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Revealing the impact of fintech on energy saving and carbon reduction innovation

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Financial technology (fintech) is the application of cutting-edge technology in the financial sector, with potential value for the low-carbon economic transition. In the context of intensified global warming, using fintech to promote energy saving and carbon reduction innovation (ESCRI) presents a thought-provoking practical challenge. This study utilizes data from 30 Chinese provinces spanning 2011 to 2022 to empirically examine whether fintech can improve ESCRI. Results revealed that first, fintech significantly promotes ESCRI, a conclusion supported by a series of robustness tests. Second, the main pathways through which fintech affects ESCRI are industrial scale, investment expansion, and R&D expenditure. Third, in provinces with poor environmental quality, lagging industrial upgrading, and in the central and western regions, fintech's positive effect on ESCRI is more significant. Fourth, fintech demonstrates a significant impact on reducing carbon emissions. The results of this study provide strong evidence for actively utilizing fintech to promote ESCRI on a global scale and offer empirical insight into the underlying logic of green and low-carbon development.

KEYWORDS

fintech, energy saving and carbon reduction innovation, scale effect, investment effect, R&D

1 Introduction

As the global greenhouse effect intensifies and energy challenges become increasingly prominent, energy saving and carbon reduction have emerged as critical drivers for achieving a low-carbon energy transition and sustainable development worldwide (Udeagha and Muchapondwa, 2023; Dai et al., 2025). Over the past few decades, China has prioritized rapid economic expansion, yet this growth trajectory has resulted in significant challenges, including widespread energy inefficiency and severe environmental degradation (Xu and Lin, 2017; Feng S et al., 2022). China's total energy consumption has steadily increased, surging from 1.555 billion tons of standard coal equivalent in 2001 to 5.720 billion tons in 2023. Recent data from the *International Energy Agency* (IEA) reveal that China accounted for 29.14% of global carbon emissions in 2021, making it the world's largest emitter (Cheng et al., 2023).

In recent years, China has demonstrated a strong commitment to energy conservation and carbon reduction (Gao et al., 2022; Zhao et al., 2024; Feng and Xie, 2024), actively pursuing energy decarbonization to enhance environmental quality and achieve sustainable development. In May 2024, the Chinese government launched the "2024–2025 Energy Conservation and Carbon Reduction Action Plan," a strategic policy designed to satisfy the binding targets of the 14th Five-Year Plan while fostering innovation in energy-saving and

carbon-reduction industries, ultimately advancing the nation's dual-carbon objectives. Given that innovation serves as a crucial driver of productivity and low-carbon transformation (Tao et al., 2022), identifying effective pathways to implement energy saving and carbon reduction innovation (ESCRI) has become pivotal for achieving China's ambitious climate goals.

Given the substantial externalities associated with ESCRI, its advancement requires considerable financial backing. Theoretically, financial technology (fintech) offers a viable solution to the financing challenges confronting ESCRI initiatives. Fintech is the fusion of finance and technology (Goldstein et al., 2019). The emergence of disruptive technologies, particularly internet-based platforms and artificial intelligence, has catalyzed the evolution of fintech (Shim and Shin, 2016). Distinct from conventional financial innovation, fintech represents a paradigm shift in technological innovation within the financial sector (Deng et al., 2019). Through integrating advanced technologies such as artificial intelligence, big data analytics, and blockchain into financial systems, fintech has facilitated the development of innovative financial models (Goldstein et al., 2019), enabling more precise and targeted financial services for the energy conservation and carbon reduction industry. This study addresses three critical research questions: Does fintech effectively promote ESCRI? What are the underlying mechanisms driving this relationship? What heterogeneous effects exist across different contexts? To investigate these questions, we employ a double fixed-effects model, using balanced panel data from 30 Chinese provinces spanning 2011 to 2022.

This study makes several significant contributions. First, although previous research has extensively examined the carbon emission reduction effects of fintech from macro and micro perspectives, the relationship between fintech and ESCRI remains underexplored. This study fills this critical gap by providing novel insights and empirical evidence. Second, it identifies and empirically validates several key transmission mechanisms through which fintech influences ESCRI, including the industrial scale effect, investment expansion effect, and R&D expenditure effect. Furthermore, we systematically examine the heterogeneous effects across different environmental quality levels, stages of industrial upgrading, and regional differences. Finally, through further analysis, this study empirically explores the carbon emission reduction effect of fintech and derives targeted policy implications. These findings not only offer valuable insights for fintech innovation and regulatory reform but also make a substantive contribution to advancing China's dual-carbon objectives during this critical implementation phase.

