ISSN: 2029-4913 / eISSN: 2029-4921

VILNIUS TECH
Vilnius Gediminas Technical University

TECHNOLOGICAL and ECONOMIC DEVELOPMENT of ECONOMY

2024
Volume 30
Issue 6
Pages 1553–1571
https://doi.org/10.3846/tede.2024.22245

CAN DIGITAL FINANCIAL INCLUSION PROMOTE THE NIGHTTIME ECONOMY? – NEW EVIDENCE FROM CHINESE COUNTIES' NIGHTTIME LIGHTING DATA AND THRESHOLD MODEL

Lei CHEN[1], Tao DU[1,2]✉, Difan WU[3], Chengrui LAI[1]

[1] *Rural Development Institute, Yan'an University, Yan'an, China*
[2] *School of Economics and Management, Yan'an University, Yan'an, China*
[3] *State Grid Shanghai Electric Power Company Shibei Power Supply Company, Shanghai, China*

Article History:
- received 23 February 2024
- accepted 15 July 2024

Abstract. In the post-pandemic era, the relative weakness of the economy is reflected not only in the macro data but also in the nighttime economy. Based on the threshold model and unbalanced panel data of 1772 county-level administrative units in China from 2014 to 2020, this paper deeply explores the relationship between digital inclusive finance and night economy and draws the following conclusions. (1) When digital financial inclusion exceeds certain thresholds, its beneficial influence on promoting the nighttime economy increases from 8.13% to 26.59% and 87.71%. (2) Digital financial inclusion promotes the nighttime economy by increasing employment in the secondary industry and promoting technological innovation. However, digital financial inclusion hinders the nighttime economy by reducing entrepreneurial activity in the accommodation and catering sectors. (3) Coverage breadth first inhibits, then promotes, and inhibits the nighttime economy in different intervals; the effect of usage depth and digital level on the nighttime economy in intervals shows an increasing trend. (4) In the Yangtze River Economic Belt region, digital financial inclusion initially inhibits the nighttime economy but turns into promotion as it develops; after the implementation of the rural revitalization strategy in 2017, digital financial inclusion can more positively and significantly promote the nighttime economy.

Keywords: nighttime economy, digital financial inclusion, threshold model, nighttime lighting, county level.

JEL Classification: G29, O11, R51.

✉Corresponding author. E-mail: ***dutao0608@yau.edu.cn***

1. Introduction

In the post-pandemic era, China's economic development faces constraints such as an aging population structure, increasing restriction on resources and the environment, a high macro leverage ratio, and a slowdown in the pace of urbanization (Wang et al., 2023). The relative weakness of the economy is reflected not only in the macro data but also in the nighttime economy related to nighttime shopping, entertainment, and travel, with about 60% of consumption occurring at night (Qi et al., 2022). Thus far, China's nighttime economy has evolved from a singular market to a diverse cultural tourism consumption market encompassing nighttime tours, shows, banquets, entertainment, shopping, accommodation, and other related products (Shaw, 2014). By the end of 2018, 81 prefecture-level cities in China had introduced nighttime economy-related policies. In 2019, The State Council issued China the Opinions on Further Stimulating the Potential of Culture and Tourism Consumption

(Xiong et al., 2024), which clearly took the construction of a national nighttime cultural and tourism consumption cluster as the starting point and vigorously developed the nighttime cultural and tourism economy (Zhang et al., 2023). The vitality of the nighttime economy is a critical part of urban economic development, a direct indicator of a city's economic openness, convenience, and vibrancy. Therefore, it is necessary to boost the nighttime economy and strengthen the foundation of economic recovery.

Digital financial inclusion emerges as a promising socio-economic catalyst in numerous developing nations, offering the capacity to expand financial inclusion, alleviate poverty, and foster cohesive social development (Ali & Ghildiyal, 2023; Aziz & Naima, 2021). As an innovative financial model enabled by digital technology, digital financial inclusion has notably expanded access to financial services and improved their quality and efficiency (Lai et al., 2020), which is expected to boost the nighttime economy, thereby increasing economic vitality. At present, scholars have conducted a large number of studies on digital financial inclusion, mainly focusing on agriculture (Fang & Zhang, 2021), carbon reduction effect (Li et al., 2022; Wang & Wang, 2021), poverty alleviation (Lee et al., 2023; Peng & Mao, 2023), innovation (Gopalan & Rajan, 2022), and consumption (Jie et al., 2020). Certain scholars also emphasize the impact of digital financial inclusion on economic development in respect of the resilience of economic growth and economic expansion based on provincial (Xi & Wang, 2023) or municipal panel data (Du et al., 2023).

The nuanced county-level perspective is frequently overlooked in research on digital financial inclusion, with attention primarily directed toward broader provincial and municipal panel data. In addition, only a few scholars focus on empirical analysis of the nighttime economy. As the combination of urban economy and rural economy, the county economy is not only a critical position to serve farmers but also a natural carrier for the integration of urban and rural elements (Chen et al., 2024), which is also the leading service group of digital financial inclusion. The use of county data can not only help to overcome the heterogeneity that is difficult to observe between provinces and the problem that the urban level is far away from rural areas but also expand the sample size to ensure the robustness and credibility of the research results. Through an in-depth study of the county economy, we can find the imbalance of regional economic development through more abundant and relatively micro dimensions and put forward policy suggestions to promote the balanced development of the regional economy.

The marginal contributions of this paper mainly focus on the following aspects. (1) Compared with the relatively macro dimension of provincial and municipal panel data, this paper uses more specific and accurate county-level data to explore the threshold effect of digitally inclusive finance on the nighttime economy. (2) This paper deeply discusses the mechanism of digital financial inclusion in promoting the nighttime economy, including different effects of the three sub-dimensions of coverage breadth, usage depth, and digitalization level, and the mediation effect of fostering technological innovation, increasing employment opportunities of the second industry and decreasing entrepreneurial activities in the accommodation and catering sectors. (3) This paper further analyzes the heterogeneous impact of digital financial inclusion on the nighttime economy and puts forward more targeted and applicable policy recommendations based on the perspective of the digital economy foundation and policy coordination.

2. Theoretical analysis and research hypotheses

According to the financial inclusion theory, building an "inclusive financial system" is crucial to achieving healthy global economic growth. Digital financial inclusion can bolster economic expansion by fueling the entrepreneurship of small to medium-sized businesses and enhancing consumer spending within households (Zhang & Liu, 2022). Digital financial inclusion is more inclusive for relatively vulnerable groups such as rural residents (Chen et al., 2022; Daud & Ahmad, 2023). However, digital financial inclusion negatively impacts the nighttime economy through "elite capture" and the "digital divide." The "elite capture" refers to the tendency where individuals with more expertise and resources disproportionately access digital financial services, which creates "mission drift" (Zou & Deng, 2022). The objective existence of the digital divide makes it difficult for some individuals to benefit from the "digital dividend" of the information age (Aziz & Naima, 2021). Digital financial inclusion still has financial profit-seeking, which inevitably intensifies commercial competition. The impact of digital financial inclusion on promoting nighttime economic seems unrealistic to pursue business sustainability and inclusiveness throughout the whole process.

