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Digital Financial Inclusion and Regional Innovation in China: Provincial Evidence from 2013 to 2022

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Abstract

Based on panel data for 30 Chinese provinces from 2013 to 2022, this paper examines the relationship between digital financial inclusion and regional innovation using a two-way fixed-effects model. Accepted patent applications are taken as the baseline innovation indicator, and invention patent grants are used as a stricter alternative in the robustness test. The estimates show a positive link between the Peking University Digital Financial Inclusion Index and provincial innovation output. In the sub-index regressions, both coverage breadth and usage depth are positive, but coverage breadth has the larger coefficient in the full sample. The regional pattern is uneven. Usage depth is more relevant in eastern China, coverage breadth matters more in western China, and the estimates for central China are not statistically significant in the current specification. Similar results are obtained when the dependent variable is replaced by invention patent grants. The evidence therefore points to a relationship between digital financial inclusion and regional innovation that varies with digital-finance structure and regional conditions.

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Keywords

Digital financial inclusion, regional innovation, China, breadth of coverage, depth of use, regional heterogeneity, panel data.

Introduction

At the regional level, innovation reflects technological accumulation, industrial renewal, and the ability to generate new sources of growth. In China, these capacities differ markedly across provinces, so regional innovation also provides a useful lens for understanding uneven digital transformation. Innovation, however, is not only a technical issue. It requires financing before returns become clear. Small technology firms, individual entrepreneurs, and innovation actors in less-developed regions often lack collateral, stable cash flow, or complete credit records. Financing constraints therefore remain an important barrier to regional innovation.

Digital financial services have partly changed this financing environment. Mobile payment, online credit, digital insurance, and internet-based investment products make financial participation less costly and extend financial services beyond traditional bank branches. In this sense, digital financial inclusion is not only an outcome of financial digitalization. It may also serve as a channel through which digitalization affects innovation, especially by improving access to finance and by making credit assessment more data-based.

The existing literature discusses this issue from both firm-level and regional-level perspectives. At the firm level, digital finance is usually linked with innovation through easier financing, lower financing costs, and a better information environment [Dong, Pan, 2024; Wang, Yu, 2024; Tang, Wu, Zhu, 2020]. At the regional level, studies have examined whether digital financial inclusion improves innovation capability, innovation performance, or technological innovation efficiency by reducing financial frictions and improving resource allocation [Sun, 2024; Xu, Zhang, Liu, 2020; Ren, Liu, 2021]. Russian studies on financial accessibility and digitalization also show that financial services and digital transformation have clear regional differences [Kurilova, 2024; Tashtamirov, 2024; Varenik, 2024].

These studies provide the basis for the present paper, but some questions remain open. Many empirical works still use the aggregate digital financial inclusion index as the main variable, while the difference between coverage breadth and usage depth receives less attention. These two dimensions may represent different processes: one concerns access to financial services, and the other concerns actual use in payment, credit, insurance, and investment. Regional differences also need further testing. In particular, the roles of digital finance in eastern, central, and western China may not be the same, especially when the sample is extended to 2013-2022.

This paper uses a balanced panel of 30 Chinese provinces over 2013-2022. The Peking University Digital Financial Inclusion Index is used as the core explanatory variable, and the empirical analysis further separates the index into coverage breadth and usage depth. Regional innovation is measured first by accepted patent applications and then by invention patent grants in the robustness test. The sample is also divided into eastern, central, and western China to examine whether the estimated relationship differs across regions.

The study makes three main contributions. First, it links digital financial inclusion with regional innovation from the perspective of financial digitalization and innovation financing. Second, it compares the aggregate index with two important sub-dimensions, coverage breadth and usage depth. Third, it examines regional heterogeneity across eastern, central, and western China, which helps clarify whether the role of digital finance is closer to access expansion or to deeper financial-service use.