2 Literature review and hypotheses development

Extensive research has explored the economic implications of fintech across macro and micro levels. At the macroeconomic level, fintech has emerged as a crucial driver of sustainable development (Deng et al., 2019). Empirical evidence suggests that proactive fintech initiatives at the regional level significantly help mitigate environmental pollution in BRICS nations, thereby enhancing ecological sustainability (Zhang, 2024). Furthermore, fintech

demonstrates substantial potential to improve urban carbon emission efficiency by accelerating the implementation of green financial policies (Teng and Shen, 2023; Xu et al., 2023; Wan et al., 2025).

At the microeconomic level, fintech applications have become integral to corporate operations and production processes, facilitating low-carbon energy transitions (Li H. et al., 2023) and reducing enterprise-level carbon emissions (Wang et al., 2024). A growing body of literature consistently demonstrates that fintech development contributes to environmental protection and enhances environmental quality (Muganyi et al., 2021; Muhammad et al., 2022; Ali et al., 2024; Li R. et al., 2024). Within this context of environmental improvement, ESCRI plays a pivotal role, delivering substantial benefits through reduced energy waste and minimized environmental pollution (Xie et al., 2023; Li Y. et al., 2024). However, despite these advancements, current research has yet to thoroughly investigate the direct effects and underlying mechanisms through which fintech influences ESCRI.

Based on ecological modernization theory (Jänicke, 2008), the widespread application of fintech may facilitate the promotion of ESCRI. First, fintech provides essential financial support for the development of the energy saving and carbon reduction industry. The advancement of ESCRI typically requires substantial capital investment and involves extended payback periods (Lv et al., 2021). Prior to fintech's widespread adoption, financial institutions were often reluctant to extend credit to energy conservation and emission reduction enterprises due to perceived risks. Contrary to conventional financial systems, fintech revolutionizes the credit evaluation process by implementing comprehensive risk management frameworks that span pre-loan assessment to post-loan monitoring, significantly mitigating default risks (Fuster et al., 2019; Chiu and Lee, 2020). This technological advancement enables financial institutions to more accurately assess the risk–return profile of energy-saving projects, thereby lowering financing barriers and facilitating ESCRI development. Moreover, fintech inherently possesses “green attributes” (Liu et al., 2023), manifested through its ability to drive innovation in green financial instruments and enhance the resource allocation efficiency of financial institutions (Wan et al., 2025). Fintech significantly contributes to advancing ESCRI initiatives by fostering the development of diverse green financial products and creating multiple financing channels for the energy conservation sector.

Second, fintech plays a pivotal role in mitigating information asymmetry and reducing transaction costs within the energy-saving and carbon reduction sectors. The development of energy-efficient and low-carbon industries requires complex innovation processes, which are often hindered by significant information gaps in investment and financing activities (Ni et al., 2023). From the perspective of information asymmetry theory and transaction cost theory, fintech integrates advanced technologies to enable comprehensive analysis of the energy conservation industry's potential and challenges, thereby reducing information asymmetry among stakeholders and significantly lowering transaction costs. Fintech facilitates intelligent data management systems for the energy-saving sector, providing investors with accurate, real-time insights into industry trends and market demands. Given the substantial investment potential of ESCRI,

fintech platforms incentivize capital allocation toward sustainable projects (Cheng et al., 2023), accelerating ESCRI development. Furthermore, the adoption of blockchain technology ensures complete traceability of funds, guaranteeing that financial resources are exclusively used for their intended ESCRI purposes.

Finally, fintech has significantly accelerated the broad dissemination of energy-saving and carbon reduction concepts across society, thereby greatly benefiting ESCRI. By leveraging fintech platforms, regional development in energy conservation and carbon reduction can be effectively advanced (Li et al., 2020). These platforms encourage public participation in energy-saving and carbon-reducing activities, fostering the spread of these principles and garnering wider support for ESCRI. For example, fintech platforms can facilitate crowdfunding campaigns that engage the public in financing energy-efficient and low-carbon projects. Moreover, fintech drives digital transformation within financial institutions, with online operations increasingly becoming the dominant mode of business. By offering green consumer financial products, fintech guides the public toward selecting low-carbon goods and services (Vu et al., 2024). This approach not only boosts demand for energy-saving and carbon-reducing practices but also provides strong momentum for advancing ESCRI. Based on this analysis, Hypothesis 1 is proposed:

H1: Ceteris paribus, fintech can promote ESCRI significantly.

Although existing studies have confirmed the carbon reduction effects of fintech (Cheng et al., 2023; Teng and Shen, 2023; Wan et al., 2025), they have largely overlooked the mechanisms through which fintech influences ESCRI. This study addresses this gap by thoroughly examining the critical roles of industrial scale, investment expansion, and R&D expenditure in shaping the relationship between fintech and ESCRI. For a detailed theoretical framework, refer to Figure 1.

