Article

Analysis of the Impact of Financial Credit on Urban Clean Energy Consumption and Energy Intensity

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Abstract: This study examines the impact of financial credit on urban clean energy consumption and energy intensity, aiming to reveal the mechanisms through which financial support influences clean energy development and its role in improving energy intensity. By collecting relevant data from various cities, constructing empirical models, and analyzing the relationship between financial credit and clean energy consumption as well as its impact on energy intensity, the results indicate that financial credit has a significant positive effect on clean energy consumption and indirectly influences energy intensity improvement. Different city types show variability in financial support, suggesting the need for policy adjustments. Based on this, the paper proposes a series of optimized financial credit policies to promote clean energy consumption and energy intensity improvement, providing theoretical and practical references for achieving sustainable urban development and green energy transformation.

Keywords: clean energy consumption; energy intensity; financial credit; urban sustainable development; energy policy

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1. Introduction

With global climate change and rising environmental issues, optimizing energy consumption structures and improving energy intensity are critical priorities worldwide. Clean energy, as a low-carbon, renewable, and eco-friendly solution, reduces carbon emissions and enhances ecological balance, playing a pivotal role in sustainable urban development. However, large-scale adoption of clean energy relies heavily on financial support. Financial credit, as a vital capital tool, can lower financing costs and increase access to funds, thereby facilitating clean energy projects. Despite growing policy support, significant differences persist in clean energy development and energy intensity improvements across cities. Urbanization has driven rising energy demand, making it crucial to balance growth with clean energy use, while variations in financial market maturity influence project financing. This study analyzes the impact of financial credit on urban clean energy consumption and energy intensity, exploring city-level variability and proposing policies to enhance green development [1].

2. Concepts of Clean Energy Consumption and Energy Intensity

Clean energy consumption refers to the use of renewable, low-pollution, and low-carbon energy sources to meet production and living needs while reducing environmental impacts. In recent years, with the exacerbation of environmental issues and the proposed carbon neutrality goals, the consumption of clean energy has gradually become a core focus of global energy structure transformation. Clean energy encompasses a wide range of forms, primarily including solar, wind, hydro, biomass, and geothermal energy [2].

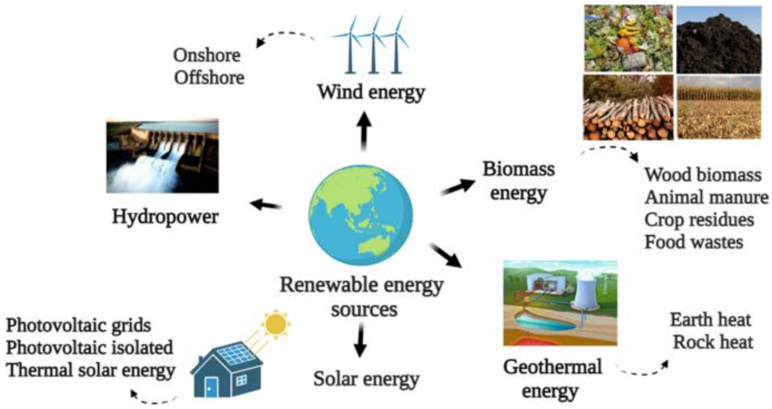

Figure 1. illustrates the sources and main applications of different types of clean energy.

