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Digital Inclusive Finance and Urban Innovation Ratio Upgrading

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Abstract. Private firms in China often struggle to obtain bank credit, especially for research and development projects that offer little tangible collateral. Digital inclusive finance may ease these constraints. This paper examines whether the development of digital inclusive finance is associated with a higher share of invention patents in Chinese cities. The analysis focuses on changes in patent composition rather than changes in the total number of patents. It combines the Peking University Digital Financial Inclusion Index, patent data, and city-level economic statistics for the period from 2011 to 2022. The data are matched by city and year. The results show a positive relationship, with a baseline coefficient of 0.2741 that is significant at the 1 percent level. This relationship is also stronger in cities with better protection of intellectual property rights. These findings suggest that digital finance and intellectual property protection may play complementary roles in supporting invention-oriented innovation at the city level.

Keywords: digital inclusive finance, invention patents, intellectual property rights

1. Introduction

Over the past ten years, private firms have grown rapidly and have played an increasingly important role in technological advancement and research and development (R&D) investment (Figure 1).

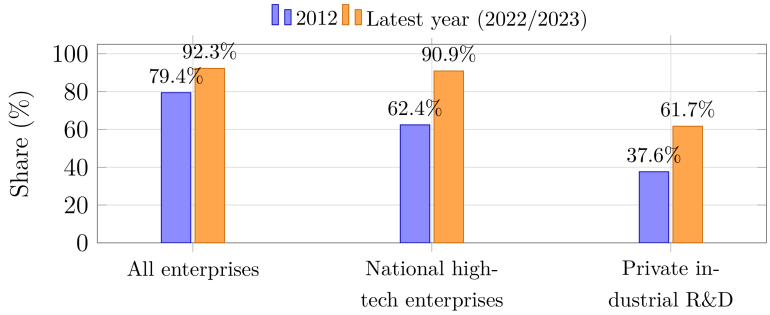


Figure 1. The scale and innovative role of China's private sector

Notes: Source: State Council (2024) [1]. Each reported percentage is the private-sector component divided by the corresponding total and multiplied by 100. The comparison uses 2012 and the latest observations: 2023 for all enterprises and 2022 for the other two measures.

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Despite their rapid growth and increasingly important role in technological innovation, private firms have historically faced disadvantages in obtaining formal bank credit compared with state-owned firms and have relied more heavily on costly alternatives such as trade credit [2, 3]. Figure 2 provides descriptive evidence of this historical financing imbalance.

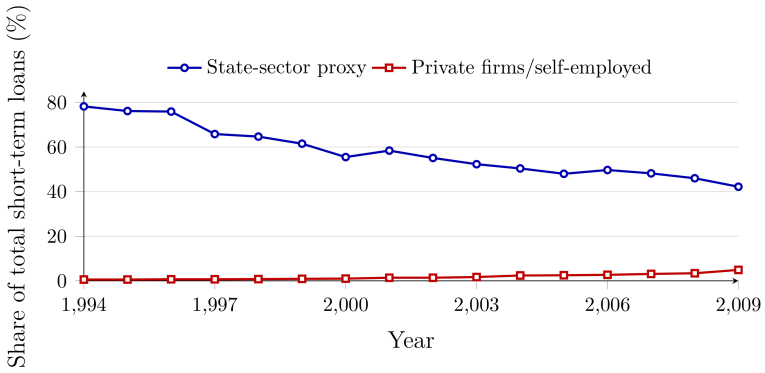


Figure 2. Historical short-term loan shares of the state and private sectors, 1994–2009

Notes: The vertical axis shows each sector's share of total year-end short-term loans (%). The state-sector series is an industry-based proxy. Source: China Statistical Yearbook [4].

One reason is that banks cannot always accurately assess project quality before lending or effectively monitor firms afterward. Private firms also tend to possess fewer tangible assets and receive less implicit government support than state-owned enterprises [5, 6]. These problems are especially severe for innovative projects, which are poorly suited to traditional collateral-based lending because R&D produces intangible knowledge and technology that are difficult to pledge as collateral [7, 8].

However, with the growth of digital finance, these financial frictions may be partly alleviated. Digital finance can provide lenders with more automated ways to monitor borrowers and reduce borrowers' fixed financing costs. Therefore, this paper examines whether digital financial inclusion promotes innovation in Chinese cities, particularly whether it increases the relative importance of invention patents [9].

2. Related literature

Previous studies show that private firms in China face more difficulty in getting loans than state-owned firms. They examine how ownership affects access to external finance [2, 3, 6, 10].

Funding is also a problem for innovation. R&D projects have uncertain results, and many of their assets cannot be used as collateral. This makes it harder for banks to assess these projects. As a result, innovative firms may face higher financing costs [7, 8, 11, 12].

Studies on digital inclusive finance find that it can ease financing constraints and support innovation [13, 14]. Many use the Peking University Digital Financial Inclusion Index, which measures coverage, use of services, and digitalization [15, 16]. Liu and Si [9] find that digital inclusive finance increases the number of patents, including both invention and non-invention patents.

This paper looks at the share of invention patents rather than only the total number of patents. This helps separate changes in patent composition from general growth in patent numbers. It also asks whether local intellectual property rights (IPR) protection makes the relationship stronger. The two hypotheses are:

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H1: Digital inclusive finance increases the share of invention patents among patent grants.