First, the industrial scale effect. Fintech drives the modernization and digital transformation of financial institutions, enabling faster and more efficient allocation of financial resources (Li et al., 2020). From the perspective of information asymmetry theory, fintech leverages technologies such as artificial intelligence, blockchain, and big data to reduce information asymmetry between financial institutions and industrial entities (Li Y. et al., 2024). This reduction facilitates optimized resource allocation (Deng et al., 2019) and enhances overall industrial efficiency. Drawing on industrial organization theory, fintech contributes to scaling up of the energy-saving and carbon reduction industry. In terms of organizational collaboration, the widespread adoption of fintech has fostered the creation of dedicated platforms for this industry. These platforms enable supply and demand stakeholders to share resources more effectively, foster knowledge dissemination, and blur organizational boundaries. These platforms open new opportunities to advance ESCRI by reducing transaction costs and promoting economies of scale.

Second, the investment expansion effect. The energy-saving and carbon reduction industry possesses significant investment potential and demand, but its continued growth requires substantial financial support involving collaboration across multiple sectors. Fintech enables financial institutions to accurately identify the value potential of this industry, assess investment needs and risks (Zhu, 2019), and provide targeted financial support. For example, green bond platforms such as

the *European Investment Bank* (EIB) leverage fintech to issue green bonds, securing investments for energy-saving and carbon-reducing projects. Evidently, accelerating investment in these projects plays a crucial role in advancing ESCRI.

Third, the R&D expenditure effect. Given the widespread societal emphasis on energy efficiency and carbon reduction, local governments and financial institutions have actively supported the energy-saving and carbon reduction industry by allocating substantial R&D funding. From the perspective of technological innovation theory, fintech may serve as a key driver of innovation. Fintech equips local governments, financial institutions, and other stakeholders with advanced data analysis tools, enabling more precise and efficient allocation of R&D funds to ESCRI (Aid et al., 2017; Breidbach et al., 2020). Furthermore, fintech assists governments address challenges within the real economy. For example, fintech enables governments to accurately identify the specific needs of energy-saving and carbon reduction industries, facilitating timely financial subsidies or identifying investment opportunities (Arner et al., 2020; Teng and Shen, 2023). This proactive approach helps safeguard and promote ESCRI. Based on this analysis, Hypotheses 2–4 are proposed:

H2: Ceteris paribus, fintech promotes ESCRI by driving industrial scale.

H3: Ceteris paribus, fintech promotes ESCRI by improving investment expansion.

H4: Ceteris paribus, fintech promotes ESCRI by increasing R&D expenditure.

3 Methods

3.1 Econometric model specification

Following the approach of Wang et al. (2024), this study establishes a double fixed effects model to examine the impact of fintech on ESCRI. The model is specified as follows:

$$ESCRI_{i,t} = \alpha_0 + \alpha_1 Fintech_{i,t} + \alpha_2 Control_{i,t} + \delta_i + \lambda_t + \varepsilon_{i,t} \quad (1)$$

where the dependent variable, $ESCRI_{i,t}$, represents energy saving and carbon reduction innovation. The key explanatory variable is $Fintech_{i,t}$, $Control_{i,t}$ includes other factors that affect ESCRI. α_0 denotes the intercept, and α_1 and α_2 represent the unknown regression coefficients, with α_1 expected to be positive. i denotes province, and t corresponds to year. δ_i and λ_t signify province-fixed effects and year-fixed effects, respectively, and $\varepsilon_{i,t}$ represents the error term.

Constructing a testing approach that aligns with characteristics of empirical economic research is essential (Jiang, 2022). A widely accepted practice involves identifying path variables that, based on theory, logically and directly exhibit a causal relationship with the dependent variable, and then using econometric methods to verify only the causal relationship between these path variables and the explanatory variables (Dell, 2010). This study adopts the argumentation framework proposed by Jiang (2022) and Feng and Zhou (2024), focusing solely on testing the front end of the influence pathway, while