H1: *Digital financial inclusion can promote the nighttime economy, and there is a threshold effect.*

The overall growth of digital financial inclusion in China has covered various development trends of its different sub-dimensions which are coverage breadth, usage depth, and digitalization level (Liu et al., 2023). The analysis of the social-economic effect of DFI should also focus on the different effects of sub-dimensions besides the index aggregate. (1) The extent of digital financial inclusion coverage breadth is primarily associated with account coverage, which expands the reach of financial services, especially to individuals and businesses in remote and non-core urban areas (Wang & Wang, 2021). This coverage provides broader support and development space for diversified activities of the nighttime economy, such as catering, entertainment, and tourism. (2) The usage depth of digital financial inclusion mainly reflects the digital financial business, provides fast loan approval and fund disbursement to help night market merchants, restaurants, and entertainment service owners turn around quickly, and maintain business operations when funds are short (Mu et al., 2023). Through credit scoring and instant loan services, consumers can quickly obtain credit support for expenditures such as nighttime shopping, dining, and entertainment, increasing consumers' purchasing willingness. (3) The digitization level of digital financial inclusion primarily measures the extent and scope of digital technologies adopted in operations and services. The increased digital level can collect and analyze consumer behavior data, helping governments and businesses better understand the needs and trends of the nighttime economy and formulate more effective policies and business strategies (Oliveira et al., 2016). In addition, digital payment forms such as QR code payment and mobile payment reduce the need for carrying large amounts of cash, which significantly increasing the convenience of transactions in the night market (Ramos de Luna et al., 2019) and reducing the security risks of night transactions.

H2: *he coverage breadth, usage depth, and digitization level of digital financial inclusion have different effects on promoting the nighttime economy.*

According to credit rationing theory and transaction cost theory, information asymmetry and excessive transaction costs are the most important reasons for hindering broader financial services. Digital financial inclusion can help people who are difficult to reach traditional financial services while making the circulation of funds more efficient and rapid, breaking traditional finance's location and service cost restrictions (Xiong et al., 2022). The development of digital financial inclusion has significantly improved financial institutions' orientation and integration role in terms of socially scattered resources, accelerating the flow of economic resources among various departments (Feng et al., 2023) and improving the efficiency of resource allocation (Khera et al., 2022). So, digital financial inclusion can change and optimize the pattern of capital conversion allocation and realize the development of secondary industries under utility maximization. Based on the labor-intensive characteristics, the development of the secondary industry will inevitably bring more employment opportunities and economic growth. With the increase in the employment of employees in the secondary industry, the income level of these people increases, and their spending power at nighttime will also increase. In addition, employees in the secondary industry will have more freedom and time during the nighttime hours outside of working hours, which offers more opportunities to participate and consume in nighttime economic activities. In addition, the increase in employment in the secondary industry often represents the development of the secondary industry, which is usually concentrated in cities or industrial areas, where the population density is high, driving the development of related services. These services often stay open at night to meet the needs of a large number of workers and promote the prosperity of the night economy.

H3a: *Digital financial inclusion promotes the nighttime economy by promoting secondary industry employment.*

By adding additional resources to traditional finance and optimizing the utilization efficiency of existing resources (Pan et al., 2022), digital financial inclusion can fully correct the mismatch problem existing in traditional finance and provide necessary conditions for alleviating corporate financing constraints and improving corporate technological innovation (Xiong et al., 2022). Innovation can lead to new business models, products, services, formats and markets for the nighttime economy. With the continuous progress of technology, some new technology applications can make nighttime economic activities more convenient and efficient. Technological innovation has driven the rise of online-to-offline services, which has also prompted more offline merchants to conduct business at night, expanding the coverage of the night economy. The widespread use of contactless payment technology is boosting floating vendors and late-night snack consumption, particularly during the pandemic, due to health and food safety concerns. Interactive technologies and multimedia displays can also enrich evening entertainment and increase the sense of fun and participation. Besides, merchants can analyze consumer behavior and preferences, provide personalized services and recommendations, and enhance consumer satisfaction through big data and artificial intelligence technology.

H3b: *Digital financial inclusion promotes the nighttime economy by fostering technological innovation.*

The entrepreneurial behavior of the accommodation and catering industry can increase consumption choices and activity places at night, enrich the diversity of urban nightlife, and enhance the vitality and attractiveness of the night economy. Digital financial inclusion should, in theory, promote economic development, including entrepreneurship in catering and accommodation. However, in some cases, it can also have some negative effects, thus discouraging entrepreneurship in these areas and in turn affecting the development of the night economy. While the goal of digital financial inclusion is to broaden access to financial services, in practice, larger and more established businesses often find it easier to secure financing. Consequently, start-ups, especially those lacking credit history and guarantees in the accommodation and catering sectors, may face greater difficulties in obtaining early-stage financing (Lai et al., 2020). Besides, digital financial inclusion facilitates access to funds for existing businesses, enabling them to expand and upgrade more easily. This increased access to financing has made these firms more competitive, resulting in a more saturated market and posing greater challenges for new entrants (Palmie et al., 2022).

H3c: *Digital financial inclusion hinders the nighttime economy by reducing entrepreneurial activity in the accommodation and catering sectors.*

3. Methodology

3.1. Variables selection

3.1.1. Explained variable

In this study, the county level average annual nighttime lighting index, which is a specific value obtained by measuring and analyzing the nighttime light situation within the region (Bharti et al., 2011), is used to measure its nighttime economic development level (*NE*). The intensity of nighttime lighting can represent the intensity of the nighttime economy mainly because of the visibility needs of night economic activities (Zhao et al., 2019). Nighttime economic activities, especially consumption nighttime activities, such as catering, entertainment, night markets, and retail, often require intense lighting to ensure the comfort and safety of customers, thereby directly driving the intensity of regional nighttime lighting.

Based on satellite remote sensing technology, the nighttime lighting index quantitatively assesses regional nighttime light brightness and spatial range (Briggs et al., 2007). This measurement method is highly accurate and reliable and excludes the influence of political factors to a certain extent (Cao et al., 2013), contributing to its objectiveness and comparison.

