0.808

LNURL	4.055	0.192	3.595	4.495
LNFDI	3.614	1.177	1.588	8.556
LNRD	5.167	1.349	1.872	7.824
LNPGDP	1.258	0.464	0.087	2.405

The China Energy Statistical Yearbook provided information on total energy consumption, while the China Industrial Statistical Yearbook provided information on interest payments made by industrial businesses over the scale. The provincial GDP, urban population, total population, foreign direct investment, social fixed asset investment, GDP per capita, and R&D expenditure of industrial enterprises above the scale are from the China Statistical Yearbook. To eliminate heteroskedasticity, the urbanization rate, trade openness, degree of technological progress, and GDP per capita are logarithmically processed in this paper. Given the availability and completeness of the research data, 30 provinces, autonomous regions, and municipalities in China (excluding Hong Kong, Macao, Taiwan, and Tibet) were chosen as the sample from 2012 to 2020. Table 1 displays descriptive statistics.

4 Model estimation and result analysis

4.1. Baseline regression results

The decision between a fixed-effects model and a random-effects model must be made first. The main distinction between the two is in the fundamental presumptions: in the former, the effect is thought to be fixed, and the random error term is connected to the explanatory variables; in the latter, the effect is thought to be random, and the random error term is unconnected to the explanatory variables. Table 1 displays the results of Hausman's test, and the p-value of 0.0000 suggests that it is more appropriate for the fixed effect model.

All of Table 2's green credit level coefficients are negative and significantly non-zero at the 1% level. In particular, according to (2), every 1% increase in the number of green credits in the current year will result in a 0.347% decrease in energy consumption intensity. This outcome supports Hypothesis 1. Green credit policy plays a general part in energy conservation and emission reduction by either directly or indirectly reducing the intensity of energy consumption using differentiated interest rate tools.

Table 2 Baseline regression results

Variables	(1)	(2)	(3)
	OLS	**FE**	**RE**
GC	-1.681*** (0.322)	-0.347*** (0.131)	-0.378*** (0.139)
lnURL	4.084*** (0.549)	-1.459*** (0.237)	-1.140*** (0.247)
lnFDI	-0.295*** (0.049)	0.067*** (0.015)	0.052*** (0.016)
lnRD	-0.125*** (0.037)	0.218*** (0.040)	0.118*** (0.039)
lnPGDP	-1.366*** (0.198)	-0.730*** (0.084)	-0.681*** (0.089)

Constant	-11.17*** (1.950)	6.789*** (0.828)	6.016*** (0.875)
N	270		
Hausman	87.23(0.000)		

a. ***, **, and * indicate significance at 1%, 5%, and 10% confidence levels.
b. Values in parentheses are the P values of the Hausman test.

Among the control variables, The intensity of energy consumption is greatly reduced by the level of urbanization, showing a strong role for the agglomeration effect and economies of scale. Foreign direct investment increases energy consumption, suggesting that local foreign investment may have focused more on the potential for economic value creation and less on the intensity of its energy consumption. The level of technological progress positively affects energy consumption, which may be related to the higher energy rebound effect of technological progress and production technology preference. This is because the increase in energy efficiency leads to a decrease in the relative price of energy, producers increase their input to energy factors due to cost considerations, and thus the direct consumption of energy factors increases[14]. The economic growth rate will greatly reduce energy consumption, and the transformation of economic development mode, quality, and efficiency will be successful.

4.2 Regional heterogeneity analysis

Table 3 Regression results by region

Variables	(1) Eastern Region	(2) Central Region	(3) Western Region
GC	-0.200*** (0.075)	0.084 (0.329)	-0.747* (0.437)
lnURL	-0.613*** (0.170)	-0.709 (0.681)	-1.703*** (0.524)
lnFDI	0.008 (0.009)	0.002 (0.044)	0.163*** (0.038)
lnRD	0.053** (0.025)	0.095 (0.081)	0.325*** (0.080)
lnPGDP	-0.517*** (0.052)	-0.802*** (0.182)	-1.020*** (0.213)
Constant	3.937*** (0.649)	4.15* (2.275)	7.791*** (1.802)
N	99	72	99

a.***, **, and * indicate significance at 1%, 5%, and 10% confidence levels.

Table 3 shows that green credits have a substantial negative impact on the regional energy consumption intensity for the eastern and western areas, but have no significant impact for the central region. The obvious regional heterogeneity in China's economic development may be the cause of the regional differences. The eastern region has natural geographical location advantages and has accumulated substantial financial capital as a result of opening up to the outside world. It also has clear advantages in terms of system and industrial structure, a higher level of green financial development, and a dense distribution of green space. The central region is home to several large coal provinces in China. As traditional industrial and coal bases, the industrial structure of these regions is still dominated by high carbon emission industries. The overall economic and financial strength of the Western region is relatively weak, and enterprises mainly obtain funds through credit. The differential high-interest rate policy of green credit can better motivate high energy consumption enterprises to actively cope with the risk of rising costs, timely reverse the crude energy use and heavy pollution production mode, and actively carry out internal transformation and upgrading to improve production efficiency. Hypothesis 2 is confirmed.

With coefficients of -0.517 in the eastern region, -0.802 in the central region, and -1.020 in the western region, which gradually increases, the coefficient of economic development level is negative in all three regions and significant at a 1% confidence level, further indicating that the economic growth rate significantly reduces the energy consumption intensity. The coefficient of foreign direct investment in the western region is positive, and the coefficient is 0.163, compared with 0.067 at the national level, which is a big difference, mainly because the western region has taken over more backward and inefficient production capacity transferred from the "squeezed out" market in the east and central regions and has paid more attention to economic efficiency in attracting investment, and not enough attention to energy consumption.

