

Financial Geography, Carbon Emission Reduction, and County Economic Development

Ziming Pan

School of Economics and Management, Nanjing University of Science and Technology, Nanjing 210094, China

Abstract: Promoting county-level economic development is a key task for achieving coordinated regional development, and the spatial pattern of financial resource allocation together with carbon emission constraints are two important factors affecting this process. Using county-level panel data of China from 2000 to 2019, this paper measures county economic development by nighttime light intensity, constructs county-level financial accessibility indicators based on geographical information of financial branches, and empirically examines the impact of financial accessibility on county development. It also investigates the moderating effect of carbon emissions and the mediating transmission mechanisms of technological innovation and industrial structure upgrading. The findings show that improved financial accessibility significantly promotes county economic development. This effect is more pronounced in counties with lower economic development levels and slower growth rates, but it is not significant in the short run in counties with extremely low initial financial accessibility. Carbon emissions negatively moderate the effect of financial accessibility, meaning that carbon emission pressure weakens the promoting effect of financial accessibility on county development. Technological innovation and industrial structure upgrading are two important mediating pathways through which financial accessibility indirectly drives county economic development. This paper provides new evidence for understanding county development gaps from the perspective of financial geography, reveals the complex mechanism of financial support for county development under carbon emission constraints, and offers policy implications for optimizing the layout of financial branches, implementing differentiated green credit policies, and promoting low-carbon transition at the county level.

Keywords: Financial accessibility, carbon emissions, county economic development.

1. Introduction

The development gap among Chinese counties has long existed and shows persistent characteristics. According to data from the China County Statistical Yearbook, even within the same prefecture-level city, the range of per capita GDP across counties has not shown a clear trend of convergence over the past two decades, and has even widened in some areas. Meanwhile, the layout of financial institution branches in China has experienced rapid expansion over the past two decades. Data from the China Banking and Insurance Regulatory Commission show that between 2000 and 2019, the average number of financial institution branches at the county level more than doubled. However, the spatial distribution of financial resources is far from homogeneous, and the disparity in financial accessibility between developed and underdeveloped counties is equally significant. On the other hand, with the establishment of the carbon peaking and carbon neutrality goals, carbon emission constraints are becoming a new factor affecting regional development patterns. High-emission counties are often traditional industrial bases that face higher transition costs under emission reduction pressure, while low-emission counties may lose growth momentum due to industrial relocation. Therefore, whether improved financial accessibility narrows or widens the county development gap, and what role carbon emissions play in this process, remain understudied questions.

Existing literature has explored the relationship between financial development and regional economic gaps from various perspectives. Some studies argue that financial development promotes cross-regional capital flows and improves resource allocation efficiency, thereby narrowing regional disparities. Other studies point out that financial

institutions tend to locate in economically developed areas, leading financial resources to favor the rich and exacerbating regional imbalances. However, most studies use provincial or prefecture-level city data, and financial accessibility is often measured by macro indicators such as the ratio of bank deposits and loans to GDP, with little attention paid to the geographical distribution of financial branches. As the physical points of financial service delivery, the spatial layout of financial branches directly affects the convenience with which firms and residents access credit resources, a perspective that has not been fully utilized in research on regional disparities.

Regarding the relationship between carbon emissions and regional development, the environmental economics literature has accumulated a rich body of work. Some scholars find an inverted U-shaped relationship between carbon emissions and economic growth, while others focus on the impact of carbon reduction policies on regional industrial competitiveness. However, incorporating carbon emissions as a moderating variable into the analytical framework of financial development and regional disparities remains relatively limited. Theoretically, carbon emissions may affect regional development through two pathways. The first is the cost effect: regions with higher carbon emissions face stricter environmental regulations, which raise firms' operating costs and may weaken their growth potential. The second is the transition effect: counties with high financial accessibility that also face carbon emission constraints are more likely to obtain green credit support, thereby achieving industrial upgrading and maintaining growth momentum. Thus, carbon emissions may moderate the effect of financial accessibility, a hypothesis that requires empirical testing.

This paper constructs a Chinese county-level panel dataset

for the period 2000 to 2019 using nighttime light data, financial institution branch data, and carbon dioxide emission grid data. The dependent variable is year-standardized nighttime light intensity, which proxies for the actual level of county economic activity. The core independent variable is county-level financial accessibility, measured by three indicators: total number of financial branches, number of branches per ten thousand persons, and number of branches per square kilometer. The mediating variables include county patent applications and the industrial structure upgrading index. Empirically, this paper first examines the effect of financial accessibility on county development, then investigates the moderating effect of carbon emissions, and finally tests the mediating transmission mechanisms of technological innovation and industrial structure upgrading. To mitigate endogeneity concerns, this paper uses the mean financial accessibility of other counties within the same prefecture-level city as an instrumental variable and conducts placebo tests.

The main findings are threefold. First, improved financial accessibility significantly promotes county development. A one-standard-deviation increase in financial branches per ten thousand persons raises the standardized nighttime light intensity by about 0.048 standard deviations. This effect is more pronounced in counties with lower economic development levels and slower growth rates, but it is not significant in the short run in counties with extremely low initial financial accessibility. Second, carbon emissions negatively moderate the effect of financial accessibility. Interaction term analysis shows that the coefficient of the interaction between financial accessibility and carbon emissions is significantly negative, indicating that carbon emission pressure weakens the promoting effect of financial accessibility on county development. Third, technological innovation and industrial structure upgrading play partial mediating roles. Financial accessibility indirectly drives county economic development by increasing the number of county patent applications and raising the industrial structure upgrading index.

The marginal contributions of this paper are threefold. First, it supplements the explanation of regional development gaps from the perspective of financial geography. Unlike previous studies that used aggregate indicators such as total deposits and loans, this paper measures financial accessibility based on the actual spatial distribution of financial branches, more accurately capturing the geographic accessibility of financial resources. Second, it incorporates carbon emissions into the analytical framework of financial development and regional disparities, identifying the negative moderating effect of carbon emissions. This finding has implications for understanding regional coordinated development under the dual carbon goals. Third, it clarifies the mediating transmission paths of technological innovation and industrial structure upgrading, providing empirical evidence for promoting balanced county development through the optimization of financial supply.

The remainder of this paper is organized as follows. Section 2 elaborates the theoretical logic and derives the research hypotheses. Section 3 describes the data sources, variable definitions, and econometric models. Section 4 reports the empirical results, including baseline regressions, robustness checks, heterogeneity analysis, moderating effect analysis, and mediation effect analysis. Section 5 concludes and discusses policy implications.