Theoretical Analysis and Research Hypotheses

Innovation projects often require financing long before their returns can be observed. This problem is more serious for small technology firms and less-developed regions, where collateral and complete

credit records are often limited. Traditional financial institutions tend to be cautious under such conditions. Digital financial inclusion may ease part of this constraint by widening access to payment, credit, and other services. Transaction records and online behavioral data can also help financial platforms assess credit risk and reduce information asymmetry. The first hypothesis is therefore stated as follows:

H1: Digital financial inclusion can promote regional innovation.

The role of digital financial inclusion also depends on its internal structure. Coverage breadth refers to the extent to which digital financial services reach firms, households, and regions. Usage depth refers to the actual use of payment, credit, insurance, investment, and related services. Where the traditional financial base is weak, a wider service network may first improve basic access. Where access is already relatively high, deeper use of digital finance may become more relevant for R&D financing and other innovation activities. The two dimensions are therefore expected to matter, but not necessarily in the same way.

H2: Coverage breadth and usage depth may both contribute to regional innovation, but their effects are expected to differ.

Regional conditions may further change the way digital financial inclusion works. Eastern China has stronger innovation resources and more developed financial services, so the effect of digital finance may be reflected more through usage depth. In western China, traditional financial coverage remains relatively insufficient, and wider digital access may generate a larger marginal improvement. Central China is undergoing industrial transition; the link between digital finance and innovation output may therefore be influenced by industrial structure, talent mobility, and local innovation platforms. These differences suggest that the same digital financial indicator may work differently across regions.

H3: The relationship between digital financial inclusion and regional innovation varies across eastern, central, and western China.

Methodology and Data

Model Construction

Following related panel-data studies on digital finance and regional innovation, the baseline equation is written as follows:

$$\ln(Innovation_{it}) = \alpha_0 + \alpha_1 \ln(DFI_{it}) + \beta_1 \ln(PGDP_{it}) + \beta_2 \ln(IS_{it}) + \beta_3 \ln(HC_{it}) + \mu_i + \lambda_t + \varepsilon_{it}$$

In the model, i refers to province and t refers to year. $\ln Innovation$ denotes the regional innovation indicator. $\ln DFI$ is the digital financial inclusion variable; in separate regressions it is replaced by coverage breadth and usage depth. $\ln PGDP$, $\ln IS$, and $\ln HC$ represent economic development, industrial structure, and human capital. Province fixed effects and year fixed effects are denoted by μ_i and λ_t , and ε_{it} is the error term.

Province fixed effects absorb stable provincial characteristics that do not change over time, while year fixed effects absorb shocks common to all provinces in the same year. With these fixed effects included, the coefficient of $\ln DFI$ is estimated from within-province changes after the selected control variables are taken into account.

Variable Selection

Regional innovation. The baseline measure of regional innovation is the logarithm of accepted patent applications. Patent applications are a direct and observable output of innovation activity and are widely used in empirical studies on regional innovation. To reduce the influence of scale differences and trend fluctuations, the variable is transformed into logarithmic form. In the robustness test,

invention patent grants are used to replace accepted patent applications. Compared with patent applications, invention patent grants have passed substantive examination and can better capture the quality dimension of innovation.

Digital financial inclusion. The core explanatory variable comes from the Peking University Digital Financial Inclusion Index. The index describes digital financial development through coverage breadth, usage depth, and the level of digitization, and is widely used in studies of digital finance in China [Guo et al., 2020]. This paper uses the overall index first, and then uses coverage breadth and usage depth separately. Coverage breadth captures the reach of digital financial services, while usage depth captures the use of payment, credit, insurance, investment, and related services. All index variables are used in logarithmic form.

Control variables. To reduce the influence of other regional factors, this paper includes economic development, industrial structure, and human capital as control variables. Economic development is measured by the logarithm of GDP per capita. Industrial structure is measured by the logarithm of the share of tertiary-industry value added in GDP. Human capital is measured by the logarithm of higher-education enrollment. These variables are included because regional innovation may be affected by economic conditions, industrial composition, and the supply of educated labor.