3.1.2. Core explanatory variable

This paper employs the digital financial inclusion index at the county level to illustrate the digital financial inclusion development level of county-level administrative units. The computation methodology for index aggregate of digital financial inclusion encompasses several steps. Standardization is performed on the indices varying in attributes and measurement units, following which the coefficient of variation approach ascertains the weighting. Ultimately, the weight for coverage breadth (DFI_{cb}) stands at 54.0% of DFI_{ia}, the corresponding weight for usage depth (DFI_{ud}) is 29.7%, and the weight for the digitalization level (DFI_{dl}) in-

dex is 16.3% (Liu et al., 2023). To ensure the regression outcomes are comparable, the model standardizes the digital financial inclusion index aggregate and sub-dimensions by dividing them by 100. This paper chooses DFI_{ia} as the core explanatory variable and threshold variable and replaces it in the robustness test with the logarithm of DFI_{ia}.

3.1.3. Control variable

This paper adopts the following control variables, referring to established studies to enhance the credibility of the research findings. (1) Economic development level ($GDP_{per\text{-}capita}$), measured by per capita regional GDP, is calculated as regional GDP / the total population. (2) The proportion of output value of primary industry ($Rate_{PI}$), measured by gross primary industry product / gross regional product. (3) Fiscal dependency ($Rate_{FD}$) stands for the government's fiscal sustainability and is measured by the proportion of local general budget revenue to regional GDP. (4) Loan debt rate ($Rate_{LDR}$), measured by the ratio of credit to GDP, is calculated as the ratio of loans outstanding by local financial institutions to local GDP at the end of the year. (5) Economic consumption level ($Level_{EC}$), measured by the total retail sales of social consumer goods / the total population.

Descriptive statistics of variables are shown in Table 1.

Table 1. Descriptive statistics

Variables	Measurement	N	Mean	STD
NE	Satellite Remote Sensing of Nighttime Lighting Observations data	40761	1.0031	4.6434
DFI_{ia}	The index aggregate of digital financial inclusion	13767	0.9173	0.2383
DFI_{cb}	The coverage breadth of digital financial inclusion	13767	0.8381	0.2038
DFI_{ud}	The usage depth of digital financial inclusion	13766	1.0772	0.3446
DFI_{dl}	The digital level of digital financial inclusion	13766	0.8887	0.3006
$GDP_{per\text{-}capita}$	Gross domestic product per capita	41162	2.6016	5.1556
$Rate_{PI}$	Proportion of output value of primary industry	43478	0.2417	0.1432
$Rate_{FD}$	Financial dependence of local governments	38224	0.0533	0.0401
$Rate_{LDR}$	Loan debt rate	37213	0.6163	0.4341
$Level_{EC}$	Level of economic consumption	38112	1.1009	2.3484

3.2. Sample selection and data sources

The explanatory variables, Digital Financial Inclusion Index data for county-level administrative units are jointly compiled by the Digital Finance Research Center at Peking University and Ant Financial Services Group, covering the period from 2014 to 2020 (Chen et al., 2024; Xu et al., 2023). The nighttime lighting index processing method utilizes the "pseudo-invariant pixel method" for calibrating Defense Meteorological Satellite Program/Operational Linescan System (DMSP-OLS) data (Liu et al., 2023). The method carefully aligns the temporal resolution between DMSP-OLS data and the National Polar-Orbiting Partnership's Visible Infrared Imaging Radiometer Suite (NPP-VIIRS) data. Missing values in the original monthly datasets

are rectified before the aggregation of the annual SNPP-VIIRS datasets to ensure coherence and accuracy. This research utilizes county-level socio-economic indicators derived from the China Stock Market & Accounting Research Database (CSMAR) and the China County Statistical Yearbook. For the accuracy of the datasets, this paper undertakes meticulous cross-referencing and supplementing the databases mentioned above. The number of county patent inventions published comes from the State Patent Office of China. Data of newly registered businesses in the accommodation and catering industry comes from China's State Administration for Industry and Commerce.

After considering the reliability and availability of data sources, this paper selects unbalanced panel data to maximize the utilization of incomplete observed samples and provide more information for regression analysis. In addition, unbalanced samples reduce the assumption of non-random selection and better capture individual heterogeneity and dynamic changes. Moreover, China's county-level empirical data has massive data, comprehensive cross-regional coverage, and vast collection coverage, so it has rich information and the characteristics of large samples. Even if some missing values exist, their impact on the regression results is negligible. Therefore, this paper chooses the unbalanced panel itself for statistical regression to ensure that the regression results have broader extrapolation ability and more flexible cycles. In this paper, unbalanced panel data of 1772 county-level administrative units in China from 2014 to 2020 are obtained after excluding counties with administrative division changes and observations are seriously missing.

3.3. Model specification

Threshold regression models present a robust methodological framework for examining non-linear inter-dependencies and discerning shifts in the impact of independent variables on dependent variables across various thresholds. Such models offer a more lucid and empirical characterization of non-linear associations than conventional linear regression models (Liu et al., 2021). Considering the multifaceted effects of DFI on the nighttime economy and the regional convergence, agglomeration, and heterogeneity intrinsic to DFI, this study elects to utilize the threshold regression model to empirically examine the aforementioned non-linear interrelations (Liu et al., 2021), and the model shown below is constructed.

$$NE_{it} = \alpha + \beta_1 \times DFI_{it} \times L(DFI_{it} \le \gamma_1) + \beta_2 \times DFI_{it} \times L(\gamma_1 < DFI_{it} \le \gamma_2) + \beta_3 \times DFI_{it} \times L(\gamma_2 < DFI_{it}) + \kappa \times C_{it} + \varepsilon_{it}, \quad (1)$$

where NE_{it} is the nighttime economy level of i counties in China in t years; DFI_{it} is the digital financial inclusion development level of i counties in t years; C_{it} is the control variable; ε_{it} is the error term; $L(.)$ serves as an indicator, adopting a value of 0 when the enclosed statement is untrue, and adopting the value of 1 when the statement is validity (Xiang et al., 2023). According to whether the threshold variable DFI is greater than the threshold values γ_1 and γ_2 ($\gamma_1 < \gamma_2$), the samples are divided into three intervals, and β_1, β_2, and β_3 are the slope values of the three intervals, respectively.

4. Empirical analysis

4.1. Baseline regression

The visualization of nighttime economy data distribution is shown in Figure 1. The missing value (which should be a blank space in Figure 1) has a limited impact on the overall sample, and the nighttime economy development level is constantly improving. However, the nighttime economy level of the county area has an apparent unbalanced development phenomenon, and the regional convergence is relatively weak.

When nighttime economy (*NE*) is the explained variable, estimate whether there is one threshold value and two threshold values for DFI_{ia} of 1772 county-level administrative units in China, respectively. Bootstrap is applied to repeatedly sample 1000 times to obtain the corresponding P-value. The results of the regression test are shown in Table 2.

As shown in Figure 2, the dashed line of the likelihood ratio function under the 95% confidence interval indicates that the critical value (7.35) is significantly greater than the two threshold values. Therefore, the above threshold value is valid.