2. Theoretical Analysis and Research Hypotheses

Financial accessibility, defined as the ease with which economic agents obtain financial services through physical bank branches, has been widely recognized as a key driver of regional economic growth. Expanding financial services in underdeveloped regions alleviates financing constraints, optimizes capital allocation, and narrows income gaps [1]. The physical distribution of bank branches determines the accessibility of financial services for micro-entities and, consequently, the growth potential of local economies [2]. Expanding bank branch coverage in financially underserved areas significantly boosts local entrepreneurship, formal employment, and average wage growth, with stronger effects in regions initially lacking bank services [2]. In China, financial inclusion exerts a stronger growth effect on regions with backward economic development and low initial financial availability, thereby fostering coordinated regional development [3]. Financial inclusion promotes regional economic development by stimulating technological innovation, and innovation serves as an important transmission channel [4]. Improved financial accessibility reduces firms' R&D financing costs, increases patent applications, and enhances regional innovation capacity [5]. Finance guides capital to high-efficiency sectors, promotes industrial upgrading, and reduces resource misallocation [6]. Digital financial inclusion significantly boosts high-quality economic development through improving resource allocation, technological innovation, and industrial upgrading, and its marginal effect is stronger in underdeveloped regions [7]. Based on this reasoning, we propose Hypothesis 1: Financial accessibility has a positive and significant effect on county-level economic development, as measured by standardized nighttime light intensity.

The impact of financial accessibility is unlikely to be uniform across counties. Regions with different initial economic conditions, financial infrastructure, and growth rates may experience heterogeneous effects. Evidence shows that financial inclusion has a stronger growth effect in regions with lower initial economic development and slower growth, helping to narrow development gaps [3, 7]. However, in counties with extremely low initial financial accessibility, the short-term effect may be weaker because financial infrastructure requires time to reach a critical mass before generating meaningful growth impacts [2]. It is reasonable to expect that the coefficient of financial accessibility is larger in low-development counties than in high-development counties, and larger in slow-growth counties than in fast-growth counties. In contrast, the coefficient is likely to be small and only marginally significant in low-initial-finance counties. Therefore, we propose Hypothesis 2: The positive effect of financial accessibility on county economic development is heterogeneous. It is stronger in counties with lower economic development levels and slower economic growth, but weaker in counties with very low initial financial accessibility.

Carbon emissions present a more complex relationship with county development. On one hand, high-emission counties typically possess a strong industrial base and generate higher output, which may create a positive correlation between carbon emissions and economic activity. On the other hand, high carbon emissions imply higher transformation costs and stricter environmental regulations,

which can weaken the growth-promoting effect of financial resources [8]. Carbon constraints create an industrial lock-in effect: high-carbon regions struggle to translate financial support into growth momentum quickly because their production structures are locked into energy-intensive sectors [9]. Emission reduction policies change the marginal effect of financial development on economic growth [10]. Financial inclusion in emerging economies still has a net positive impact on carbon footprint because it expands production and consumption scales, and the emission reduction effect materializes only when matched with renewable energy transition [11]. There exists an inverted U-shaped relationship between financial inclusion and environmental pollution: initially increasing pollution but improving green sustainability beyond a threshold [12]. Consequently, while carbon emissions themselves may be positively associated with current output, they act as a negative moderator on the effect of financial accessibility. In high-carbon counties, the marginal benefit of financial accessibility is attenuated because the existing industrial structure resists rapid decarbonization and credit may still flow to conventional high-carbon sectors. This leads to Hypothesis 3: Carbon emissions negatively moderate the effect of financial accessibility on county economic development. Specifically, the positive impact of financial accessibility is smaller in high-carbon counties than in low-carbon counties.

Understanding the mechanisms through which financial accessibility affects county development is essential. Two channels are particularly relevant: technological innovation and industrial structure upgrading. Financial inclusion promotes regional development by stimulating technological innovation, which serves as an important transmission channel [4]. Improved financial accessibility reduces firms' R&D financing costs, increases patent applications, and enhances regional innovation capacity [5]. Finance guides capital to high-efficiency sectors, promotes industrial upgrading, and reduces resource misallocation [6]. Digital financial inclusion significantly promotes high-quality economic development by boosting technological innovation and accelerating industrial upgrading [7]. Industrial structure upgrading is a key mediating channel through which financial inclusion reduces regional disparities [13, 14]. Financial inclusion reduces regional disparities by easing financing constraints for innovative subjects and improving total factor productivity and green technology innovation level [7]. Formal credit accessibility significantly enhances the performance of micro, small and medium enterprises, with stronger marginal effects for firms in less developed regions, generating economic convergence effects [15]. Based on these arguments, we propose Hypothesis 4a: Technological innovation mediates the positive relationship between financial accessibility and county economic development. Hypothesis 4b: Industrial structure upgrading mediates the positive relationship between financial accessibility and county economic development.

3. Research Design

3.1. Data Sources

The data used in this paper come from five main sources. County-level nighttime light data are derived from the DMSP-OLS and NPP-VIIRS satellite remote sensing products released by the National Oceanic and Atmospheric Administration of the United States. After cross-sensor

calibration, these data form annual mean nighttime light brightness for Chinese counties from 2000 to 2019. The original resolution of the data is 1 kilometer, and this paper aggregates them to the county level to obtain the average light intensity for each county. Carbon dioxide emission data are taken from the carbon emission grid database of the Center for Global Environmental Research, which provides monthly carbon dioxide emission estimates at a spatial resolution of 1 kilometer. After similarly clipping and aggregating by county boundaries, the annual total carbon dioxide emissions for each county are obtained, and the natural logarithm is taken and denoted as $\ln co_2$.

Financial branch data come from the financial license information published by the China Banking and Insurance Regulatory Commission. This dataset records the names, addresses, approval establishment dates, and closure dates of more than 250,000 financial institution branches across the country since 1949. Based on the registered address of each branch, this paper uses the Baidu Maps geocoding interface to parse its longitude and latitude coordinates, then matches them to the corresponding county, and determines the number of branches surviving in each year according to the establishment and closure dates. Three financial accessibility indicators are obtained accordingly: the total number of financial branches in the county ($\ln finance$), the number of branches per ten thousand persons in the county ($\ln finance_2$), and the number of branches per square kilometer in the county ($\ln finance_3$). To mitigate heteroscedasticity, all three indicators enter the regression models in natural logarithm form.

County-level socioeconomic data mainly come from the China County Statistical Yearbook, the China Economic Net Statistical Database, and the EPS Data Platform over the years. Variables extracted from these sources include gross domestic product, value added by three industries, year-end resident population, number of secondary school students, administrative area, value added by secondary industry, etc. Based on these raw data, this paper calculates per capita GDP and its square term, population density, education level (proportion of secondary school students), and industrial structure (share of secondary industry value added in GDP) as control variables. County-level patent application data come from the official website of the China National Intellectual Property Administration. By using the advanced search function to restrict the patent application address and application year, the number of invention patent applications in each county is counted year by year, and the natural logarithm is taken and denoted as $\ln patent$. The industrial structure upgrading index is calculated as a weighted sum of the three industries' value added shares, specifically: share of primary industry multiplied by 1, plus share of secondary industry multiplied by 2, plus share of tertiary industry multiplied by 3. This index is denoted as ind_stru_up .

The sample period of this paper covers Chinese county-level units from 2000 to 2019, excluding Hong Kong, Macau, and Taiwan. Considering that municipal districts may have systematic differences from ordinary counties in economic development and financial resource distribution, municipal district samples are excluded in the robustness checks.