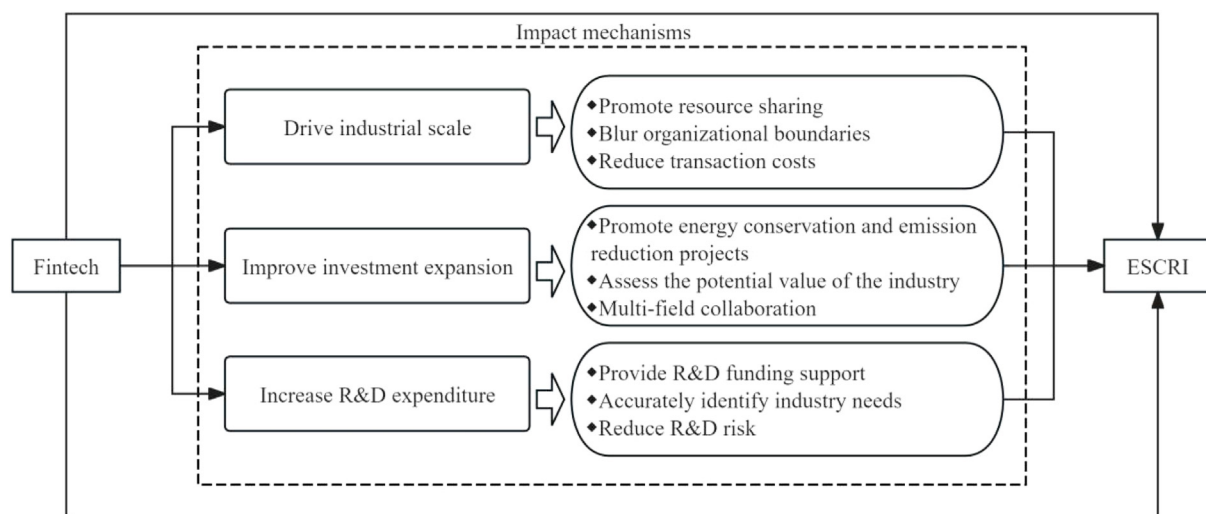


FIGURE 1
Theoretical framework.

TABLE 1 Descriptive statistical analysis of variables.

Var	N	Max	Mean	Min	P50	SD
ESCRI	360	10.876	7.495	3.296	7.456	1.431
Fintech	360	9.137	7.405	4.949	7.472	0.698
Scale	360	11.018	8.380	5.263	8.462	1.207
Invest	360	3.100	0.402	0.012	0.216	0.497
Rd	360	17.720	14.945	11.627	15.119	1.331
EQ	360	5.208	3.128	-2.228	3.296	1.290
IU	360	5.310	1.266	0.518	1.112	0.722
Pgdp	360	12.156	10.909	9.706	10.875	0.452
Fd	360	8.096	3.298	1.514	3.082	1.151
Fcr	360	1.156	0.523	0.154	0.475	0.191
Open	360	12.549	8.166	3.125	8.093	1.703
Insur	360	9.443	7.537	5.941	7.562	0.636

relying on existing literature to support and explain the back end. To validate the mechanism through which fintech impacts ESCRI, we further constructed Equation 2 as follows:

$$\text{Mediator}_{i,t} = \beta_0 + \beta_1 \text{Fintech}_{i,t} + \beta_2 \text{Control}_{i,t} + \delta_i + \lambda_t + \varepsilon_{i,t} \quad (2)$$

The mediating variables comprise primarily industrial scale (Scale), investment expansion (Invest), and R&D investment (Rd). β_0 represents the intercept term, and β_1 and β_2 denote the unknown regression coefficients. Our primary focus is on assessing the significance of α_1 and β_1 . The other variables remain consistent with those specified in the previous model.

To further explore the external factors that moderate fintech's influence on ESCRI, this study constructs Equation 3, incorporating an interaction term, as follows:

$$\begin{aligned} \text{ESCRI}_{i,t} = & \theta_0 + \theta_1 \text{Fintech}_{i,t} + \theta_2 \text{Moderator}_{i,t} \\ & + \theta_3 \text{Fintech}_{i,t} * \text{Moderator}_{i,t} + \theta_4 \text{Control}_{i,t} + \delta_i + \lambda_t + \varepsilon_{i,t}. \end{aligned} \quad (3)$$

The moderator variables comprise primarily environmental quality (EQ) and industrial upgrading (IU). θ_0 represents the intercept term, and θ_1 and θ_2 denote unknown regression coefficients. Our main focus lies in determining the significance of θ_3 . All other variables remain consistent with those defined in the previous model. Notably, the test for regional heterogeneity was conducted based on Equation 1.

3.2 Main variables

3.2.1 Energy saving and carbon reduction innovation

ESCRI is a key dependent variable in this study. Existing research generally measures innovation levels by the number of patent applications (Huang and Ma, 2024; Zhao et al., 2024). Therefore, this study measures ESCRI as the natural logarithm of one plus the number of patent applications in the energy-saving and carbon reduction industry. The total number of patent applications is the sum of applications submitted by energy-saving and carbon-reducing enterprises within each province.

3.2.2 Fintech

The search for online data is driven by public demand and serves as a valuable tool for tracking current situations and predicting trends (Ripberger, 2011). This study adopts the research approach of Wang et al. (2024) and Chen et al. (2024), using web crawling and text analysis techniques to extract fintech-related keywords from the Baidu index¹. The sum of keyword search volumes is then added by

¹ <https://index.baidu.com/>

TABLE 2 Baseline regression results.