Table 1 - Variable Definitions and Data Sources

Variable	Symbol	Measurement	Main source
Regional innovation	ln Innovation	Logarithm of accepted patent applications	NIPA; China Statistical Yearbook
High-quality innovation	ln Invention	Logarithm of invention patent grants; used for robustness	NIPA; China Statistical Yearbook
Digital financial inclusion	ln DFI	Logarithm of the Peking University Digital Financial Inclusion Index	Institute of Digital Finance, Peking University
Coverage breadth	ln Breadth	Logarithm of the coverage breadth sub-index	Peking University index
Usage depth	ln Depth	Logarithm of the usage depth sub-index	Peking University index
Economic development	ln PGDP	Logarithm of GDP per capita	China Statistical Yearbook; provincial bulletins
Industrial structure	ln IS	Logarithm of tertiary-industry value added as a share of GDP	China Statistical Yearbook; provincial bulletins
Human capital	ln HC	Logarithm of higher-education enrollment	China Statistical Yearbook; provincial bulletins

Data Sources and Descriptive Statistics

The sample consists of 30 provincial-level regions in mainland China during 2013-2022. Tibet is excluded because several variables are missing for a large part of the period. Hong Kong, Macao, and Taiwan are not included because their statistical systems are not directly comparable with the mainland provincial data. The final dataset is a balanced panel of 300 province-year observations.

Digital financial inclusion data are taken from the Peking University index. Patent data are collected from the National Intellectual Property Administration and relevant statistical yearbooks. GDP per capita, industrial structure, and higher-education enrollment are drawn from the China Statistical Yearbook and provincial statistical bulletins.

Table 2 reports the descriptive statistics for the main variables. The mean of ln Innovation is 10.993, with a standard deviation of 1.312, indicating clear differences in innovation output across provinces. The mean values of ln DFI, ln Breadth, and ln Depth are 5.584, 5.502, and 5.529, respectively. The

standard deviation of coverage breadth is slightly larger than that of usage depth, suggesting that cross-provincial differences in basic access to digital financial services remain visible. Among the control variables, $\ln$ PGDP shows relatively larger dispersion, while $\ln$ IS and $\ln$ HC vary more moderately across provinces.

Table 2 - Descriptive Statistics of the Main Variables

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
$\ln$ Innovation	300	10.993	1.312	7.002	13.809
$\ln$ DFI	300	5.584	0.310	4.771	6.133
$\ln$ Breadth	300	5.502	0.373	4.479	6.122
$\ln$ Depth	300	5.529	0.355	4.676	6.236
$\ln$ PGDP	300	10.965	0.436	10.016	12.240
$\ln$ IS	300	3.888	0.171	3.466	4.429
$\ln$ HC	300	7.644	0.262	6.789	8.381

Empirical Results

Baseline Regressions

Table 3 presents the baseline results. All specifications include province and year fixed effects. The table reports coefficients, with standard errors in parentheses.

Column (1) uses the overall digital financial inclusion index. The coefficient of $\ln$ DFI is 1.103 and is significant at the 5% level. Since both the dependent variable and the core explanatory variable are in logarithms, the coefficient can be read as an elasticity. Holding the controls and fixed effects constant, a 1% increase in the overall index is associated with a 1.103% increase in regional innovation. This result supports H1.

Column (2) replaces the overall index with coverage breadth. The coefficient of $\ln$ Breadth is 1.343 and significant at the 1% level. It is larger than the coefficient in the overall-index regression, which suggests that access expansion was still important during the sample period. For provinces or groups that were previously less connected to formal finance, entering the digital financial system may improve the financing environment for small firms and individual entrepreneurs [Beck, Demircuc-Kunt, Levine, 2007; Tang, Wu, Zhu, 2020].