3.2. Variable Definitions and Measurement

The dependent variable is the actual level of county economic activity, measured by nighttime light intensity. Nighttime light data capture spatial differences in economic

activity and have the advantage of being free from statistical changes and human manipulation compared to indicators such as per capita GDP. The nighttime light data used in this paper have been calibrated across sensors to form a temporally continuous series from 2000 to 2019, and then the original annual mean light brightness is standardized by year using Z-score. A positive value of this indicator means that the county's light brightness in that year is higher than the average level of all counties, while a negative value means it is lower than the average. Its change reflects the shift in the county's relative position in the overall distribution.

The core independent variable is county-level financial accessibility. Financial accessibility measures the convenience with which market entities obtain financial services. This paper uses the number of financial institution branches within the county to capture this concept. According to the financial license information of the China Banking and Insurance Regulatory Commission, this paper counts the number of financial branches actually surviving in each county each year, takes the natural logarithm, and denotes it as \lnfinance . Considering that counties differ in population size and land area, the total number of branches alone may not accurately reflect the actual accessibility for residents and firms. Therefore, this paper constructs two relative indicators. The first is the number of financial branches per ten thousand persons, which is obtained by dividing \lnfinance by the county's resident population and then taking the natural logarithm, denoted as $\lnfinance2$. The second is the number of financial branches per square kilometer, obtained by taking the natural logarithm of \lnfinance divided by the county's administrative area, denoted as $\lnfinance3$. These three indicators capture different aspects of county financial accessibility and are separately included in the baseline regressions to test the robustness of the results.

The moderating variable is county-level carbon dioxide emissions, and the mediating variables include technological innovation and industrial structure upgrading.

Control variables mainly include economic development level, population density, education level, and industrial structure. Economic development level is measured by the natural logarithm of per capita GDP and its square term, denoted as \lnpgdp and $\lnpgdp2$, to capture possible nonlinear relationships. Per capita GDP data are taken from the county statistical yearbooks and are calculated at current prices. Population density is the county's resident population divided by its administrative area, denoted as $density$. Education level is measured by the proportion of secondary school students in the year-end resident population, denoted as edu . Industrial structure is measured by the share of secondary industry value added in GDP, denoted as ind . The above control variables are widely used in the existing literature on regional development and financial accessibility and can help mitigate omitted variable bias in terms of economic scale, population agglomeration, human capital, and the degree of industrialization. Descriptive statistics for all variables are presented in Table 1.

Table 1. Descriptive Statistics

Variable	mean	sd	min	max
dn_std	0.000	1.000	-0.783	12.383
\lnfinance	3.558	1.052	0.000	7.252
$\lnfinance2$	0.704	0.394	0.000	4.517
$\lnfinance3$	0.503	0.296	0.000	3.365
$\lnco2$	12.492	1.866	0.000	17.082
\lnpatent	3.525	2.285	0.000	12.621
ind_stru_up	208.810	23.190	4.847	318.548
\lnpgdp	1.140	0.630	0.068	3.808
$density$	0.069	0.261	0.000	14.500
edu	0.053	0.034	0.000	4.275
ind	0.409	0.162	0.008	0.954

3.3. Econometric Models

To examine the impact of financial accessibility on county development, this paper specifies the following two-way fixed effects panel model as the baseline regression equation.

$$DN_{ct} = \alpha + \beta Finance_{ct} + \gamma X_{ct} + \mu_c + \delta_t + \varepsilon_{ct} \quad (1)$$

Where the subscripts c and t denote county and year, respectively. The dependent variable DN_{ct} is the year-standardized nighttime light intensity, which captures the actual level of county economic activity. The core explanatory variable $Finance_{ct}$ is measured by three indicators: the natural logarithm of the total number of financial branches in the county (\lnfinance), the natural logarithm of the number of branches per ten thousand persons ($\lnfinance2$), and the natural logarithm of the number of branches per square kilometer ($\lnfinance3$). X_{ct} is a set of control variables, including per capita GDP, its square term, population density, education level, and the share of secondary industry. μ_c and δ_t denote county fixed effects and year fixed effects, respectively; the former controls for time-invariant county characteristics, and the latter controls for common time shocks at the national level. ε_{ct} is the random error term. To address potential heteroscedasticity and within-county autocorrelation, all regressions use county-level cluster-robust standard errors.

Based on the baseline regression, this paper further investigates the moderating effect of carbon emissions on the impact of financial accessibility. The following model with an interaction term is constructed.

$$DN_{ct} = \alpha + \beta_1 Finance_{ct} + \beta_2 \ln CO_{2ct} + \beta_3 (Finance_{ct} \times \ln CO_{2ct}) + \gamma X_{ct} + \mu_c + \delta_t + \varepsilon_{ct} \quad (2)$$

Where $\ln CO_{2ct}$ is the natural logarithm of the county's total carbon dioxide emissions. The coefficient β_3 on the interaction term is the main focus. If it is significantly negative, it indicates that carbon emission pressure weakens the promoting effect of financial accessibility on county development, i.e., carbon emissions have a negative moderating effect.

To identify the channels through which financial accessibility affects county development, this paper employs a mediation effect model. Following the three-step method of Baron and Kenny (1986), the following equations are specified.

$$M_{ct} = \alpha + a Finance_{ct} + \gamma X_{ct} + \mu_c + \delta_t + \varepsilon_{ct} \quad (3)$$

$$DN_{ct} = \alpha + c Finance_{ct} + b M_{ct} + \gamma X_{ct} + \mu_c + \delta_t + \varepsilon_{ct} \quad (4)$$

Where M_{ct} is the mediating variable, which is taken as either the natural logarithm of the county's invention patent applications (Inpatent) or the industrial structure upgrading index (ind_stru_up). The first step examines the effect of financial accessibility on the mediator, i.e., whether the coefficient a is significant. The second step adds the mediator to the baseline regression and examines the significance of the coefficient b and the change in the coefficient c relative to β in the baseline regression.

To address potential endogeneity problems arising from reverse causality and omitted variables between financial accessibility and county development, this paper uses a two-stage least squares instrumental variable approach. The instrumental variable is constructed as the arithmetic mean of financial accessibility of other counties within the same prefecture-level city, excluding the county itself. This variable is highly correlated with local financial accessibility, and given the exogeneity of prefecture boundaries, it is reasonable to assume that financial supply in other counties does not directly affect the economic development of the focal county but only indirectly affects it through local financial accessibility. The first-stage regression reports the F-statistic of the instrumental variable to test for weak instruments, and the second-stage regression reports the estimated coefficient of the core independent variable. All endogeneity tests control for county and year fixed effects and use cluster-robust standard errors at the prefecture level.