As shown in Table 3, when the development level of DFI is low ($DFI_{ia} \leq 1.1610$), its influence coefficient is 8.13%; When the development level of DFI is moderate ($1.1610 < DFI_{ia} \leq 1.2409$), its influence coefficient is 26.59%; When DFI thrives ($1.2409 < DFI_{ia}$), its influence coefficient becomes 87.71%, and both are significant at 1% level. As DFI continues to evolve, its beneficial influence on the nighttime economy is expected to become even more prominent in counties.

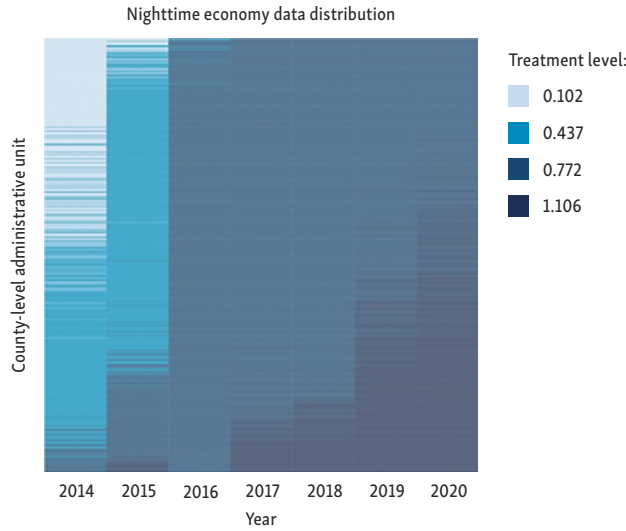

Figure 1. Data distribution visualization of the nighttime economy

Table 2. Threshold effect test of digital financial inclusion

Model	RSS	MSE	Fstat	Prob	Threshold	
Single	441.613	0.050	2249.510	0.000	1.241	
Double	416.055	0.047	542.920	0.000	1.161	1.251

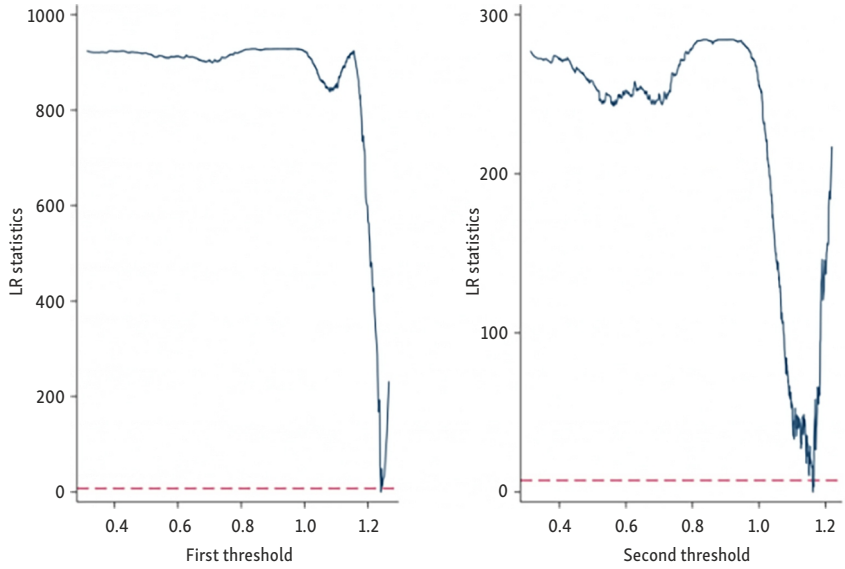

Figure 2. Threshold estimates and likelihood ratio tests for DFI_{ia}

Table 3. Baseline regression

Variables	*NE*	Standard Error
$DFI_{ia} \leq 1.1610$	0.0813^{***}	(0.0166)
$1.1610 < DFI_{ia} \leq 1.2409$	0.2659^{***}	(0.0207)
$1.2409 < DFI_{ia}$	0.8771^{***}	(0.0285)
$GDP_{per\text{-}capita}$	0.0511^{***}	(0.0033)
$Rate_{PI}$	0.2910^{***}	(0.1071)
$Rate_{FD}$	1.3979^{***}	(0.1488)
$Rate_{LDR}$	0.0949^{***}	(0.0158)
$Level_{EC}$	-0.0286^{***}	(0.0015)
Constant	0.0535^{*}	(0.0318)
Observation	11,089	
R-squared	0.400	
Year-fix	YES	
Individual-fix	YES	

Note: * and *** denote significant at the level of 10% and 1% respectively.

The threshold regression model employed in this study enhances the identification of the nonlinear association between the development level of DFI and the nighttime economy. By effectively capturing the nonlinear characteristics inherent in the data, the threshold model offers a more realistic and comprehensive expression of the relationship. The evidence supports H1, indicating that the promotion effect of digital financial inclusion on the nighttime economy is amplified once it exceeds the threshold value.

4.2. Robust test

In order to prove the reliability of the benchmark regression, this paper conducts the robustness test as shown below. (1) The core explanatory variable is replaced by the logarithm of DFIia (ln_DFIia) to measure DFI. (2) Two-sided winsorization is performed at the 5% quantile of the sample to avoid the influence of extreme values on the regression results. (3) Considering the political and social dimensions differences between urban areas and general county-level administrative units, the city's urban area is excluded, and the samples are stripped down to non-urban counties. The regression results are shown in column (1) ~ (3) of Table 4 in turn.

The robustness tests provide substantial evidence that the threshold effect is consistent in both trend and numerical magnitude with the baseline regression analyses, further validating their credibility.

Table 4. Robustness test

Variables	(1)	(2)	(3)
	NE	*NE*	*NE*
$DFI_{ia} \leq \gamma_1$	0.0319***	0.0890***	0.0554***
	(0.0074)	(0.0077)	(0.0105)
$\gamma_1 < DFI_{ia} \leq \gamma_2$	0.0945***	0.2105***	0.1964***
	(0.0079)	(0.0080)	(0.0118)
$\gamma_2 < DFI_{ia}$	0.3138***	0.4074***	0.8850***
	(0.0094)	(0.0112)	(0.0228)
Constant	0.1158***	0.1935***	0.1133***
	(0.0366)	(0.0213)	(0.0204)
Control Variables	YES	YES	YES
Observations	11,089	11,089	9,030
R-squared	0.396	0.400	0.345

Note: *** denotes significant at the level of 1%.

4.3. Endogenous test

Given that the instrumental variable two-stage least squares (IV-2SLS) estimation method can alleviate the endogenous problem caused by reverse causation, this paper uses the lagged one-period index aggregate of DFI (*l.DFI*) and the average index aggregate of DFI of other counties in the same city (*m-DFI*) are used as instrumental variables. These two variables exhibit a strong correlation with the county's digital financial inclusion development level, although they do not directly impact the county's nighttime economy. Consequently, they can serve as effective instrumental variables for investigating the relationship between the DFI and the nighttime economy from a theoretical standpoint.