Wind energy is utilized through wind power generation, including both onshore and offshore wind farms. Solar energy has diverse utilization methods, such as photovoltaic grids, independent photovoltaic systems, and solar thermal conversion systems, providing green energy for households and industries. Hydropower is extensively used in generating electricity by harnessing the potential energy of rivers, lakes, and dams, characterized by high efficiency and sustainability. Biomass energy has diverse sources, including wood, crop residues, food waste, and animal manure, which can be converted into energy through various biological processes, offering reliable green energy for urban and rural areas. Geothermal energy is harnessed by extracting heat from underground rocks and geothermal resources, providing stable energy for heating and electricity generation. Energy intensity, closely related to clean energy consumption, is a concept used to measure the amount of energy consumed in economic activities. It reflects the energy efficiency level on which a country's or region's economic development relies. Lower energy intensity typically indicates less energy consumption per unit of economic output, representing higher energy efficiency and lower carbon emissions. Improving energy intensity is an important indicator of achieving sustainable development, as it reflects both increased resource utilization efficiency and progress towards a green, low-carbon economy. Promoting clean energy consumption is a crucial means of reducing energy intensity. By increasing the share of renewable energy in the energy structure, reliance on traditional fossil fuels can be reduced, thereby decreasing carbon emissions, enhancing energy efficiency, and providing strong support for addressing global climate change and achieving green economic growth. In this context, financial credit plays a vital role in promoting clean energy consumption, optimizing energy structures, and reducing energy intensity. By lowering project financing costs and providing diversified funding channels, financial support has driven the implementation and expansion of clean energy projects. Due to differences in economic development levels, financial market maturity, and policy environments, cities exhibit significant variability in the effectiveness of financial credit support for clean energy consumption and energy intensity improvement. Therefore, in-depth research on the role of financial credit in clean energy consumption can enhance understanding of the effectiveness of financial policies and provide a scientific basis for the clean energy transition and efficient economic development of cities [3].

3. Research Methodology and Data Sources

This study employs empirical analysis and a multivariate regression model to explore the relationship between financial credit, urban clean energy consumption, and energy intensity. The research data primarily originate from the National Bureau of Statistics, Energy Research Institute, annual reports of regional financial institutions, and the China Urban Statistical Yearbook, covering the clean energy consumption volume, financial credit support scale, energy intensity, and other related indicators of multiple cities nationwide. The data span from 2015 to 2023, encompassing different regions and city types in terms of energy consumption and credit support. To ensure representativeness and accuracy, 100 sample cities were selected, including first- and second-tier large cities as well as smaller cities with typical characteristics, reflecting differences in clean energy consumption and financial credit support across various cities [4].

3.1. Data Sources and Sample Selection

The core data sources used in this study are shown in Table 1:

Table 1. Specific definitions of each variable.

Data Type	Source	Description
Clean Energy Consumption	National Bureau of Statistics & Energy Research Institute	Annual clean energy consumption statistics for each city, including solar, wind, etc.
Financial Credit Scale	Annual reports of regional financial institutions	Financial credit amounts supporting clean energy projects
Energy Intensity Data	China Urban Statistical Yearbook	Annual energy consumption per unit GDP for each city
Urban Economic Indicators	China Urban Statistical Yearbook & Local Statistical Reports	GDP, industrial structure, etc.
Policy Support Information	Public policy documents from provincial and municipal governments	Related to clean energy promotion and financial credit support policies

To enhance data comprehensiveness and multi-dimensionality, the study also employed survey data and interviews to gather operational insights from clean energy projects and the support modes of financial institutions. Sample cities were selected based on the scale of clean energy consumption and financial market maturity, ensuring the external validity of the research findings. The selection included developed coastal cities, provincial capitals in central and western regions, and representative small and medium-sized cities, providing comprehensive coverage of financial credit and clean energy consumption across different economic levels and regions. By collecting and processing this data, a database covering various variables was constructed, providing a solid foundation for subsequent empirical analyses. The analysis incorporates city-specific variables to control for differences in economic development, policy support, geographic environment, and other heterogeneity factors, enabling accurate assessment of the role of financial credit in clean energy consumption and energy intensity improvement [5].

3.2. Variable Definition and Description

The study defines and utilizes multiple key variables to analyze the impact of financial credit on clean energy consumption and energy intensity. The definitions and descriptions of these variables are summarized in Table 2:

Table 2. Main variable definition table.