4. Empirical Results

4.1. Baseline Regressions

Table 2 reports the baseline regression results of financial accessibility on standardized nighttime light intensity at the county level. Column (1) includes only the core independent variable *Infinance*, without any fixed effects or control

variables. Its coefficient is 0.044 and is significant at the 1% level. Column (2) adds year fixed effects and county fixed effects to Column (1), and the coefficient of *Infinance* is 0.042, still highly significant. These two columns preliminarily indicate a positive association between financial accessibility and county nighttime light intensity, although the models have not yet controlled for other factors that may affect county economic development. Column (3) further adds control variables including per capita GDP and its square term, population density, education level, and the share of secondary industry. The results show that the coefficient of *Infinance* is 0.048, remaining significant at the 1% level, indicating that the promoting effect of financial accessibility remains robust after controlling for county characteristics and economic development levels. In terms of coefficient magnitude, a 1 percentage point increase in the number of financial branches is associated with an approximately 0.048 standard deviation increase in standardized nighttime light intensity. Given that the dependent variable has been standardized, this effect has a clear economic meaning: improved financial accessibility can significantly raise the level of county economic activity relative to the national average across counties.

Columns (4) and (5) replace the core explanatory variable with the number of financial branches per ten thousand persons (*Infinance2*) and the number of branches per square kilometer (*Infinance3*), respectively. Their coefficients are 0.097 and 0.140, both significant at the 1% level. Because the units of measurement of *Infinance2* and *Infinance3* differ from that of *Infinance*, the magnitudes of the coefficients are not directly comparable across columns, but the consistent sign and significance indicate that regardless of the measure used, improved financial accessibility significantly promotes county development.

Table 2. Main Regressions

Variable	(1)	(2)	(3)	(4)	(5)
<i>Infinance</i>	0.044***	0.042***	0.048***		
	(16.954)	(7.185)	(6.921)		
<i>Infinance2</i>				0.097***	
				(5.216)	
<i>Infinance3</i>					0.140***
					(5.644)
Controls	No	No	Yes	Yes	Yes
Year FE	No	Yes	Yes	Yes	Yes
Individual FE	No	Yes	Yes	Yes	Yes
Observations	56240	56240	28073	28073	28073
R-squared	0.001	0.002	0.021	0.021	0.022

The above results support the core hypothesis of this paper that financial accessibility can effectively promote county economic development. An increase in the number of financial institution branches reduces the transaction costs for market entities to obtain credit resources, improves the efficiency of financial resource allocation, and thus provides financial support for county economic growth. Meanwhile, all three financial accessibility indicators yield the same conclusion, enhancing the reliability of the baseline results.

4.2. Robustness Checks

To ensure the reliability of the baseline regression results, this paper conducts robustness checks from several

dimensions. First, standard errors are clustered at the prefecture level to account for potential spatial correlation and within-group autocorrelation among counties within the same prefecture. Table 3 reports the corresponding estimates. The coefficients of the three financial accessibility indicators are 0.048, 0.097, and 0.140, respectively, identical to those in the baseline regressions, with only slight decreases in t-values, but the significance levels remain within 1%. This indicates that the baseline results are not driven by underestimation of standard errors.

Table 3. Robustness: Clustering at Prefecture Level

Variable	(1)	(2)	(3)
Infinance	0.048***		
	(5.043)		
Infinance2		0.097***	
		(4.604)	
Infinance3			0.140***
			(4.966)
Controls	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes
Observations	28073	28073	28073
R-squared	0.021	0.021	0.022

Second, considering that municipal districts may have systematic differences from ordinary counties in economic development, financial resource density, and statistical definitions, this paper re-runs the regressions after excluding municipal district samples. Table 4 shows that the coefficients of Infinance, Infinance2, and Infinance3 are 0.051, 0.108, and 0.152, respectively, all higher than those in the baseline regressions and still significant at the 1% level.

Table 4. Robustness: Excluding Municipal Districts

Variable	(1)	(2)	(3)
Infinance	0.051***		
	(7.339)		
Infinance2		0.108***	
		(6.200)	
Infinance3			0.152***
			(6.463)
Controls	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes
Observations	25294	25294	25294
R-squared	0.042	0.043	0.044

To further alleviate endogeneity concerns due to reverse causality and omitted variables, this paper employs a two-

stage least squares instrumental variable approach. The instrumental variable is the mean financial accessibility of other counties within the same prefecture-level city, excluding the county itself. Table 5 reports the IV estimation results. In the first-stage regression, the coefficient of the instrumental variable on Infinance is 0.992, with a t-value of 56.2, and the first-stage F-statistic is 3160.1, far above the critical value for the Stock-Yogo test at the 10% bias level, indicating that weak instrument bias is not a concern. In the second-stage regression, the coefficient of Infinance is 0.055, significant at the 1% level, which is slightly larger than the baseline coefficient of 0.048 but consistent in sign, supporting the robustness of the causal inference.

Table 5. Endogeneity Test

Variable	dn_std (1)	Infinance (2)
Infinance	0.055***	
	(3.601)	
IV		0.992***
		(56.215)
Controls	Yes	Yes
Year FE	Yes	Yes
Individual FE	Yes	Yes
Observations	28073	28073
F_first		3160.099

This paper also conducts a placebo test to examine whether the baseline results are driven by chance. Specifically, the core independent variable Infinance is randomly shuffled across all counties and years, and the baseline regression is repeated 1,000 times, with the estimated coefficient recorded each time. Figure 1 plots the kernel density distribution of these 1,000 placebo coefficients. The true coefficient of 0.048 lies at the far right of the distribution, and the absolute values of all placebo coefficients are smaller than the true coefficient, with a p-value of 0.000. This suggests that the baseline result is unlikely to have arisen by chance, further confirming the statistical robustness of the promoting effect of financial accessibility on county development.

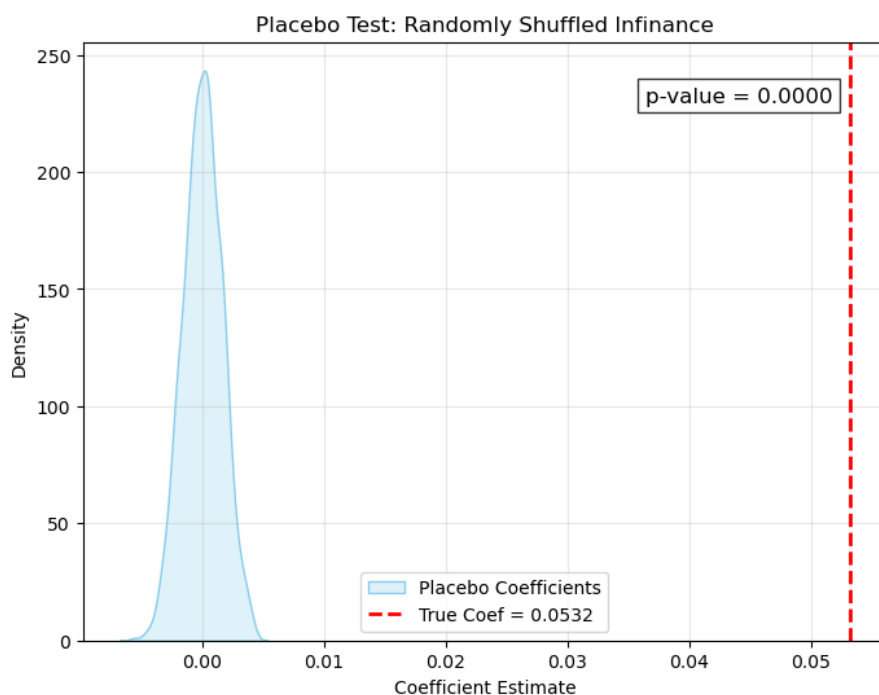


Figure 1. Distribution of Placebo Estimates

4.3. Heterogeneity Analysis

The baseline regressions reveal the average promoting effect of financial accessibility on county development, but this effect may vary across counties with different characteristics. This paper conducts subgroup regressions from three dimensions: economic development level, initial financial accessibility level, and economic growth rate, to uncover the heterogeneous features of the effect of financial accessibility. Table 6 reports the corresponding results.