As shown in Table 5, *l.DFI* and *m-DFI* passed the under-recognition, over-recognition, and weak instrumental variable tests. After the implementation of instrumental variables, the effect of DFI on the NE is maintained as both positive and statistically significant.

Table 5. Endogenous test

VARIABLES	(1)	(2)	(3)	(4)
	DFI_{ia}	*NE*	DFI_{ia}	*NE*
l.DFI	0.2673***	/	/	/
	(0.0137)	/	/	/
m-DFI	/	/	0.6608***	/
	/	/	(0.0588)	/
DFI_{ia}	/	3.3573**	/	0.9284***
	/	(1.3118)	/	(0.2165)
Kleibergen-Paap rk LM statistic	/	227.55***	/	276.16***
Cragg-Donald Wald F statistic	/	487.17	/	4076.74
Kleibergen-Paap rk Wald F statistic	/	380.69	/	126.17
Hansen J statistic	/	0.000	/	0.000
Endogeneity test of endogenous	/	5.885**	/	5.856**
Control Variables	YES	YES	YES	YES
Observations	6137	6137	7879	7879

Note: ** and *** denote significant at the level of 5% and 1% respectively.

4.4. Sub-dimension analysis

The visualization of sub-dimensions data distribution is shown in Figure 3. The digitalization level index of financial inclusion is growing most rapidly, the coverage breadth index is ranked second, and the usage depth index is growing more slowly.

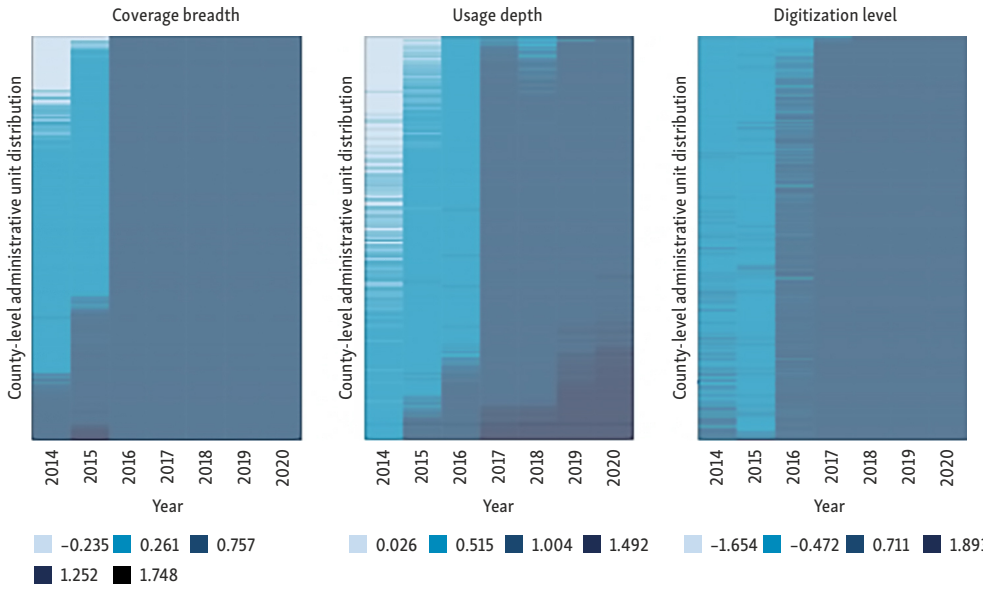

Figure 3. Data distribution visualization of sub-dimensions

When DFI_{cb}, DFI_{ud}, and DFI_{dl} are threshold variables, both single-threshold and double-threshold models are significant at 1%. Therefore, the effect of DFI_{cb}, DFI_{ud}, and DFI_{dl} on NE has two thresholds.

The threshold regression result of DFI_{cb} is shown in Table 6, the correlation coefficient of DFI_{cb} on *NE* in different intervals is 4.45%, 22.95%, and –11.67%, respectively. When DFI_{cb} is at a low development level, it will inhibit the development of the nighttime economy. When DFI_{cb} is in the starting stage, the excessive trial and error costs and huge information barriers of DFI lead to the dominance of elite capture in DFI, which manifests as a prevailing force in impeding the progress of the nighttime economy. However, as DFI_{cb} continues to progress and reaches the moderate level, its influence on the nighttime economy will begin to shift from negative to positive, and the inclusiveness of DFI will take center stage in driving the progress of the nighttime economy. Nevertheless, as the DFI_{cb} reaches the last threshold, its effect on the nighttime economy will again reverse from promoting to suppressing, and the financial market will experience heightened competition, leading to intensified profit-seeking behaviors of digital financial inclusion.

The threshold regression results of DFI_{ud} and DFI_{dl} are similar to the baseline regression. The impact of usage depth and digital level on the nighttime economy in different regions shows an increasing promotion effect. The evidence supports H2, the coverage breadth, usage depth, and digitization level of digital financial inclusion have different threshold effects on promoting the nighttime economy.

Table 6. Threshold regression of digital financial inclusion sub-dimensions

VARIABLES	DFI_{cb}	DFI_{ud}	DFI_{dl}
	NE	*NE*	*NE*
$DFI_{sub} \leq \gamma_1$	–0.0445***	0.0750***	0.0673***
	(0.0142)	(0.0097)	(0.0109)
$\gamma_1 < DFI_{sub} \leq \gamma_2$	0.2295***	0.2236***	0.1471***
	(0.0213)	(0.0105)	(0.0123)
$\gamma_2 < DFI_{sub}$	–0.1167***	0.7113***	0.2088***
	(0.0236)	(0.0159)	(0.0118)
Control Variables	YES	YES	YES
Observations	11,089	11,088	11,088
R-squared	0.234	0.379	0.238

Note: *** denotes significant at the level of 1%.

4.5. Mediation test

The number of the secondary industry labour force (NE_{SIU}) directly reflects the number of people employed in secondary industries such as manufacturing and construction. Therefore, NE_{SIU} is chosen for measuring the employment scale and development status of the secondary industry. The total amount of patented inventions published and authorized (*TI*) directly reflects the achievements of a region in science and technology research and innovation,

reflecting the intensity of investment in science and technology research and development in the region and the efficiency of input and output. Therefore, *TI* is chosen for measuring the level of technological innovation. The increase in the number of newly registered enterprises in accommodation and catering (*EAACI*) directly reflects that more people are willing to enter the accommodation and catering industry for entrepreneurship, and also means that there are more new business entities in the market, and the entry of these entities has enhanced the vitality and diversity of the industry. Therefore, *EAACI* is chosen for measuring the entrepreneurial activity in the accommodation and catering industry.