Column (3) uses usage depth. The coefficient of $\ln$ Depth is 0.930 and significant at the 1% level. Although the sign is positive, the elasticity is smaller than that of coverage breadth. One possible reason is that deeper service use requires a certain access base. Payment, credit, insurance, and investment services are more likely to support innovation after firms and households have already entered the digital financial system. In addition, depth-of-use indicators may partly overlap with the level of economic development, so part of their explanatory power may be captured by the control variables [Ben Abdallah et al., 2024; Guo et al., 2020].

Among the controls, $\ln$ PGDP is positive and significant in all three models, indicating that stronger economic conditions are associated with higher innovation output. $\ln$ IS and $\ln$ HC are not statistically significant in these specifications. This does not mean that industrial structure and human capital are unimportant; their effects may be partly absorbed by province fixed effects, or the selected proxies may not capture more direct inputs into innovation, such as R&D personnel. The R^2 values are above 0.80, indicating that the fixed-effects structure explains a large share of the variation in provincial innovation.

Table 3 - Baseline Regression Results

Variable	(1) Overall Index	(2) Breadth of Coverage	(3) Depth of Use
ln DFI	1.103**		
	(0.514)		
ln Breadth		1.343***	
		(0.367)	
ln Depth			0.930***
			(0.281)
ln PGDP	0.622*	0.569*	0.709**
	(0.320)	(0.311)	(0.308)
ln IS	0.0222	-0.0650	0.0498
	(0.268)	(0.263)	(0.259)
ln HC	-0.00839	-0.391	0.0367
	(0.215)	(0.248)	(0.200)
Province fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	300	300	300
R ²	0.807	0.813	0.811
Number of provinces	30	30	30

Note: Standard errors are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. Constant terms are not reported.

Regional Heterogeneity

Regional differences are expected because eastern, central, and western China do not share the same economic base, financial conditions, digital infrastructure, or innovation resources [Xu, Zhang, Liu, 2020; Ren, Liu, 2021]. The sample is therefore divided into three groups: eastern China with 11 provinces, central China with 8 provinces, and western China with 11 provinces. Table 4 reports the estimated coefficients for these regional subsamples.

For eastern China, the coefficient of usage depth is 1.327 and significant at the 5% level. Coverage breadth is also positive and weakly significant, while the overall index is not significant. This pattern suggests that the eastern region has largely passed the stage in which simple access expansion is the main constraint. In this region, firms and households already have relatively high access to digital finance, so innovation may depend more on whether digital financial services are used deeply, especially for credit, investment, insurance, and other functions connected with R&D activity [Tang, Wu, Zhu, 2020].

For western China, the results are different. The coefficient of coverage breadth is 2.327 and significant at the 1% level, while usage depth is positive and significant only at the 10% level. The larger coefficient of coverage breadth is consistent with a catch-up process: where the initial level of financial access is lower, the marginal effect of expanding basic digital financial coverage may be stronger. In this sense, western provinces appear to remain more dependent on access expansion than on sophisticated service use.

The results for central China should be interpreted more cautiously. None of the three digital financial variables is statistically significant, and the coefficient of coverage breadth is negative. The data do not allow a direct test of the reason behind this result, but several explanations are possible. Central provinces may be located between the more mature digital-finance environment of the east and the stronger catch-up process of the west. They may also face a mismatch between digital financial services and the needs of traditional manufacturing or resource-based industries. For this reason, the insignificant estimates should not be read as evidence that digital finance has no value in central China.

They more likely suggest that digital finance has not yet been effectively translated into measurable patent output in this region.

Table 4 - Regional Heterogeneity Results

Region	Overall Index	Breadth of Coverage	Depth of Use
Eastern	0.864 (1.168)	1.443* (0.729)	1.327** (0.602)
Central	-1.609 (1.352)	-2.254 (1.383)	-0.572 (0.729)
Western	0.350 (1.000)	2.327*** (0.798)	1.012* (0.553)
Eastern sample size	110	110	110
Central sample size	80	80	80
Western sample size	110	110	110

Note: Standard errors are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. Control variables and fixed effects are included but omitted for brevity.