The sample is divided into a high-development group and a low-development group according to whether the county's per capita GDP in the base period is above the national county median for that year. Columns (1) and (2) show that in the high-development group, the coefficient of *Infinance* is 0.024, significant at the 5% level. In the low-development group, the coefficient is 0.074, significant at the 1% level, and its magnitude is about three times that of the high-development group. This difference suggests that financial accessibility has a much stronger promoting effect on underdeveloped counties than on developed counties. A possible explanation is that developed counties already have relatively well-developed financial infrastructure, so the marginal effect of further improving financial accessibility diminishes, while underdeveloped counties face more severe financing constraints, and the entry of financial branches can unleash greater growth potential.

The sample is divided into a high-initial-finance group and a low-initial-finance group according to whether the county's number of financial branches per ten thousand persons in the

base period is above the national county median. Columns (3) and (4) report the results. In the high-initial-finance group, the coefficient of *Infinance* is 0.087, significant at the 5% level. In the low-initial-finance group, the coefficient is 0.006, only marginally significant at the 10% level and very small in magnitude. This result may seem to contradict the findings from the economic development level grouping, but it actually reveals another important feature. In areas with very low initial financial accessibility, the absolute number of financial branches is very small, and even if the number increases, the density remains low, making it difficult to achieve scale effects in the short run. At the same time, these areas are often economically backward with insufficient financial demand, so the expansion of financial supply needs to match the local industrial structure and enterprise needs, and the effect may take longer to materialize.

The sample is divided into a high-growth group and a low-growth group according to whether the county's GDP growth rate in the current year is above the national county median. Columns (5) and (6) show that in the high-growth group, the coefficient of *Infinance* is 0.037, significant at the 1% level. In the low-growth group, the coefficient is 0.069, also significant at the 1% level, and notably larger. This indicates that financial accessibility plays a stronger "timely assistance" role in counties with relatively slow economic growth, helping them catch up with high-growth areas by improving credit availability. From a policy perspective, tilting financial resources toward low-growth areas may be more conducive to promoting coordinated development across counties.

Table 6. Heterogeneity

	High development	Low development	High finance	Low finance	Fast growth	Slow growth
Variable	(1)	(2)	(3)	(4)	(5)	(6)
Infinance	0.024**	0.074***	0.087**	0.006*	0.037***	0.069***
	(2.307)	(7.897)	(2.075)	(1.827)	(4.070)	(6.010)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	16695	11378	13711	14362	17631	10442
R-squared	0.022	0.036	0.068	0.765	0.020	0.034

Combining the three sets of heterogeneity analyses, the promoting effect of financial accessibility is more pronounced in counties with lower economic development levels and slower growth rates, which provides empirical support for narrowing county development gaps through the optimization of financial geography. However, in areas with very low initial financial accessibility, the short-term effect has not yet materialized, suggesting that the improvement of financial infrastructure is a long-term process that requires supporting industrial policies and human capital accumulation to fully play its role.

4.4. Moderating Effect Analysis

Having confirmed that financial accessibility significantly promotes county development, this paper further examines whether this effect is influenced by carbon emission constraints by introducing interaction terms. Table 7 reports the moderating effect estimates. Column (1) includes only Infinance, control variables, and two-way fixed effects as a baseline reference. Column (2) adds the carbon emission variable Inco2 to Column (1); its coefficient is 0.010 and significantly positive, indicating a positive association between carbon emissions and county development, which may reflect that counties with higher carbon emissions typically have a stronger industrial base and consequently

higher economic output.

Column (3) presents the full moderating effect model, adding the interaction term between Infinance and Inco2. The coefficient of Infinance is 0.190, the coefficient of Inco2 is 0.030, and the coefficient of the interaction term Infinance_co2 is negative and highly significant. The negative interaction coefficient has a clear economic meaning: the promoting effect of financial accessibility on county development weakens as the level of carbon emissions increases. When the carbon emission level is low, the marginal effect of financial accessibility is larger, and financial institutions can allocate credit resources to clean energy and green technology areas, promoting low-carbon growth. When the carbon emission level is high, the county's economy may be locked into an energy-intensive, high-emission industrial structure, making it difficult for financial resources to achieve rapid green transformation even when accessible, thereby weakening the promoting effect of financial accessibility.

Columns (4) and (5) replace the core independent variable with Infinance2 and Infinance3, respectively. The interaction term coefficients are also negative and significant at the 5% level. The signs of the interaction terms are consistent across the three different measures, indicating that the negative moderating effect of carbon emissions is robust.

Table 7. Moderating Effect

Variable	(1)	(2)	(3)	(4)	(5)
Infinance	0.048***	0.049***	0.190***		
	(6.921)	(6.970)	(5.097)		
Infinance2				0.331***	
				(3.746)	
Infinance3					0.413***
					(3.551)
Inco2		0.010***	0.030***	0.021***	0.019***
		(3.336)	(4.918)	(3.953)	(3.808)
Infinance_co2			-0.012***		
			(-3.815)		
Infinance2_co2				-0.019**	
				(-2.460)	
Infinance3_co2					-0.023**
					(-2.175)
Controls	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes	Yes
Observations	28073	28073	28073	28073	28073
R-squared	0.021	0.021	0.023	0.022	0.023

The above results help to understand the complex relationship between financial accessibility and carbon

emissions. Carbon emissions themselves do not directly suppress county development; in fact, high-emission areas

tend to have higher economic output. However, by moderating the effect of financial accessibility, carbon emissions change the way financial resources promote economic growth. In the context of the carbon peaking and carbon neutrality goals, high-emission areas face greater transition pressure, and part of the positive effect of improved financial accessibility is offset by transition costs. This implies that simply increasing financial supply is not enough to narrow county development gaps; green credit policies and industrial upgrading support are also needed to fully realize the promoting effect of financial accessibility.

4.5. Mediation Effect Analysis

The baseline regression and moderating effect analyses have confirmed the promoting effect of financial accessibility on county development and the negative moderation of carbon emissions, but the channels through which financial accessibility affects county development require further examination. This paper tests the mediation effect through two pathways: technological innovation and industrial structure upgrading. Table 8 reports the estimates.