The above mediating variables are processed by logarithmic translation, which means adding one to the original value and then taking the logarithm. Based on the existing literature (Chen et al., 2024; Jiang, 2022), this paper constructs the mediation model as shown below.

$$M_{it} = \alpha + \beta \times DFI_{it} + \kappa \times C_{it} + \pi_t + \lambda_t + \varepsilon_{it}, \quad (2)$$

where M_{it} is the mediating variable, which is replaced by NE_{SIU}, *TI* and *EAACI* in the mediation test. The regression results are shown in columns (1) ~ (3) of Table 7. The correlation coefficient of DFI for NE_{SIU} and *TI* is 12.12% and 51.16%, respectively. The development of digital financial inclusion can increase secondary industry employment and foster technological innovation, which contributes to promoting the nighttime economy. The correlation coefficient of DFI for *EAACI* is –15.25%, indicating that the development of digital financial inclusion reduces entrepreneurial activity in the accommodation and catering industry which will hinder the promotion effect of digital financial inclusion on the nighttime economy. The empirical results of the mediation test support H3a, H3b and H3c.

Table 7. Mechanism analysis

Variables	(1)	(2)	(3)
	NE_{SIU}	*TI*	*EAACI*
DFI_{ia}	0.1212***	0.5116***	–0.1525**
	(0.0352)	(0.1335)	(0.0706)
Constant	1.6434***	4.1374***	6.1451***
	(0.0395)	(0.1484)	(0.0794)
Control Variables	YES	YES	YES
Observations	9,259	10,626	5,393
R-squared	0.968	0.925	0.894

Note: ** and *** denote significant at the level of 5% and 1% respectively.

5. Heterogeneity analysis

5.1. Yangtze River Economic Belt

As one of China's prominent national-level "three strategies," the Yangtze River Economic Belt has proactively aligned with national policies and implemented diverse measures to facilitate the advancement of the digital economy, leading to notable achievements (Ding et al., 2022). The Yangtze River Economic Belt has a sound economic foundation, especially in the digital economy. For example, Shanghai has achieved a significant milestone by surpassing a digital economy output value, which accounts for more than 50% of its regional GDP in 2021. The digital economy has emerged as a pivotal industry driving economic progress in Shanghai. Considering the good digital industry and technological innovation foundation of the Yangtze River Economic Belt, as well as the fact that it plays a leading and exemplary role in promoting the nighttime economy, the sample of this paper is categorized by whether it pertains to the Yangtze River Economic Belt.

The threshold regression results for the Yangtze River Economic Belt are presented in column (1) of Table 8, revealing that a lower development level of DFI impedes the nighttime economy in this region. Nevertheless, once the development of DFI reaches the certain threshold, the dynamics shift from hindering to enhancing the nighttime economy. Regarding the region outside the Yangtze River Economic Belt, the threshold regression outcomes are illustrated in column (2) of Table 8. Notably, the threshold values and results from the threshold regression align reasonably well with the baseline regression values.

The rationale lies in the solid economic footing, a well-balanced industrial framework, and the advanced state of digital economy progression within the Yangtze River Economic Belt region. During the initial developmental phase of DFI, a noticeable prevalence of elite capture and profit-driven endeavors was observed, dramatically diminishing its inclusive efficacy and ultimately stifling nocturnal economic activities. This prominent trend significantly undermined its inclusive effectiveness and ultimately stifled vitality within the nighttime economy. As DFI progresses to a certain stage, its economic benefits and inclusiveness for "vulnerable groups" will take the leading role, notably stimulating the growth of the nighttime economy.

5.2. Time heterogeneity

China put forward the rural revitalization strategy in 2017, which focuses on strengthening infrastructure construction, industrial upgrading and transformation, and equalization of public services in rural areas, significantly improving the living standards of rural residents and developing digital financial inclusion is one of the priorities of this policy. The implementation of the rural revitalization strategy has made progress in improving infrastructure, including power, network, and transportation, laying the foundation for the development of the nighttime economy. However, these infrastructure improvements are uneven and may lead to an unbalanced distribution of resources, allowing some regions to utilize digital financial services better and promote the development of the nighttime economy, while others may face lagging development (Sun et al., 2023). In summary, implementing rural revitalization will amplify the beneficial role of digital financial inclusion in promoting the nighttime economy.

In order to find the time heterogeneous effect, this paper divides the sample into two sub-samples before 2017 and after 2017 (including 2017). Before 2017, there is only a single threshold for DFI, the threshold regression results before 2017, as shown in column (3). When DFI is at its initial stages, its correlation coefficient is –0.98%; only when the developmental stage of DFI attains a specific threshold, its influence coefficient escalates to 6.22%, achieving statistical significance at the 1% level. This suggests that until 2017, DFI will have a reliable positive catalytic impact only if it reaches a certain level. The threshold regression results after 2017 are shown in column (4), aligning with the baseline regression model findings. However, it reveals a particularly noteworthy amplification of the positive impact of DFI on the nighttime economy. The implementation of China's rural revitalization strategy has made the role of digital financial inclusion in promoting the nighttime economy more positive and significant.

Table 8. Heterogeneity analysis

Variables	(1)	(2)	(3)	(4)
	NE	NE	NE	NE
$DFI_{ia} \leq \gamma_1$	–0.1556***	0.1087***	–0.0098	0.0849***
	(0.0224)	(0.0141)	(0.0077)	(0.0117)
$\gamma_1 < DFI_{ia}$	/	/	0.0622***	/
	/	/	(0.0095)	/
$\gamma_1 < DFI_{ia} \leq \gamma_2$	0.4509***	0.2910***	/	0.3379***
	(0.0374)	(0.0152)	/	(0.0152)
$\gamma_2 < DFI_{ia}$	0.9356***	0.9788***	/	1.1541***
	(0.0396)	(0.0303)	/	(0.0236)
Constant	0.1960***	0.2291***	0.3620***	0.1935***
	(0.0490)	(0.0237)	(0.0223)	(0.0213)
Observations	4,028	7,061	4,784	11,089
R-squared	0.566	0.308	0.049	0.400
Threshold effect test	Double	Double	Single	Double

Note: *** denotes significant at the level of 1%.

6. Conclusions and discussion

6.1. Conclusion

Utilizing unbalanced panel data covering 1772 county-level administrative units in China from 2014 to 2020, this paper conducts empirical research to discuss in-depth the promotion of digital financial inclusion on the nighttime economy and its mechanism. The main findings of this paper are shown as follows. (1) When digital financial inclusion exceeds certain thresholds, its beneficial influence on nighttime economy will increase from 8.13% to 26.59% and 87.71%. (2) Digital financial inclusion promotes the nighttime economy by increasing

secondary industry employment and fostering technological innovation. However, digital financial inclusion hinders the nighttime economy by reducing entrepreneurial activity in the accommodation and catering sectors. (3) The impact of digital financial inclusion coverage breadth on the nighttime economy shows first inhibition, promotion lately, and then inhibition in different intervals; the impact of usage depth and digitalization level on the nighttime economy in different intervals shows an increasing trend. (4) Through heterogeneity analysis from the perspective of digital economy foundation and coordination of policy in the Yangtze River Economic Belt region, digital financial inclusion initially inhibits the nighttime economy, but as it developed, its impact turns into promotion; before 2017, digital financial inclusion could promote the nighttime economy only if it exceeded a certain level of development; after the implementation of rural revitalization strategy in 2017, digital financial inclusion can more positively and significantly promote the nighttime economy.