Variable Name	Symbol	Definition and Description	Unit
Clean Energy Consumption	CEC	Total clean energy used by a city during a specific period, including solar, wind,	Million kWh (MW·h)

		hydro, etc. , reflecting the level of clean energy consumption.	
Energy Intensity	EI	Energy consumption per unit GDP, calculated as total energy consumption divided by GDP, measuring energy efficiency.	Tons of standard coal per 10,000 RMB
Financial Credit Support Scale	FCS	Financial credit support scale for clean energy projects, including loans and investment amounts.	Billion RMB
Urban Economic Development Level	GDP	Total economic output of a city, used to control for the impact of economic development on clean energy consumption and energy intensity.	Billion RMB
Policy Support Strength	PS	Quantification of policy support strength for clean energy promotion and financial credit, rated from 1 to 5.	No unit
Population Size	POP	Total resident population of a city, used as a control variable.	Million people
Industrial Structure	IS	The share of each industry in GDP, reflecting the differences in urban economic structure.	%
Geographic Location	LOC	Dummy variable, with 1 representing coastal cities and 0 representing inland cities.	No unit

These variables form the analytical framework for this study, allowing for systematic evaluation of the relationship between financial credit support, clean energy consumption, and their impact on energy intensity.

3.3. Empirical Model Construction

To investigate the impact of financial credit on urban clean energy consumption, we constructed the following regression model to estimate the role of financial credit in promoting clean energy consumption while controlling for other key variables that might influence the results as shown in Formula 1:

$$\mathrm{CEC}_{i,t} = \alpha + \beta_1 \mathrm{FCS}_{i,t} + \beta_2 \mathrm{GDP}_{i,t} + \beta_3 \mathrm{PS}_{i,t} + \beta_4 \mathrm{POP}_{i,t} + \beta_5 \mathrm{IS}_{i,t} + \beta_6 \mathrm{LOC}_i + \epsilon_{i,t}$$

where $\mathrm{CEC}_{i,t}$ denotes the clean energy consumption (in million kWh) of city i at year t. $\mathrm{FCS}_{i,t}$represents the financial credit support scale (in billion RMB), measuring the funding support provided by financial institutions for clean energy projects. $\mathrm{GDP}_{i,t}$ indicates the economic development level of the city (in billion RMB) to control for the impact of economic growth on clean energy consumption. $\mathrm{PS}_{i,t}$ is the policy support strength, quantified by a score ranging from 1 to 5 to reflect varying levels of policy support across cities. $\mathrm{POP}_{i,t}$ denotes the population size of the city (in million people) to control for the impact of population scale on clean energy consumption. $\mathrm{IS}_{i,t}$ refers to the industrial structure variable, reflecting the share of different sectors in the city's GDP. LOC_i is a dummy variable, with 1 representing coastal cities and 0 representing inland cities. α is the constant term, $\beta_1, \beta_2, \ldots, \beta_6$ are the coefficients to be estimated, and $\epsilon_{i,t}$ is the error term. The aim of this model is to evaluate the direct impact of financial credit scale on clean energy consumption through regression analysis, while controlling for key factors such as economic development, policy support, population size, industrial structure, and geographic location. We expect the results of the model estimation to reveal the role of financial credit in clean energy development and its varying impact across different city types. To ensure the robustness of the model results, we will conduct robustness checks and heteroscedasticity corrections in the regression analysis, and introduce interaction terms where necessary to explore the moderating effects of policy support and economic variables [6].