Column (1) takes the technological innovation variable *lnpatent* as the dependent variable. The coefficient of *lnfinance* is 0.244, significant at the 1% level. This means that for every 1 percentage point increase in financial accessibility, the number of county invention patent applications increases by about 0.244 percentage points. The increase in financial branches lowers the threshold for firms to obtain R&D financing, making it easier for innovative entities to access long-term capital support. At the same time, the information spillover effect brought by the agglomeration of financial institutions also helps to stimulate local innovation vitality. Column (2) adds *lnpatent* to the development regression equation. The coefficient of *lnfinance* falls from 0.048 in the baseline regression to 0.046, and the coefficient of *lnpatent* is 0.009 and significantly positive. This indicates that technological innovation plays a partial mediating role between financial accessibility and county development.

Column (3) takes the industrial structure upgrading index *ind_stru_up* as the dependent variable. The coefficient of *lnfinance* is 2.575, also significant at the 1% level. Improved financial accessibility promotes the flow of credit resources from low-efficiency sectors to high-efficiency sectors, driving the upgrading of the three industrial sectors. Column (4) adds *ind_stru_up* to the development regression equation. The coefficient of *ind_stru_up* is 0.001 and significantly positive.

Table 8. Mediation

Variable	<i>lnpatent</i> (1)	<i>dn_std</i> (2)	<i>ind_stru_up</i> (3)	<i>dn_std</i> (4)
<i>lnfinance</i>	0.244*** (7.353)	0.046*** (6.595)	2.575*** (7.151)	0.044*** (6.301)
<i>lnpatent</i>		0.009*** (3.076)		
<i>ind_stru_up</i>				0.001*** (3.317)
Controls	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Individual FE	Yes	Yes	Yes	Yes
Observations	28073	28073	27845	27845
R-squared	0.721	0.022	0.569	0.024

In summary, financial accessibility not only directly promotes county economic development but also generates indirect effects through two pathways: stimulating technological innovation and promoting industrial structure upgrading. The technological innovation pathway reflects the support of financial supply for R&D activities, while the industrial structure upgrading pathway reflects the ability of financial resources to optimize cross-sectoral allocation. The two pathways complement each other and together constitute an important mechanism through which financial accessibility promotes county development. In the context of the carbon peaking and carbon neutrality goals, strengthening green technology innovation and clean industrial transformation will be key to amplifying the positive effect of financial accessibility.

5. Conclusions and Policy Implications

Using county-level panel data of China from 2000 to 2019, this paper investigates the impact of financial accessibility on county development from the perspective of financial geography, and examines the moderating effect of carbon emissions as well as the mediating transmission mechanisms of technological innovation and industrial structure upgrading. The main conclusions are as follows.

Improved financial accessibility significantly promotes county economic development. Whether measured by the total number of financial branches, the number of branches per ten thousand persons, or the number of branches per square kilometer, this positive effect is significant at the 1% level. Heterogeneity analysis shows that the promoting effect of financial accessibility is more pronounced in counties with lower economic development levels and slower growth rates, indicating that optimizing the financial geography helps promote economic development in underdeveloped counties. However, in areas with extremely low initial financial accessibility, the short-term effect is not yet significant because the density of branches has not reached an effective threshold. This finding is not contradictory; instead, it suggests that the improvement of financial infrastructure needs to cross a critical scale and be coordinated with industrial policies and human capital accumulation.

Carbon emissions have a negative moderating effect on the role of financial accessibility. The interaction term analysis shows that the coefficient of the interaction between financial accessibility and carbon emissions is significantly negative, indicating that carbon emission pressure weakens the promoting effect of financial accessibility on county development. In high-carbon-emission areas, traditional industries are locked in and transition costs are high, making it difficult for financial resources, even when accessible, to quickly promote green and low-carbon transformation. This finding reveals new challenges for financial support to county development under the carbon peaking and carbon neutrality goals.

Technological innovation and industrial structure upgrading are two important mediating pathways through which financial accessibility promotes county development. Financial accessibility indirectly drives economic development by increasing the number of county invention patent applications and raising the industrial structure upgrading index. This result implies that simply increasing financial supply is not sufficient to maximize its development effect; strengthening innovation incentives and industrial guidance is also necessary.

Based on the above conclusions, this paper proposes three policy recommendations. First, optimize the spatial layout of financial branches at the county level, with a focus on areas that are economically lagging and have insufficient financial accessibility. Policymakers should relax market access conditions for financial institutions in underdeveloped counties, encourage commercial banks and rural banks to set up more branches, and promote the complementary role of digital finance and traditional branches to improve the accessibility of financial services. Second, promote the green transformation of financial supply under carbon emission reduction constraints. Financial institutions should incorporate carbon emission indicators into credit approval considerations, provide preferential financing for green technology and clean energy projects, and implement differentiated credit policies for high-carbon industries. Government departments can reduce the financing costs of green transformation in high-carbon areas through measures such as green credit subsidies and carbon reduction support instruments. Third, strengthen the mediating transmission role of technological innovation and industrial structure upgrading. At the county level, platforms for industry-academia-research cooperation and green technology innovation funds should be established to guide financial resources toward technology fields with emission reduction potential. At the same time, traditional industries should be upgraded toward technology-intensive and knowledge-intensive directions, so that improved financial accessibility can truly translate into sustainable development momentum.

The limitations of this paper are that nighttime light data, as a proxy variable for economic activity, still have measurement errors, especially in agriculture-dominated counties, where they may be underestimated. Future research could further incorporate firm-level microdata to examine the heterogeneous effects of financial accessibility on different industries and types of enterprises within counties. In addition, the moderating mechanism of carbon emissions on the effect of financial accessibility awaits more in-depth causal identification, for example by using policy shocks such as environmental protection inspections and carbon trading pilots for quasi-experimental studies.