6.2. Discussion

Based on this paper's theoretical and empirical analysis, the following policy recommendations have been put forward. (1) The government can invest more in improving digital infrastructure, promoting fin-tech companies, and working with traditional banks to expand the scope of inclusive financial lending services while promoting mobile payments, digital wallets, and other convenient non-cash transactions. (2) Implement technological innovation-oriented policies and improve financial services convenience and security. Policymakers should consider promoting industrial upgradation, improving the development level of the secondary industry, targeting support for entrepreneurial activities in the accommodation and catering industries, and balancing the negative impact of digital financial inclusion through tax cuts and subsidies. (3) Promote digital financial inclusion in the Yangtze River Economic Belt, take advantage of policy coordination and the region's economic foundation, and create a demonstration zone for the nighttime economy. Moreover, the government should strengthen support for digital financial inclusion in rural areas and address the specific needs of the rural nighttime economy through inclusive financial products and services centred on rural revitalization.

The research results of this paper apply not only to China but also to the development problems of the nighttime economy in other developing countries similar to China by digital financial inclusion. In extending it to other countries, special attention must be paid to differences in economic and technological bases, as well as cultural and consumer habits. Significant differences exist in economic development and technical infrastructure among different countries. Building and upgrading infrastructure, such as network coverage and payment systems, may be necessary for countries with a weak technical base. Local culture and consumption habits influence the development of the nighttime economy; consumers in some countries may prefer to be active during the day and less active at night. Therefore, it is necessary to investigate and understand consumer behaviour and preferences in target countries to adjust policies to match the local culture.

This study also has some things that could be improved. First, it is essential to note that this paper covers only 2014 to 2020 due to the constrained availability of county-level data in China. Future researchers may utilize the most recent updated data to conduct relevant

studies and expand the study of this field. In addition, considering the integrity and authenticity of the data, this study adopts the unbalanced panel data threshold model. However, it does not consider the spatial spillover effect of digital financial inclusion. Because the existing spatial econometric models focus on the linear relationship between variables and require the balance of panel data to be very high. In the future, better measurement methods may consider both threshold values and spatial correlations based on unbalanced panels, enabling further in-depth studies.

Funding

This work was supported by the Industry-University-Research Cooperation Project of Rural Development Institute of Yan'an University in 2022 under Grant number 002, Research Project of Philosophy and Social Sciences in Shaanxi Province under Grant number 2023ZD0663 and Yan'an University Graduate Education Innovation Plan Project in 2024 under Grant number 99.

References

Ali, J., & Ghildiyal, A. K. (2023). Socio-economic characteristics, mobile phone ownership and banking behaviour of individuals as determinants of digital financial inclusion in India. *International Journal of Social Economics*, *50*(10), 1375–1392. https://doi.org/10.1108/IJSE-10-2022-0673

Aziz, A., & Naima, U. (2021). Rethinking digital financial inclusion: Evidence from Bangladesh. *Technology in Society*, *64*, Article 101509. https://doi.org/10.1016/j.techsoc.2020.101509

Bharti, N., Tatem, A. J., Ferrari, M. J., Grais, R. F., Djibo, A., & Grenfell, B. T. (2011). Explaining seasonal fluctuations of measles in Niger using nighttime lights imagery. *Science*, *334*(6061), 1424–1427. https://doi.org/10.1126/science.1210554

Briggs, D. J., Gulliver, J., Fecht, D., & Vienneau, D. M. (2007). Dasymetric modelling of small-area population distribution using land cover and light emissions data. *Remote Sensing of Environment*, *108*(4), 451–466. https://doi.org/10.1016/j.rse.2006.11.020

Cao, C., Shao, X., & Uprety, S. (2013). Detecting light outages after severe storms using the S-NPP/VIIRS day/night band radiances. *IEEE Geoscience and Remote Sensing Letters*, *10*(6), 1582–1586. https://doi.org/10.1109/LGRS.2013.2262258

Chen, L., Liu, C., Li, Z., & Wu, D. (2024). The impact of clean energy demonstration province policies on carbon intensity in Chinese counties based on the multi-phase PSM-DID method. *Environmental Science and Pollution Research*. https://doi.org/10.1007/s11356-023-31799-5

Chen, Y., Yang, S., & Li, Q. (2022). How does the development of digital financial inclusion affect the total factor productivity of listed companies? *Evidence from China*. *Finance Research Letters*, *47*, Article 102956. https://doi.org/10.1016/j.frl.2022.102956

Daud, S. N. M., & Ahmad, A. H. (2023). Financial inclusion, economic growth and the role of digital technology. *Finance Research Letters*, *53*, Article 103602. https://doi.org/10.1016/j.frl.2022.103602

Ding, R., Shi, F., & Hao, S. (2022). Digital inclusive finance, environmental regulation, and regional economic growth: An empirical study based on spatial spillover effect and panel threshold effect. *Sustainability*, *14*(7), Article 4340. https://doi.org/10.3390/su14074340

Du, Y., Wang, Q., & Zhou, J. (2023). How does digital inclusive finance affect economic resilience: Evidence from 285 cities in China. *International Review of Financial Analysis*, *88*, Article 102709. https://doi.org/10.1016/j.irfa.2023.102709

Fang, D., & Zhang, X. (2021). The protective effect of digital financial inclusion on agricultural supply chain during the COVID-19 pandemic: Evidence from China. *Journal of Theoretical and Applied Electronic Commerce Research*, *16*(7), 3202–3217. https://doi.org/10.3390/jtaer16070174

Feng, S., Liu, J., & Xu, D. (2023). Digital financial development and indirect household carbon emissions: Empirical evidence from China. *Environment, Development and Sustainability*, *26*, 23401–23435. https://doi.org/10.1007/s10668-023-03603-4

Gopalan, S., & Rajan, R. S. (2022). Does digital financial inclusion moderate or exacerbate output volatility? *Applied Economics Letters*, *29*(19), 1804–1809. https://doi.org/10.1080/13504851.2021.1963400

Jiang, T. (2022). Mediating effects and moderating effects in causal inference. *China Industrial Economics*, *5*, 100–120. https://doi.org/10.19581/j.cnki.ciejournal.2022.05.005

Jie, L., Yu, W., & Jing, J. (2020). The impact of digital finance on household consumption: Evidence from China. *Economic Modelling*, *86*, 317–326. https://doi.org/10.1016/j.econmod.2019.09.027