3.4. Research Methodology

This study employs an empirical approach using econometric models to explore the impact of financial credit on urban clean energy consumption, revealing the role of financial support in clean energy development. The research begins by collecting and processing panel data from 100 cities across the country from 2015 to 2023, covering key variables such as clean energy consumption, financial credit support scale, economic development level, policy support strength, population size, industrial structure, and geographic location. Data sources primarily include the National Bureau of Statistics, the Energy Research Institute, the China Urban Statistical Yearbook, and annual reports from regional financial institutions. To ensure data completeness and accuracy, missing data were imputed and data smoothing techniques were applied to reduce the impact of data fluctuations on analysis results. Additionally, all variables were standardized to minimize bias caused by differences in units. Following data collection and processing, the study conducted descriptive statistical analysis to gain an initial understanding of the data distribution characteristics, including mean values, standard deviations, maximum, and minimum values. Correlation and distribution analyses of variables were performed to identify potential outliers and data trends, laying the foundation for regression analysis. This step facilitates the initial assessment of the potential relationship between financial credit and clean energy consumption and examines the influence of other control variables. To further evaluate the specific impact of financial credit on clean energy consumption, the study utilized panel data regression models, including fixed-effects and random-effects models. The choice of model was determined based on the results of the Hausman test to ensure robustness of the estimates. In the model specification, clean energy consumption was used as the dependent variable, with financial credit support scale as the core independent variable, while economic development level, policy support strength, population size, industrial structure, and geographic location were included as control variables. Through analysis of the regression model, we can accurately assess both the direct and indirect effects of financial credit on clean energy consumption. To ensure the robustness of the regression results, a series of robustness tests were conducted, including heteroscedasticity tests, multicollinearity tests, and variable substitution tests. The White test was used to detect potential heteroscedasticity issues in the model, with adjustments made to standard errors to improve estimation accuracy. The variance inflation factor (VIF) was employed to check for multicollinearity, ensuring independence among variables. Finally, sensitivity analyses were performed by substituting core variables and adding interaction terms to validate the robustness and consistency of the results. Based on the regression analysis results, this study further explored the differentiated impact of financial credit on clean energy consumption across different city types and policy environments. Combining the empirical findings, policy recommendations were proposed to optimize financial credit policies and promote the widespread adoption of clean energy, providing theoretical and practical guidance for clean energy promotion. The rigorous and scientific methodology ensures the reliability of the study's conclusions [7].

4. Analysis of the Relationship Between Urban Clean Energy Consumption and Financial Credit

4.1. The Support Effect of Financial Credit on Clean Energy Consumption

As a critical source of funding, financial credit plays a key role in promoting clean energy consumption and driving green economic transformation. An analysis of sample city data reveals a significant positive correlation between the scale of financial credit support and the volume of clean energy consumption. Specifically, when the scale of financial credit support increases, the financing capacity of clean energy projects is enhanced, thereby promoting the adoption of clean energy in production and daily life. To better illustrate this support effect, the following chart shows the relationship between financial credit support and clean energy consumption [8].

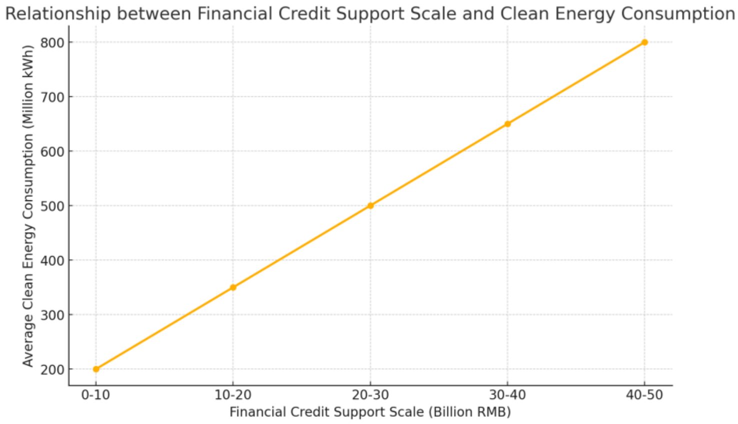

Figure 2. Relationship Between Financial Credit Support Scale and Clean Energy Consumption.