References

- [1] Demir, A., Pesqué-Cela, V., Altunbas, Y., & Murinde, V. (2022). Fintech, financial inclusion and income inequality: a quantile regression approach. *The European Journal of Finance*, 28(1), 86–107. <https://doi.org/10.1080/1351847X.2021.1952653>
- [2] Fonseca, J., & Matray, A. (2024). Financial inclusion, economic development, and inequality: Evidence from Brazil. *Journal of Financial Economics*, 156(2), 103854. <https://doi.org/10.1016/j.jfineco.2024.103854>
- [3] Lee, C. C., Lou, R., & Wang, F. (2023). Digital financial inclusion and poverty alleviation: evidence from the sustainable development of China. *Economic Analysis and Policy*, 77, 418–434. <https://doi.org/10.1016/j.eap.2023.01.011>
- [4] Suhrab, M., Chen, P., & Ullah, A. (2024). Digital financial inclusion and income inequality nexus: Can technology innovation and infrastructure development help in achieving sustainable development goals? *Technology in Society*, 76, 102411. <https://doi.org/10.1016/j.techsoc.2024.102411>
- [5] Zhang, H., Gao, S., & Zhou, P. (2023). Role of digitalisation in energy storage technological innovation: evidence from China. *Renewable and Sustainable Energy Reviews*, 171, 113014. <https://doi.org/10.1016/j.rser.2022.113014>
- [6] Kling, G., Pesqué-Cela, V., Tian, L., & Luo, D. (2022). A theory of financial inclusion and income inequality. *The European Journal of Finance*, 28(1), 137–157. <https://doi.org/10.1080/1351847X.2021.1961894>
- [7] Wu, J., Liew, C. Y., & Ji, D. Y. (2026). Digital finance and high-quality economic development: Evidence from Chinese municipal data. *Journal of Asian Economics*, 103, 102136. <https://doi.org/10.1016/j.asieco.2026.102136>
- [8] Rani, T., Wang, F., Rehman, S. A. U., & Amjad, M. A. (2025). Shaping sustainable futures in BRICS-T economies: The role of digitalization with moderating effects of green technology innovation and financial inclusion. *Technology in Society*, 82, 102879. <https://doi.org/10.1016/j.techsoc.2025.102879>
- [9] Ozturk, I., & Ullah, S. (2022). Does digital financial inclusion matter for economic growth and environmental sustainability in OBRI economies? An empirical analysis. *Resources, Conservation and Recycling*, 185, 106489. <https://doi.org/10.1016/j.resconrec.2022.106489>
- [10] Paramati, S. R., Mo, D., & Huang, R. (2021). The role of financial deepening and green technology on carbon emissions: Evidence from major OECD economies. *Finance Research Letters*, 41, 101794. <https://doi.org/10.1016/j.frl.2021.101794>
- [11] Zeraibi, A., Jahanger, A., Adebayo, T. S., Ramzan, M., & Yu, Y. (2023). Greenfield investments, economic complexity, and financial inclusion-environmental quality nexus in BRICS Countries: Does renewable energy transition matter? *Gondwana Research*, 117, 139–154. <https://doi.org/10.1016/j.gr.2023.01.012>
- [12] Eshun, S. F., & Kočenda, E. (2025). Money talks, green walks: Does financial inclusion promote green sustainability in Africa? *Global Finance Journal*, 64, 101070. <https://doi.org/10.1016/j.gfj.2025.101070>
- [13] Guan, Z., & Han, J. (2025). Evaluating digital financial inclusion's impact on regional economic efficiency in China. *International Review of Economics & Finance*, 102, 104325. <https://doi.org/10.1016/j.iref.2025.104325>
- [14] Huang, Z., Han, J., Xu, Z., & Dai, R. (2025). Digital financial inclusion and urban-rural disparities. *International Review of Economics & Finance*, 104, 104563. <https://doi.org/10.1016/j.iref.2025.104563>
- [15] He, M., Bai, Y., Liu, F., & Stamatogiannis, M. P. (2026). Exploring heterogeneity in the impact of financial inclusion on MSMEs' performance. *International Review of Economics & Finance*, 109, 105370. <https://doi.org/10.1016/j.iref.2026.105370>
- [16] Hodula, M. (2023). Fintech credit, big tech credit and income inequality. *Finance Research Letters*, 51, 103387. <https://doi.org/10.1016/j.frl.2023.103387>
- [17] Herron, C. B., Nilakantan, R., Iyengar, D., Richey, R. G., & Rao, S. (2026). On social inequality, financial inclusion, and poverty at the bottom of the pyramid: Is financial equity enough? *World Development*, 200, 107313. <https://doi.org/10.1016/j.worlddev.2026.107313>
- [18] Anser, M. K., Subhan, M., Abdullahi, S. G., Aloffaysan, H., Ahmad, G., & Mohammed, K. S. (2026). Multidimensional drivers of sustainable development in South Asia: The dynamic roles of low-carbon energy, ICT, financial development, trade, and governance. *Energy Strategy Reviews*, 64, 102091. <https://doi.org/10.1016/j.esr.2026.102091>
- [19] Sohail, H. M., Ullah, M., Nazir, M. S., & Tang, C. (2024). Harmonizing sustainable horizons: Deciphering the intricate nexus between disaggregated financial inclusion and clean energy transition in BRICS economies. *Energy Strategy*