	[1]	[2]
	ESCRI	ESCRI
Fintech	0.784*** (4.32)	0.816*** (4.25)
Pgdp		-0.481** (-2.20)
Fd		-0.158** (-2.30)
Fcr		0.076 (0.37)
Open		0.070* (1.69)
Insur		0.418*** (2.61)
Province FE	Yes	Yes
Year FE	Yes	Yes
_cons	1.168 (0.98)	2.962 (1.19)
R ²	0.859	0.864
F	160.962***	116.977***
Obs	360	360

*, **, and *** denote significance at 10%, 5%, and 1%, respectively; t statistics in parentheses, the following is the same.

one using the natural logarithm measurement. The specific keywords include “Fintech”, “Internet finance”, “Artificial intelligence”, “Big data”, “Cloud computing”, “Blockchain”, “Biometrics”, “Mobile payment”, “Online payment”, “Third-party payment”, “Online loan”, “Online banking”, “E-banking”, “Internet banking”, and “Direct selling bank”.

3.2.3 Mediator variables

Based on the impact pathway proposed earlier, this study selected three mediator variables. First, industrial scale (Scale), measured as the natural logarithm of the number of energy-saving and carbon-reducing enterprises in each province plus one. A greater number of such enterprises indicates more advanced scale development; hence, a higher value on this indicator reflects better scale expansion. Second, investment expansion (Invest), measured as the ratio of investment in the energy conservation and carbon reduction industry to GDP. A higher investment ratio signals greater expansion in this sector; therefore, a higher value indicates stronger investment growth. Third, R&D expenditure (Rd), measured by the natural logarithm of allocated R&D funds. Larger R&D funding corresponds to greater scale of innovation expenditure within each province. Accordingly, a higher value signifies more extensive R&D investment.

3.2.4 Moderator variables

To delve deeper into the external factors impacting fintech’s influence on ESCRI, this study investigates the disparities between the two through the lenses of environmental quality, industrial upgrading, and regional differences. (1) EQ is quantified using the natural logarithm of SO₂ emissions per province, serving as an inverse indicator where higher values correspond to worse environmental conditions. (2) IU is measured by the ratio of the tertiary industry’s value added to the secondary industry’s value, functioning as a positive indicator where higher values reflect more progressive industrial structures. (3) Regional differences is measure based on standard geographical classifications. In this study, the sample is divided into eastern and midwestern regions.

3.2.5 Control variables

Wu et al. (2021) and Zhang et al. (2023) integrated the following control variables, which affect ESCRI, to the double fixed effects model: (1) Regional economic development (Pgdp), measured by the natural logarithm of regional *per capita* GDP; (2) Financial development (Fd), measured by the ratio of the sum of financial deposits and loan balances to GDP; (3) Fiscal self-sufficiency rate (Fcr), measured by the ratio of fiscal revenue to fiscal expenditure of local governments; (4) Openness to the outside (Open), measured by the proportion of foreign trade volume to GDP; (5) Insurance development (Insur), measured by the

TABLE 3 Robustness checks.

	[1]	[2]	[3]	[4]	[5]	[6]
	Fintech	ESCRI	ESCRI	ESCRI	ESCRI	ESCRI
IV	0.083*	3.950**				
	(1.97)	(2.88)				
Fintech			0.788***	0.630***	0.805***	1.080***
			(3.92)	(4.57)	(3.94)	(5.73)
Pgdp	0.380***	−1.445***	−0.466**	−0.432**	−0.377	−0.565**
	(4.62)	(−2.92)	(−2.12)	(−2.01)	(−1.62)	(−2.52)
Fd	0.059**	−0.268***	−0.154**	−0.184***	−0.119	−0.157**
	(2.33)	(−2.73)	(−2.24)	(−2.67)	(−1.63)	(−2.32)
Fcr	0.058	−0.222	0.0950	0.120	−0.251	−0.188
	(0.68)	(−0.76)	(0.46)	(0.58)	(−1.13)	(−0.90)
Open	0.012	0.085	0.0670	0.089**	0.0560	0.0410
	(0.51)	(1.40)	(1.61)	(2.15)	(1.29)	(0.98)
Insur	0.036	0.251	0.430***	0.259	0.431**	0.177
	(0.49)	(0.88)	(2.67)	(1.57)	(2.53)	(1.07)
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
_cons	−16.49	9.869***	5.168**	6.499***	1.457	4.660*
	(−1.67)	(9.43)	(2.13)	(2.68)	(0.55)	(1.78)
R ²	0.982	0.749	0.863	0.865	0.877	0.831
F	1554.393***	58.224***	115.907***	118.131***	130.920***	86.971***
Obs	360	360	360	360	360	330

natural logarithm of insurance density, which is determined using *per capita* insurance expenditure.