4.3 Robustness tests

Robustness tests must be performed on the model to make sure that the link between the explained variables and the explanatory variables in the empirical findings of the model is correct and dependable. The robustness of the model's empirical findings is examined in this research in three different methods. The first is to replace the explanatory variables, using per capita energy consumption as an indicator of energy consumption. The second is to add control variables and use the level of trade openness as a control variable. Finally, the benchmark regression is re-estimated using the difference GMM method, taking into account the possible endogeneity of the variables. Per capita energy consumption (PEI) is calculated as the ratio of total energy consumption to the region's total population, and the level of trade openness (lnOPEN) is the ratio of total imports and exports to GDP and is treated logarithmically.

The results of the regression analysis using energy consumption per capita as the explanatory variable are shown in Tables 4 (1) and (2). According to the findings, which are in line with those of the initial regression, there is a substantial negative relationship between the amount of green credit and per-person energy use.

Table 4 Robustness test results

	(1)	**(2)**	**(3)**	**(4)**	**（5）**
Variables	**PEI_FE**	**PEI_RE**	**EI_FE**	**EI_RE**	**EI_GMM**
L.EI					0.423*** (0.065)
GC	-1.576*** (0.545)	-1.922*** (0.545)	-0.336** (0.131)	-0.377*** (0.138)	-0.179** (0.084)
lnURL	0.405 (0.984)	1.208 (0.956)	-1.416*** (0.236)	-1.128*** (0.246)	-0.801*** (0.196)
lnFDI	0.255*** (0.064)	0.181*** (0.065)	0.0654*** (0.015)	0.0507*** (0.016)	0.0370* (0.037)

lnRD	0.238 (0.167)	-0.0998 (0.140)	0.210^{***} (0.040)	0.115^{***} (0.039)	0.122 (0.080)
lnPGDP	0.125 (0.348)	0.439 (0.347)	-0.706^{***} (0.084)	-0.661^{***} (0.089)	-0.265** (0.103)
lnOPEN			0.0566^{**} (0.027)	0.0436 (0.028)	
Constant	0.615 (3.436)	-0.853 (3.401)	6.464^{***} (0.837)	5.839^{***} (0.880)	
N	270	270	270	270	270
Hausman (p)	12.23 (0.030)		193.62 (0.000)		
AR(1)					0.052
AR(2)					0.238
Sargan					0.228

a. ***, **, and * indicate significance at 1%, 5%, and 10% confidence levels.

b. Values in parentheses are the P values of the Hausman test.

The regression results for the fixed-effects model should be chosen, according to the Hausman test, while the results for the random-effects model and fixed-effects model with the addition of the trade openness variable are shown in (3) and (4). The findings of the regression also show that the amount of green credits can greatly lower the intensity of energy usage. In (3), the level of trade openness's positive coefficient shows that trade openness encourages energy consumption, which may be related to China's big energy consumption and substantial crude oil imports. The benchmark regression model is strong, and the coefficients of this model's coefficients are still significant and have the same sign as the previous ones.

(5) in Table 4 shows the results of constructing a dynamic panel model for differential GMM estimation. The p-value of the AR(1) test is 0.052 and the p-value of the AR(2) test is 0.238, which satisfies the assumption of no autocorrelation of the perturbation term of the original model. Sargan's test shows the result of 0.228, which indicates that the instrumental variables of the model are chosen reasonably. The coefficient of green credit is significantly negative at the national level, and the significance of the other variables does not differ much from that of the fixed-effects model, which suggests that our main conclusions still hold after taking into account the potential endogeneity problem of the model.

5 Conclusions

This study examines how green credit policy affects the amount of energy consumed and whether the degree of impact varies by area. Regression is used to analyze panel data from 30 provinces, autonomous regions, and municipalities in China from 2012 to 2020 (Hong Kong, Macao, Taiwan, and Tibet are excluded). Based on this, the East, Middle East, and West are divided, and the results of regional differences are obtained. In the first place, green credit policy significantly reduces energy consumption intensity, urbanization, and economic development inhibit energy consumption intensity to a certain extent, and foreign investment and technology levels enhance energy consumption intensity. Second, the inhibitory effect is notable in the eastern and western regions but not in the central region when it comes to regions.

The aforementioned conclusions show that green credit policy is a crucial tool for creating a green economy and a crucial addition to conventional administrative-command-style environmental management. Financial institutions must first actively promote and adopt green credit practices. In terms of "energy saving" and "emission reduction," they should intensify the application of the quality effect, lower overall energy consumption, and encourage decarbonization of the energy consumption structure. Secondly, we need to actively innovate green credit products, develop new types of pollutant emission loans, and fully consider the impact of environmental risk pricing and revenue. Finally, build a green credit information platform. Improve the existing green credit policies, build a green credit data docking platform among the government, banks, and enterprises, and efficiently integrate various industrial financial policies and services.

At the same time, according to the status quo of green credit development and resource system endowment in each region, differentiated green credit policy optimization paths should be constructed in different regions. On the basis of continuing to promote green credit regulatory measures, the eastern region should focus on giving full play to the clustering and diffusion effect of resources, and radiate the central and western regions. The central and western regions should take advantage of the high energy-consumption businesses, actively pursue the development of green financial systems, and successfully bolster the impact of green credit policy on energy conservation and emission reduction.

In order to advance China's green economy, this research focuses on the effect of green credit on energy consumption intensity. However, there are two main limitations of the study. Firstly, due to the limitation of data, green credit is expressed inversely using the interest share of energy-intensive industries; secondly, the article focuses on the economic efficiency of energy use, therefore, the indicator of energy consumption intensity only includes the positive output of GDP, while the negative outputs such as pollution emissions generated by energy consumption are not included in the scope of this paper.

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