- Reviews, 55, 101531.
<https://doi.org/10.1016/j.esr.2024.101531>
- [20] Azmeh, C. (2025). Financial globalization, poverty, and inequality in developing countries: The moderating role of Fintech and financial inclusion. *Research in Globalization*, 10, 100277. <https://doi.org/10.1016/j.resglob.2025.100277>
- [21] Karim, R., Hoque, M. A., Mahmood, R., Bhowmik, R. C., Islam, S., & Ramachandaran, S. D. (2026). Unveiling the roles of green tax, financial development, banking development, fintech adoption, and economic growth on sustainable development in Bangladesh. *World Development Sustainability*, 8, 100277. <https://doi.org/10.1016/j.wdsus.2026.100277>
- [22] Li, Y. (2025). How does digital financial inclusion affect households' CO₂? Micro-evidence from an emerging country. *Journal of Economics and Business*, 133, 106222. <https://doi.org/10.1016/j.jeconbus.2025.106222>
- [23] Hussain, S., Gul, R., & Ullah, S. (2023). Role of financial inclusion and ICT for sustainable economic development in developing countries. *Technological Forecasting and Social Change*, 194, 122725. <https://doi.org/10.1016/j.techfore.2023.122725>
- [24] Zhao, C., Jia, R., & Dong, K. Y. (2023). Does financial inclusion achieve the dual dividends of narrowing carbon inequality within cities and between cities? Empirical evidence from China. *Technological Forecasting and Social Change*, 195, 122774. <https://doi.org/10.1016/j.techfore.2023.122774>
- [25] Wang, X., Yang, W. P., Ren, X. H., & Lu, Z. D. (2023). Can financial inclusion affect energy poverty in China? Evidence from a spatial econometric analysis. *International Review of Economics & Finance*, 85, 255–269. <https://doi.org/10.1016/j.iref.2023.03.003>
- [26] Donou-Adonsou, F., Basnet, H., & Mathey, S. (2025). Energy poverty and financial development: Evidence from developing countries. *Energy Economics*, 147, 108563. <https://doi.org/10.1016/j.eneco.2025.108563>
- [27] Liu, J., Chen, Y., Chen, X., & Chen, B. (2024). Digital financial inclusion and household financial vulnerability: An empirical analysis of rural and urban disparities in China. *Heliyon*, 10, e35540. <https://doi.org/10.1016/j.heliyon.2024.e35540>
- [28] Dong, Q., Balsalobre-Lorente, D., & Syed, Q. R. (2025). The critical role of financial inclusion in green growth: Evidence from BRICS countries. *Research in International Business and Finance*, 76, 102847. <https://doi.org/10.1016/j.ribaf.2025.102847>
- [29] Pang, D., Li, K., Wang, G., & Ajaz, T. (2022). The asymmetric effect of green investment, natural resources, and growth on financial inclusion in China. *Resources Policy*, 78, 102885. <https://doi.org/10.1016/j.resourpol.2022.102885>
- [30] Abdullah, M. A., Han, X., Amjad, M. A., & Makhmudov, S. (2025). Revisit the role of financial development on economic growth, human development, and sustainable development in higher-income countries. *Journal of Environmental Management*, 392, 126874. <https://doi.org/10.1016/j.jenvman.2025.126874>
- [31] Oyewole, O. J., Al-Faryan, M. A. S., Adekoya, O. B., & Oliyide, J. A. (2024). Energy efficiency, financial inclusion, and socio-economic outcomes: Evidence across advanced, emerging, and developing countries. *Energy*, 289, 130062. <https://doi.org/10.1016/j.energy.2024.130062>
- [32] Mwita, N. W., Dossa, J. V., & Charles, S. R. (2025). Catalyzing green growth: How financial inclusion and trade reduce carbon intensity in Southern Africa. *Journal of Cleaner Production*, 524, 146497. <https://doi.org/10.1016/j.jclepro.2025.146497>
- [33] Ali, W., Dash, D. P., Dagar, V., Kagzi, M., & Elmawazini, K. (2025). Financial development for energy access: Evidence from credit rationing and carbon emission in MENA region. *International Review of Financial Analysis*, 103, 104176. <https://doi.org/10.1016/j.irfa.2025.104176>
- [34] Nguyen, T. H. P., & Le, H. P. (2026). Financial development, digitalization, and the trajectories of sustainable development. *International Review of Economics & Finance*, 108, 105248. <https://doi.org/10.1016/j.iref.2026.105248>
- [35] Song, Q., Li, J., Wu, Y., & Yin, Z. (2020). Accessibility of financial services and household consumption in China: Evidence from micro data. *North American Journal of Economics and Finance*, 53, 101213. <https://doi.org/10.1016/j.najef.2020.101213>
- [36] Mukalay, N. M., & Inglesi-Lotz, R. (2023). Digital financial inclusion and energy and environment: Global positioning of Sub-Saharan African countries. *Renewable and Sustainable Energy Reviews*, 173, 113069. <https://doi.org/10.1016/j.rser.2022.113069>
- [37] Xu, S., & Ma, Z. (2025). Insurance density, financial accessibility, and the upgrade of resident consumption. *Finance Research Letters*, 86, 108807. <https://doi.org/10.1016/j.frl.2025.108807>
- [38] Qiao, S., Xiong, H., Wu, X., & Zhang, J. (2026). Financial accessibility, digital skills, and family entrepreneurship: Evidence from the China family panel studies (CFPS). *Finance Research Letters*, 91, 109486. <https://doi.org/10.1016/j.frl.2026.109486>
- [39] Song, Q., Yan, M., Tang, S., Han, Z., & Fang, F. (2026). Digital financial inclusion and common prosperity in China: Spatial spillovers and regional divergence. *Finance Research Letters*, 94, 109624. <https://doi.org/10.1016/j.frl.2026.109624>
- [40] Oanh, T. T. K. (2024). Digital financial inclusion in the context of financial development: Environmental destruction or the driving force for technological advancement. *Borsa Istanbul Review*, 24, 292–303. <https://doi.org/10.1016/j.bir.2024.03.004>
- [41] Law, S. H., Sabri, M. F., Damayanti, S. M., Putri, A. M., & Trinugroho, I. (2025). Economic uncertainty, financial inclusion, and income inequality in developing countries: Evidence from a dynamic panel threshold analysis. *Borsa Istanbul Review*. <https://doi.org/10.1016/j.bir.2025.100987>
- [42] Nguyen Quoc, H., Le Quoc, D., & Van, H. N. (2025). Assessing digital financial inclusion and financial crises: The role of financial development in shielding against shocks. *Heliyon*, 11, e41231. <https://doi.org/10.1016/j.heliyon.2025.e41231>
- [43] Li, H., Wei, X., & Chen, W. (2025). Digital financial inclusion's impact on farmers' income and spatial spillover effects: Evidence from Inner Mongolia, China. *Heliyon*, 11, e42155. <https://doi.org/10.1016/j.heliyon.2025.e42155>
- [44] Tabash, M. I., Ezekiel, O., Ahmed, A., Oladiran, A., Elsantil, Y., & Lawal, A. I. (2024). Examining the linkages among financial inclusion, economic growth, poverty, and inequality reduction in Africa. *Scientific African*, 23, e02096. <https://doi.org/10.1016/j.sciaf.2024.e02096>
- [45] Briano-Turrent, G. C. (2025). The effect of financial inclusion on economic and social indicators in Mexico. *Latin American Journal of Central Banking*, 6, 100161. <https://doi.org/10.1016/j.latcb.2025.100161>
- [46] Daly, S., & Jarbou, S. (2025). Aligning financial development with environmental sustainability in Saudi Arabia: Evidence from Islamic finance and renewable energy investment. *Sustainable Futures*, 10, 101542. <https://doi.org/10.1016/j.sufut.2025.101542>

- [47] Adjei-Mantey, K., & Opoku, E. E. O. (2024). Can energy transition interventions promote financial inclusion? Measuring unintended effects of Ghana's energy transition program. *Energy and Climate Change*, 5, 100157. <https://doi.org/10.1016/j.egycc.2024.100157>
- [48] Qamruzzaman, M., Hoque, M. A., & Khan, M. R. (2026). Bridging inequality: The interplay of renewable energy, digitization, and financial globalization in G7, E7, and N11 economies. *Sustainable Futures*, 11, 101756. <https://doi.org/10.1016/j.sufut.2026.101756>
- [49] Malik, S., Saleem, F., Yeo, S. F., Keoy, K. H., & Anwar, A. (2026). Sustainable futures through green technology: The paradox of green information and communication technologies and financial inclusion on load capacity factor. *Green Technologies and Sustainability*, 4, 100381. <https://doi.org/10.1016/j.greents.2026.100381>
- [50] Lee, C. C., Wang, F. H., & Lou, R. C. (2022). Digital financial inclusion and carbon neutrality: Evidence from non-linear analysis. *Resources Policy*, 79, 102974. <https://doi.org/10.1016/j.resourpol.2022.102974>
- [51] Zhao, T. (2023). The impact of financial inclusion and natural resource endowment on China's carbon emissions in the post-covid-19 period. *Resources Policy*, 86, 104198. <https://doi.org/10.1016/j.resourpol.2023.104198>
- [52] Wang, W., & Sun, M. (2025). How does financial accessibility affect the resource allocation of enterprises? Micro-evidence from the financial geographical structure of investment-oriented enterprises. *Finance Research Letters*, 84, 107820. <https://doi.org/10.1016/j.frl.2025.107820>
- [53] Li, N., & Wu, D. (2023). Nexus between natural resource and economic development: How green innovation and financial inclusion create sustainable growth in BRICS region? *Resources Policy*, 85, 103883. <https://doi.org/10.1016/j.resourpol.2023.103883>
- [54] Nuta, A. C., Abban, O. J., Ayad, H., & Nuta, F. M. (2025). Role of financial development and inclusivity in moderating the environmental effects of human development. *Research in International Business and Finance*, 73, 102623. <https://doi.org/10.1016/j.ribaf.2025.102623>
- [55] Huang, H., Mbanyele, W., Fan, S., & Zhao, X. (2022). Digital financial inclusion and energy-environment performance: What can learn from China. *Structural Change and Economic Dynamics*, 63, 342–366. <https://doi.org/10.1016/j.strueco.2022.09.007>