Robustness Test

A robustness test is conducted by replacing the dependent variable with invention patent grants. This alternative measure is more restrictive than accepted patent applications because invention patents must pass substantive examination. It therefore provides a useful check on whether the baseline results are driven only by changes in the number of applications.

The results are reported in Table 5. The coefficient of the overall index is 1.315 and significant at the 1% level. The coefficients of coverage breadth and usage depth are 1.238 and 1.091, respectively, and both are significant at the 1% level. The signs are consistent with the baseline regressions, and all three core variables remain statistically significant. This suggests that the main conclusion is not sensitive to the choice of patent indicator.

There are also some differences in magnitude. Compared with the baseline results, the coefficient of usage depth becomes larger when invention patent grants are used, while the coefficient of coverage breadth becomes slightly smaller. This may mean that deeper use of digital financial services is more relevant for higher-quality innovation, whereas coverage expansion has a stronger relationship with broader patent application activity. This interpretation should be treated as suggestive, because the current model does not directly identify the micro-level mechanism.

Table 5 - Robustness Test: Replacing the Dependent Variable with Invention Patent Grants

Variable	(1) Overall Index	(2) Breadth of Coverage	(3) Depth of Use
ln DFI	1.315*** (0.461)		
ln Breadth		1.238*** (0.332)	
ln Depth			1.091*** (0.251)
ln PGDP	0.483* (0.288)	0.480* (0.281)	0.589** (0.274)
ln IS	0.228 (0.240)	0.183 (0.238)	0.262 (0.231)
ln HC	0.211 (0.193)	-0.0919 (0.224)	0.268 (0.178)

Variable	(1) Overall Index	(2) Breadth of Coverage	(3) Depth of Use
Province fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	300	300	300
R ²	0.913	0.914	0.916
Number of provinces	30	30	30

Note: Standard errors are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. Constant terms are not reported.

Conclusions and Policy Implications

Main Findings

This paper examines the relationship between digital financial inclusion and regional innovation in China from the perspective of financial digitalization. Using panel data for 30 provinces over 2013–2022, the fixed-effects estimates show a positive relationship between the overall digital financial inclusion index and accepted patent applications. The coefficient of the overall index is 1.103 and statistically significant, which indicates that provinces with stronger digital financial inclusion tend to have higher innovation output after the selected controls and fixed effects are considered.

The sub-index results show that the two dimensions of digital financial inclusion do not have exactly the same association with innovation. The coefficient of coverage breadth is 1.343, compared with 0.930 for usage depth. In the full sample, the access dimension therefore appears to have a stronger connection with provincial innovation output. This is consistent with the fact that, during 2013–2022, some firms and individuals were still being brought into the digital financial system for the first time. For these actors, basic access to digital payment, online credit, and related financial services may already improve the financing conditions needed for innovation activities [Guo et al., 2020; Tang, Wu, Zhu, 2020].

The regional regressions add another layer to this result. In eastern China, usage depth is more closely related to innovation, while coverage breadth is only weakly significant. This pattern is understandable because digital financial access in the east is already relatively mature; further support for innovation is more likely to come from deeper use of credit, insurance, investment, and other financial functions. In western China, the situation is different. The coefficient of coverage breadth reaches 2.327, showing that access expansion still has a strong relationship with innovation output. This may reflect the lower starting point of financial inclusion in the west, where the marginal effect of bringing more users into digital financial services is larger. The estimates for central China are not statistically significant. This result should be read carefully: it does not imply that digital financial inclusion has no relevance for central China, but it indicates that the link between digital financial services and measurable patent output is not yet stable under the present model and data.

The robustness test gives similar evidence. When accepted patent applications are replaced by invention patent grants, the coefficients of the overall index, coverage breadth, and usage depth remain positive and statistically significant. The main conclusion therefore does not depend only on the patent application indicator. It also suggests that digital financial inclusion is related not only to the expansion of innovation quantity, but also to the quality-oriented measure captured by invention patent grants.