3.3 Sample and data

This study uses data from 30 Chinese provinces (excluding Tibet, Hong Kong, Macao, and Taiwan) spanning 2011 to 2022 to empirically examine whether fintech can enhance ESCRI. Ultimately, a dynamic equilibrium panel comprising 360 observations is obtained. Fintech data are collected from the Baidu index. ESCRI data are gathered from the China Public Policy and Green Development Database (CPPGD). Data on mediator and moderator variables are obtained from CPPGD and Express Professional Superior data platform (EPS). Other data sources include China Statistical Yearbook, China Financial Yearbook, statistical yearbooks of various provinces, and Center for Global Environmental Research (CGER).

Table 1 presents the descriptive statistical results of the variables. The maximum value of ESCRI is 10.876, with a mean of 7.495 and a median of 7.456, indicating that the ESCRI of most samples is at a relatively high level. This finding is consistent with the reality of China, encouraging

energy conservation and carbon reduction in recent years. However, the standard deviation is 1.431, suggesting the significant differences between provinces. At the same time, the descriptive results of fintech show synchronicity, providing a foundation for further tests on the relationship between fintech and ESCRI. The overall levels of industrial scale (Scale) and R&D expenditure (Rd) in the sample are relatively high, but significant differences exist within the sample. On the contrary, the overall level of investment expansion (Invest) in most provinces is still relatively low. Other variables are consistent with existing research. In addition, tests for multicollinearity have been conducted in this study, results of which indicate that the mean value of variance inflation factor is 5.19, implying the absence of multicollinearity.

4 Empirical results

4.1 Baseline regression results

Table 2 demonstrates the baseline regression results for fintech and ESCRI. Column [1] illustrates the regression result without control variables. The results show that the regression coefficient of fintech is significantly positive. After adding control variables, the

TABLE 4 Mechanism analysis.

	[1]	[2]	[3]	[4]
	ESCRI	Scale	Invest	Rd
Fintech	0.816*** (4.25)	0.195*** (2.75)	0.007*** (3.18)	0.172* (1.91)
Pgdp	-0.481** (-2.20)	0.116 (1.43)	-0.005** (-2.18)	1.227*** (11.97)
Fd	-0.158** (-2.30)	0.020 (0.79)	0.001 (1.45)	0.088*** (2.76)
Fcr	0.076 (0.37)	0.149* (1.94)	-0.003 (-1.26)	0.035 (0.36)
Open	0.070* (1.69)	0.006 (0.37)	0.000 (0.80)	0.008 (0.44)
Insur	0.418*** (2.61)	0.133** (2.24)	0.002 (1.17)	-0.051 (-0.68)
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
_cons	2.962 (1.19)	4.281*** (4.67)	0.009 (0.32)	0.321 (0.28)
R ²	0.864	0.930	0.550	0.935
F	116.977***	243.636***	22.501***	263.533***
Obs	360	360	360	360

regression coefficient of fintech in Column [2] becomes 0.816 and significantly positive at the 1% statistical level. This finding indicates that fintech significantly promotes ESCRI, confirming [Hypothesis 1](#). Previous studies have investigated the positive effect of fintech on green innovation from the enterprise level ([Huang and Ma, 2024](#); [Li Y. et al., 2024](#)). The results obtained from the macro level in this study are mutually corroborative.

4.2 Robustness checks

To ensure the robustness of our findings, a series of robustness tests was conducted, including endogeneity tests. Following the methodology of [Li R. et al. \(2024\)](#), this study uses the spherical distance from each provincial capital to Hangzhou city multiplied by the year, as an IV for fintech. This IV satisfies the requirements of correlation and exogeneity in the selection of instrumental variables and has passed the weak instrumental variable test. The results of regression using the two-step least squares (2SLS) method are shown in columns [1]–[2] of [Table 3](#). The results of the first stage indicate that the regression coefficient of IV is 0.083, which is significant at the 10% statistical level. The results of the second stage suggest that the regression coefficient of IV is 3.950, which is significant at the 5% statistical level. These findings further confirm [Hypothesis 1](#).

Second, the explanatory variable is replaced. This study measures fintech by considering the natural logarithm of the arithmetic mean of word frequency. The results of column [3] indicate that the regression coefficient of fintech is 0.788, which is significantly positive at the 1% statistical level, further confirming the robustness of the above conclusion. Furthermore, this study employs the digital inclusive finance index provided by Peking University to measure fintech, with the specific results shown in [4] remaining robust.

Third, the dependent variable is replaced. This study measures ESCRI by regarding the natural logarithm of the number of patent authorizations. The results of column [5] indicate that the regression coefficient of fintech is 0.805, which is significantly positive at the 1% statistical level, further confirming the robustness of the above conclusion.