Khera, P., Ng, S., Ogawa, S., & Sahay, R. (2022). Measuring digital financial inclusion in emerging market and developing economies: A new index. *Asian Economic Policy Review*, *17*(2), 213–230. https://doi.org/10.1111/aepr.12377

Lai, J. T., Yan, I. K. M., Yi, X., & Zhang, H. (2020). Digital financial inclusion and consumption smoothing in China. *China & World Economy*, *28*(1), 64–93. https://doi.org/10.1111/cwe.12312

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.2022.12.004

Li, G., Zhang, R., Feng, S., & Wang, Y. (2022). Digital finance and sustainable development: Evidence from environmental inequality in China. *Business Strategy and the Environment*, *31*(7), 3574–3594. https://doi.org/10.1002/bse.3105

Liu, C., Chen, L., Li, Z., & Wu, D. (2023). The impact of digital financial inclusion and urbanization on agricultural mechanization: Evidence from counties of China. *PLoS ONE*, *18*(11), Article e0293910. https://doi.org/10.1371/journal.pone.0293910

Liu, Y., Luan, L., Wu, W., Zhang, Z., & Hsu, Y. (2021). Can digital financial inclusion promote China's economic growth? *International Review of Financial Analysis*, *78*, Article 101889. https://doi.org/10.1016/j.irfa.2021.101889

Mu, W., Liu, K., Tao, Y., & Ye, Y. (2023). Digital finance and corporate ESG. *Finance Research Letters*, *51*, Article 103426. https://doi.org/10.1016/j.frl.2022.103426

Oliveira, T., Thomas, M., Baptista, G., & Campos, F. (2016). Mobile payment: Understanding the determinants of customer adoption and intention to recommend the technology. *Computers in Human Behavior*, *61*, 404–414. https://doi.org/10.1016/j.chb.2016.03.030

Palmie, M., Miehe, L., Oghazi, P., Parida, V., & Wincent, J. (2022). The evolution of the digital service ecosystem and digital business model innovation in retail: The emergence of meta-ecosystems and the value of physical interactions. *Technological Forecasting and Social Change*, *177*, Article 121496. https://doi.org/10.1016/j.techfore.2022.121496

Pan, Y., Ma, L., & Wang, Y. (2022). How and what kind of cities benefit from the development of digital inclusive finance? Evidence from the upgrading of export in Chinese cities. *Economic Research-Ekonomska Istraživanja*, *35*(1), 3979–4007. https://doi.org/10.1080/1331677X.2021.2007414

Peng, P., & Mao, H. (2023). The effect of digital financial inclusion on relative poverty among urban households: A case study on China. *Social Indicators Research*, *165*(2), 377–407. https://doi.org/10.1007/s11205-022-03019-z

Qi, Z., Wang, W., & Zhang, W. (2022, September). Promoting high-quality development of nighttime economy. *People's Daily*, 019. https://doi.org/10.28655/n.cnki.nrmrb.2022.011011

Ramos de Luna, I., Liebana-Cabanillas, F., Sanchez-Fernandez, J., & Munoz-Leiva, F. (2019). Mobile payment is not all the same: The adoption of mobile payment systems depending on the technology applied. *Technological Forecasting and Social Change*, *146*, 931–944. https://doi.org/10.1016/j.techfore.2018.09.018

Shaw, R. (2014). Beyond night-time economy: Affective atmospheres of the urban night. *Geoforum*, *51*, 87–95. https://doi.org/10.1016/j.geoforum.2013.10.005

Sun, Y., Jin, K., Wang, D., Wu, Q., & Li, Z. (2023). Revisiting the natural resources-financial development nexus in China: The importance of economic policy uncertainty. *Resources Policy*, *86*, Article 104182. https://doi.org/10.1016/j.resourpol.2023.104182

Wang, K.-H., Su, C.-W., Umar, M., & Lobont, O.-R. (2023). Oil price shocks, economic policy uncertainty, and green finance: A case of China. *Technological and Economic Development of Economy*, *29*(2), 500–517. https://doi.org/10.3846/tede.2022.17999

Wang, X., & Wang, Q. (2021). Research on the impact of green finance on the upgrading of China's regional industrial structure from the perspective of sustainable development. *Resources Policy*, *74*, Article 102436. https://doi.org/10.1016/j.resourpol.2021.102436

Xi, W., & Wang, Y. (2023). Digital financial inclusion and quality of economic growth. *Heliyon*, *9*(9), Article e19731. https://doi.org/10.1016/j.heliyon.2023.e19731

Xiang, W., Qi, Q., & Gan, L. (2023). Non-linear effects of green finance on air quality in China: New evidence from a panel threshold model. *Frontiers in Ecology and Evolution*, *11*, Article 1162137. https://doi.org/10.3389/fevo.2023.1162137

Xiong, S., Wang, H., Liao, Z., & Hashim, R. (2024). Exploring the factors and spatial patterns of national night cultural tourism consumption agglomeration zones in China. *Heliyon*, *10*(2), Article e24132. https://doi.org/10.1016/j.heliyon.2024.e24132

Xiong, W., Xiao, W., Ren, R., & Wen, F. (2022). Can digital financial inclusion affect CO2 emissions of China at the prefecture level? Evidence from a spatial econometric approach. *Energy Economics*, *109*, Article 105966. https://doi.org/10.1016/j.eneco.2022.105966

Xu, D., Chen, Y., Wang, J., & Huang, X. (2023). Legal environmental regulation and green technology innovation of energy enterprises: Based on panel threshold regression. *Frontiers in Energy Research*, *11*, Article 1198706. https://www.frontiersin.org/articles/10.3389/fenrg.2023.1198706

Zhang, M., & Liu, Y. (2022). Influence of digital finance and green technology innovation on China's carbon emission efficiency: Empirical analysis based on spatial metrology. *Science of The Total Environment*, *838*, Article 156463. https://doi.org/10.1016/j.scitotenv.2022.156463

Zhang, W., Ming, Q., & LIu, H. (2023). The impact of night economy policy on regional tourism economic growth: An empirical analysis based on multi-time difference-in-differences model. *Social Sciences in Guangxi*, *6*, 110–119. https://doi.org/10.3969/j.issn.1004-6917.2023.06.014

Zhao, M., Zhou, Y., Li, X., Cao, W., He, C., Yu, B., Li, X., Elvidge, D. C., Cheng, W., & Zhou, C. (2019). Applications of satellite remote sensing of nighttime light observations: Advances, challenges, and perspectives. *Remote Sensing*, *11*(17), Article 1971. https://doi.org/10.3390/rs11171971

Zou, J., & Deng, X. (2022). To inhibit or to promote: How does the digital economy affect urban migrant integration in China? *Technological Forecasting and Social Change*, *179*, Article 121647. https://doi.org/10.1016/j.techfore.2022.121647