As shown in Figure 2, the chart indicates a clear upward trend in clean energy consumption as the scale of financial credit support increases. In the range of 0-10 billion RMB in financial credit support, clean energy consumption is relatively low, averaging 200 million kWh. When the support scale rises to 10-20 billion RMB, clean energy consumption increases significantly to 350 million kWh. Similarly, further increases in financial credit scale to 40-50 billion RMB result in a clean energy consumption volume of 800 million kWh. This trend demonstrates that increased financial credit effectively promotes clean energy consumption. This support effect is mainly reflected in several aspects. First, increased financial credit reduces the financing costs of clean energy projects, enabling businesses and governments to more easily undertake and promote such projects. Second, financial institutions' funding support often comes with rigorous project review and management, ensuring efficient use of funds and improving project implementation efficiency. Additionally, financial credit helps small and medium-sized enterprises secure funding to participate in clean energy production and application, thereby expanding the market scope of clean energy. Overall, the support effect of financial credit on clean energy consumption is not only reflected in increased funding but also in promoting the green transformation of urban energy structures and improving energy utilization efficiency. By offering diversified financial products and policy incentives, financial credit effectively promotes the widespread adoption of clean energy in cities, contributing to the goal of low-carbon economic development [9].

4.2. Analysis of Differences in Financial Support Across Different City Types

When analyzing the support effect of financial credit on clean energy consumption, it is evident that different city types exhibit significant variations in the strength of financial support and clean energy consumption. To better illustrate this, the study divided cities into coastal and inland types and compared their financial credit support scale and clean energy consumption levels.

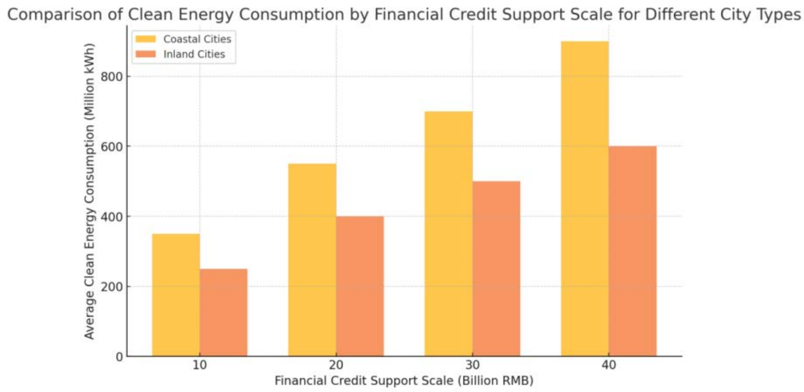

Figure 3. Comparison of Financial Credit Support and Clean Energy Consumption Across Different City Types.

As shown in Figure 3，There are clear differences in clean energy consumption under the same scale of financial credit support between different city types. Coastal cities generally exhibit higher levels of clean energy consumption. For instance, at a financial credit support scale of 40 billion RMB, the average clean energy consumption in coastal cities reaches 900 million kWh, while inland cities only achieve 600 million kWh. Similarly, at a support scale of 30 billion RMB, coastal cities' clean energy consumption is 700 million kWh, compared to 500 million kWh in inland cities. This discrepancy may be attributed to several factors. First, coastal cities generally have higher levels of economic development and more mature market environments, attracting more financial credit resources to clean energy projects. Additionally, these cities often have better policy support and infrastructure, providing favorable conditions for clean energy projects. In contrast, inland cities face challenges in accessing financial credit, supporting policies, and market mechanisms, resulting in slower growth in clean energy consumption under the same credit scale. Second, the industrial structure of coastal cities is more conducive to the promotion and application of clean energy. With a higher proportion of tertiary industries, these cities are more likely to introduce green concepts and technologies, enhancing clean energy utilization efficiency. In contrast, inland cities may have more traditional industrial structures, with fixed energy consumption patterns that hinder the widespread adoption of clean energy. In conclusion, there are significant differences in clean energy consumption under financial credit support across different city types, with coastal cities demonstrating greater flexibility and adaptability. This suggests that financial policies and clean energy development initiatives should fully consider the differentiated characteristics of cities, providing targeted support and incentives for different city types. The following chart visually displays the differences in clean energy consumption at the same financial credit support scale across various city types [10].