Fourth, the core variable lags behind by one period. This study regresses the results after lagging fintech by one period. The results of column [6] still support the above conclusion.

4.3 Mechanism analysis

[Table 4](#) presents the results of the impact mechanisms through which fintech influences ESCRI. Column [1] displays the empirical results for Hypothesis 1, indicating that fintech exhibits a positive and significant effect on ESCRI. Column [2] illustrates the results for fintech's impact on industrial scale. The regression coefficient for fintech is 0.195, which is statistically significant at the 1% level, suggesting that it exerts a significant industrial scale effect. Previous studies have established a direct relationship between rapid industrial development and the enhancement of innovation levels ([Liu and Zhang, 2021](#)). Expanding industrial scale creates opportunities for improving ESCRI ([Zeng et al., 2021](#)), thereby confirming [Hypothesis 2](#).

Column [3] presents the results of fintech's impact on investment expansion. The regression coefficient for fintech is 0.007, which is statistically significant at the 1% level, indicating that fintech exhibits a significant investment expansion effect. Fintech's support enables financial institutions and other investors to more accurately identify and capitalize on investment opportunities in energy-saving and carbon-reducing projects ([Zhu, 2019](#)). This approach contributes to the advancement of ESCRI, thereby confirming [Hypothesis 3](#).

Column [4] illustrates the results of fintech's impact on R&D expenditure. The regression coefficient for fintech is 0.172, which is statistically significant at the 10% level, indicating that it exhibits a significant R&D expenditure effect. Fintech guarantees the orderly implementation of ESCRI by ensuring that R&D funds are effectively allocated to energy-saving and carbon-reduction programs ([Lee et al., 2022](#)). This outcome can be attributed to fintech's ability to accurately identify and monitor funding needs ([Aid et al., 2017](#); [Breibach et al., 2020](#)), thereby confirming [Hypothesis 4](#).

4.4 Heterogeneity analysis

To delve deeper into the external factors impacting fintech's influence on ESCRI, this study investigates the disparities between the two through the lenses of environmental quality, industrial upgrading, and regional differences.

TABLE 5 Heterogeneity analysis.

	[1]	[2]	[3]	[4]
	ESCRI	ESCRI	ESCRI (East)	ESCRI (Midwest)
Fintech	0.536**	0.966***	0.324	1.283***
	(2.45)	(5.01)	(1.23)	(4.36)
EQ	−0.454*			
	(−1.87)			
Fintech*EQ	0.062**			
	(2.23)			
IU		1.227***		
		(3.66)		
Fintech*IU		−0.151***		
		(−3.79)		
Pgdp	−0.295	−0.292	0.124	−0.896***
	(−1.29)	(−1.32)	(0.40)	(−3.11)
Fd	−0.106	−0.131*	−0.058	−0.142
	(−1.50)	(−1.94)	(−0.63)	(−1.41)
Fcr	0.095	0.033	0.161	0.063
	(0.46)	(0.16)	(0.52)	(0.24)
Open	0.072*	0.072*	−0.059	0.142***
	(1.73)	(1.78)	(−0.77)	(2.76)
Insur	0.301*	0.245	0.365*	−0.348
	(1.82)	(1.47)	(1.71)	(−1.21)
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
_cons	3.673	0.926	1.764	8.374**
	(1.48)	(0.36)	(0.47)	(2.54)
R ²	0.867	0.870	0.882	0.878
F	106.678***	109.544***	45.729***	81.375***
Obs	360	360	132	228

4.4.1 Environmental quality

Variations in regional environmental quality may influence the relationship between fintech and ESCRI. Regions with poorer environmental conditions may face greater urgency to improve their environment than areas with better environmental quality. Consequently, fintech adoption in these regions is more likely to accelerate in energy-saving and carbon-reduction industries and related projects, thereby fostering ESCRI. We developed an interaction term between fintech and environmental quality (Fintech*EQ) to analyze this relationship. As shown in Column [1] of Table 5, the regression coefficient for the interaction term is 0.062, statistically significant at the 5% level. This finding suggests that fintech’s contribution to ESCRI is significantly stronger in regions with inferior environmental quality.

4.4.2 Industrial upgrading

The regional industrial structure plays a crucial role in facilitating innovation activities (Feng T et al., 2022). Typically, regions with more advanced industrial structures demonstrate a greater demand for ESCRI development. In such contexts, fintech is likely to exert a more substantial positive influence on ESCRI advancement. We constructed an interaction term between fintech and industrial upgrading (Fintech*IU) to examine this relationship. As presented in Column [2] of Table 5, the regression coefficient for the interaction term is −0.151, statistically significant at the 1% level. This result indicates that fintech’s contribution to ESCRI is particularly significant in regions with less developed industrial structures.

TABLE 6 Further analysis.