Policy Implications

The results point to the need for differentiated digital financial policies. A single policy design is unlikely to fit all regions, because the same dimension of digital financial inclusion does not play the same role across eastern, central, and western China.

For eastern China, the main task is not simply to expand digital financial access. The empirical results show that usage depth has a stronger relationship with innovation in this region. Policy support should therefore focus on improving the quality and precision of digital financial services. More attention can be given to R&D loans, intellectual-property-backed lending, digital insurance, and data-based credit evaluation for technology-oriented firms. These services are more directly connected with innovation financing than simple account coverage or payment access.

For western China, the priority is different. The stronger coefficient of coverage breadth indicates that basic access remains important. Policies should continue to improve the availability of mobile payment, online banking, digital credit, and other basic financial services in less-developed areas. At the same time, digital financial inclusion should be linked with local development activities, such as rural e-commerce, specialty agriculture, tourism, and small-scale entrepreneurship. In this way, wider financial access can be more easily converted into local innovation activity [Beck, Demirguc-Kunt, Levine, 2007; Shang, Liu, 2024].

The case of central China requires more caution. The insignificant estimates suggest that expanding digital finance alone may not be enough to generate visible innovation output. For this region, digital financial inclusion needs to be combined with industrial upgrading, local innovation platforms, skilled labor retention, and better connections between financial services and manufacturing firms. In other words, the policy focus should not be limited to financial inclusion itself, but should also consider whether local industries and innovation actors are able to use digital finance effectively.

Limitations and Future Research

This paper still has several limitations. The first limitation is the use of provincial panel data. This level of data is suitable for observing broad regional patterns, but it may conceal differences within the same province. Provincial capitals, smaller cities, counties, and rural areas may differ greatly in digital financial use and innovation activity. Future research could use prefecture-level or county-level data to examine these differences more closely [Khairullina, 2023; Guo et al., 2020].

The second limitation concerns the measurement of innovation. Patent applications and invention patent grants are useful because they are comparable and available across provinces. However, they cannot cover all forms of innovation. Some innovation activities may appear in business models, production processes, organizational changes, or green technology practices rather than in patent statistics [Tang, Wu, Zhu, 2020; Sun, 2024]. Future studies may use more detailed innovation indicators to test whether the findings remain valid for different types of innovation.

Conclusion

Finally, the empirical model should be interpreted with caution. The two-way fixed-effects model controls for province-specific factors and common yearly shocks, but it cannot fully remove reverse causality or time-varying omitted variables. Therefore, the results are better understood as strong empirical associations rather than strict causal estimates. Further work could use instrumental variables, quasi-natural experiments, dynamic panel models, or firm-level data to improve causal identification and examine the mechanisms more directly.

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Цифровая финансовая инклюзия и региональные инновации в Китае: данные провинциального уровня за 2013–2022 гг.

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Аннотация

В статье рассматривается взаимосвязь между цифровой финансовой инклюзией и региональными инновациями в Китае на основе панельных данных по 30 провинциям за период 2013–2022 гг. В качестве основного показателя региональных инноваций используются принятые патентные заявки, а в качестве проверки устойчивости результатов — выданные патенты на изобретения. Для эмпирического анализа применяется модель с двусторонними фиксированными эффектами. Результаты показывают положительную связь между индексом цифровой финансовой инклюзии Пекинского университета и инновационной активностью регионов. Отдельный анализ субиндексов показывает, что

широта охвата и глубина использования цифровых финансовых услуг положительно связаны с инновациями, однако их роль различается по регионам. В восточном Китае более важна глубина использования, тогда как в западном Китае большее значение имеет расширение охвата. Для центрального Китая результаты статистически менее устойчивы. Полученные выводы подчеркивают необходимость дифференцированной политики развития цифровых финансовых услуг с учетом региональных условий.

Для цитирования в научных исследованиях

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Ключевые слова

Цифровая финансовая инклюзия, региональные инновации, Китай, широта охвата, глубина использования, региональная неоднородность, панельные данные.

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