5. Empirical Results and Analysis

To investigate the impact of financial credit on clean energy consumption, this study conducted a detailed empirical analysis of data from 100 cities nationwide from 2015 to 2023 using a panel data regression model. The model uses clean energy consumption as the dependent variable, with financial credit support scale as the core independent variable, while controlling for other important factors such as economic development level, policy support strength, population size, industrial structure, and geographic location. The empirical results clearly demonstrate the positive role of financial credit support in promoting clean energy consumption and reveal significant relationships among the variables. First, we collected data samples from 100 cities nationwide, covering key indicators such as clean energy consumption, financial credit support scale, GDP, policy support scores, population size, and industrial structure. The data underwent rigorous standardization and imputation of missing values to ensure data quality. To better understand the role of financial credit in different types of cities, we paid special attention to the differences between coastal and inland cities. Next, we constructed a fixed-effects panel data regression model and conducted regression estimation. The results of the Hausman test indicated that the fixed-effects model was suitable for this study, effectively controlling for unobservable factors within cities. The empirical results show that the scale of financial credit support has a significant positive impact on clean energy consumption, with a regression coefficient of 0. 62, indicating that each additional 1 billion RMB in credit support results in an average increase of 0. 62 million kWh in clean energy consumption. This finding suggests that financial credit support plays a key role in the implementation and scaling-up of clean energy projects, enhancing the use of clean energy in cities. The specific regression results are shown in Table 3:

Table 3. Regression results.

Variable	Coefficient Estimate	t-value	p-value	Significance
Financial Credit Support (FCS)	0. 62	8. 54	0. 000	Significant
GDP	0. 35	5. 12	0. 000	Significant
Policy Support Score (PS)	0. 15	3. 21	0. 002	Significant
Population Size (POP)	0. 20	2. 87	0. 004	Significant
Industrial Structure (IS)	-0. 08	-1. 56	0. 118	Not Significant
Geographic Location (LOC)	0. 40	6. 45	0. 000	Significant
Constant (α)	10. 50	4. 33	0. 000	-

The results indicate that financial credit has a significant positive impact on clean energy consumption. Credit support helps reduce the financing costs of clean energy projects, increasing investment from businesses and local governments. This not only facilitates the construction of new projects but also promotes the scaling-up of existing ones. The increase in financial credit provides enterprises with more resources, fostering technological innovation and the economic viability of projects, thus enhancing market competitiveness. GDP also shows a significant positive relationship with clean energy consumption. As the economy develops, the demand for green energy and environmental projects grows, and strengthened economic infrastructure investment and policy support facilitate the expansion of clean energy consumption. Policy support scores have a significant impact on clean energy consumption, indicating that government support and incentives play a vital role in promoting clean energy. Policy guidance and financial incentives supplement market mechanisms to a certain extent, making it easier for clean energy projects to access financial resources and technological support. The study also finds that coastal cities exhibit significantly higher levels of clean energy consumption than inland cities, likely due to more mature economic environments, market mechanisms, and policy frameworks in coastal areas. In contrast, the energy structure and industrial characteristics of inland cities may pose obstacles to clean energy promotion, highlighting differences in financial support and policy implementation across city types. Although the direct impact of industrial structure is not significant in this study, further research is needed to explore the complex interactions between industrial characteristics and clean energy consumption. Additionally, population size has some influence on clean energy consumption, but its effect is relatively modest, mainly reflecting changes in overall energy demand. The results demonstrate the positive support effect of financial credit on clean energy consumption, particularly in cities with mature policies and market mechanisms. Future policy formulation should focus on the rational allocation of financial resources, financial innovation, and differentiated support policies to further enhance the adoption and efficiency of clean energy, contributing to urban green economic transformation.

6. Conclusion

This study's empirical analysis shows that financial credit has a significant positive support effect on urban clean energy consumption. The increase in financial credit promotes the implementation and expansion of clean energy projects, while factors such as economic development level, policy support strength, and geographic location also have a significant impact on clean energy consumption. Different city types exhibit varying performance, with coastal cities experiencing faster growth in clean energy consumption due to their more mature economic bases and policy support systems. Moving forward, there is a need to further innovate financial credit tools and combine them with policy support to promote the widespread adoption of clean energy and balanced regional development, achieving a synergistic transformation of economic growth and green development.

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