	[1]	[2]
	CO ₂	CO ₂
Fintech	−0.108***	−0.086***
	(−3.60)	(−2.78)
Pgdp		0.032
		(0.91)
Fd		0.044***
		(4.01)
Fcr		−0.004
		(−0.13)
Open		−0.003
		(−0.47)
Insur		−0.041
		(−1.61)
Province FE	Yes	Yes
Year FE	Yes	Yes
_cons	1.549***	1.265***
	(7.92)	(3.18)
R ²	0.717	0.740
F	66.990***	52.477***
Obs	360	360

4.4.3 Regional differences

In China, the central and western regions experience relatively slower economic growth than their eastern counterparts, primarily due to disparities in regional endowments (Bi et al., 2024). The traditional financial system has often been less accommodating to these less developed areas (Du, 2017). However, the advent of fintech has effectively addressed these gaps, significantly benefiting the economic development of the central and western regions (Jin, 2017; Ye et al., 2022). In this study, the sample is divided into eastern and midwestern regions based on standard geographical classifications. Columns [3]–[4] of Table 5 present the findings on regional disparities. The regression coefficients for fintech in the eastern region sample do not exhibit statistical significance. On the contrary, in the midwestern sample, the regression coefficient for fintech is 1.283, which is significant at the 1% level. These results indicate that fintech plays a more crucial role in enhancing ESCRI in the Midwest than in the East.

5 Further analysis: fintech's carbon reduction effect

Fintech offers financial support for green and low-carbon initiatives, thereby playing a pivotal role in improving environmental quality (Udeagha and Muchapondwa, 2023). In addition, it drives technological innovation within the

financial sector and increases the share of clean energy consumption in economic activities, further aiding in the carbon reduction (Li G. et al., 2023; Xu et al., 2023). This study delves deeper into the carbon emission reduction effects of fintech, the findings of which are presented in Table 6. Column [1] displays the regression results without control variables, revealing a significantly negative regression coefficient for fintech. Upon incorporating control variables, the regression coefficient in Column [2] is −0.086, which remains significantly negative at the 1% statistical level. This finding underscores that fintech effectively curbs carbon emissions, demonstrating a clear carbon abatement effect. Our findings are consistent with the results reported by Tao et al. (2022) and Xu et al. (2023). Building on these insights, we conclude that fintech significantly contributes to carbon emission reduction by enhancing ESCRI levels.

6 Conclusions and policy implications

Promoting ESCRI is widely recognized as a crucial strategy for advancing carbon reduction efforts in the current climate, with fintech playing a pivotal role in driving this progress. This study empirically examines whether fintech enhances ESCRI using data from 30 Chinese provinces spanning 2011 to 2022. The findings reveal that fintech significantly promotes ESCRI, a conclusion further supported by a series of robustness tests. The primary pathways through which fintech affects ESCRI are industrial scale, investment expansion, and R&D expenditure. Moreover, fintech's impact on ESCRI is particularly pronounced in provinces characterized by poor environmental quality, lagging industrial upgrading, and those located in central and western regions. Finally, fintech demonstrates a significant impact on reducing carbon emissions.

The findings presented not only align with and enrich the existing research but also hold substantial academic value. Building on these insights, this study proposes several policy recommendations to harness the potential of fintech for environmental and economic benefits. First, fintech demonstrates a strong capacity to enhance ESCRI and to effectively reduce carbon emissions. Thus, the government must integrate fintech's role in supporting energy conservation and carbon reduction into future strategic frameworks, clearly delineating developmental objectives. Concurrently, regulatory policies and frameworks must be refined, ensuring a coordinated approach to fintech application management to mitigate resource wastage.

Second, the adoption and implementation of fintech must be promoted, alongside fostering innovation in green financial products to bolster industries focused on energy efficiency and carbon reduction. Establishing a robust data-sharing platform that connects the government, financial institutions, and real enterprises is crucial. This platform would serve as a foundational data repository, facilitating the broader application of fintech. Furthermore, the government should incentivize financial institutions to harness fintech in developing green financial products, thereby channeling financial resources into energy-saving and carbon-reducing sectors at reduced costs. In addition, financial institutions are encouraged to utilize fintech

in crafting insurance products tailored for ESCRI, aimed at risk mitigation.

Third, proactive steps must be taken to develop a cross-regional fintech collaboration network. The adoption levels of fintech vary significantly given the disparities in regional economic development. Establishing a provincial cooperation network would foster mutual benefits and drive overall ESCRI growth. For example, leading cities, such as Beijing and Shanghai, could partner with less developed regions in central and western China, offering fintech guidance and support to stimulate ESCRI advancements.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

BY: Conceptualization, Methodology, Writing – original draft. FZ: Conceptualization, Data curation, Formal Analysis, Writing – review and editing.

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