H2: Stronger IPR protection strengthens the positive effect of digital inclusive finance on the invention-patent share.

3. Data

This paper combines three datasets at the city-year level. The first is the Peking University Digital Financial Inclusion Index of China, compiled jointly by the Institute of Digital Finance at Peking University and Ant Group [15, 16]. It provides a measure of digital finance that can be compared across cities and years. Its absolute value does not have a direct economic interpretation.

The index combines three dimensions. First, breadth of coverage measures how common electronic financial accounts are. Second, depth of usage reflects the use of services such as digital payments and credit. Third, the level of digitalization captures mobile access and lower service costs. Together, they form a composite index of digital finance. Its values are used to rank relative levels of development, rather than to measure a real economic quantity.

The second source is the China Patent Database, obtained mainly from the replication package released by Liu and Si [17]. It records patent applications and grants. These records are used to examine both the level of patenting activity and the share of invention patents across cities. The third source is the China City Statistical Yearbook [18], which provides the economic and demographic information needed to construct the controls.

The three datasets overlap from 2011 to 2022. After they are matched by city and year, the resulting panel forms the sample for the empirical analysis.

4. Methods and results

This section defines the variables and regression models. It then reports the baseline estimates to examine whether digital finance can help increase the invention-patent share and whether local IPR protection changes the relationship.

4.1. Variable construction

The dependent variable, $Quality_{it}$, measures invention patents as a share of all patent grants in city i and year t. It is calculated as shown in equation (1):

$$Quality_{it} = \frac{\exp(InnH_{it}) - 1}{[\exp(InnH_{it}) - 1] + [\exp(InnL_{it}) - 1]} \tag{1}$$

Here, $InnH_{it}$ and $InnL_{it}$ are the $\ln(1 + x)$ -transformed numbers of invention and non-invention patent grants per 10,000 residents. Taking the exponential and subtracting one returns each variable to its original level. The invention-patent share is then calculated from those levels.

Using the share helps reduce the influence of general growth in patent numbers and focuses on the proportion of invention patents.

The main explanatory variable, DIF_{it}, is the Digital Financial Inclusion Index. Higher values indicate a higher level of digital financial inclusion. As discussed above, the index is used for comparisons across cities and years rather than interpreted as an absolute economic quantity.

The baseline controls describe local economic conditions. They include log employment (*Lab*), log gross domestic product (GDP) per capita (*Pgdp*), foreign direct investment as a share of GDP (*Fdi*), government spending on science and technology as a share of GDP (*Gov*), and fixed-asset

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investment as a share of GDP (*Inv*). An expanded specification adds marketization, internet development, human capital, and IPR protection. For the interaction model, the IPR-protection measure is standardized before it is multiplied by DIF_{it}.

4.2. Empirical strategy

Equation (2) gives the baseline model for the relationship between digital inclusive finance and the invention-patent share:

$$Quality_{\mathrm{it}} = \alpha + \beta\, DIF_{\mathrm{it}} + \gamma'\, X_{\mathrm{it}} + \mu_{\mathrm{i}} + \lambda_{\mathrm{t}} + \varepsilon_{\mathrm{it}} \tag{2}$$

In this model, i represents cities and t represents years. The dependent variable $Quality_{\mathrm{it}}$ is defined in equation (1), and DIF_{it} measures digital financial inclusion. The vector X_{it} contains the city-level controls. The coefficient of interest is β. The intercept is α, and γ is the vector of control coefficients; the prime denotes transposition.

The model also includes city fixed effects, μ_{i}, and year fixed effects, λ_{t}. The error term is $\varepsilon_{\mathrm{it}}$. Standard errors are clustered by city.

The interaction model in equation (3) adds IPR protection and its interaction with digital inclusive finance:

$$\begin{aligned} Quality_{it} \;=\; \alpha \;+\; \beta_1\, DIF_{it} \;+\; \beta_2\, IPR_{it} \;+\; \beta_3\, (DIF_{it} \times IPR_{it}) \\ +\, \gamma'\, X_{it} \;+\; \mu_i \;+\; \lambda_t \;+\; \varepsilon_{it} \end{aligned} \tag{3}$$

Here, IPR_{it} is the standardized measure of local IPR protection. The coefficients β_1 and β_2 correspond to digital inclusive finance and IPR protection, respectively. The interaction coefficient, β_3, is the coefficient of interest. It shows how the relationship between digital inclusive finance and the invention-patent share changes with IPR protection. A positive value means that stronger protection reinforces the positive association. The remaining symbols have the same meanings as in equation (2).

4.3. Baseline results

Table 1 brings together the baseline estimates. Columns (1)–(4) report the baseline and robustness results. Column (5) reports the moderation estimate discussed in Section 4.4.

In column (1), the coefficient on digital inclusive finance is 0.2741, with a standard error of 0.0581. It is positive and significant at the 1 percent level. This result is consistent with H1: cities with greater digital financial inclusion tend to have a higher invention-patent share.

Columns (2)–(4) report results with different model specifications. Using the one-year lag of the index gives a coefficient of 0.2940. Replacing year fixed effects with province-by-year fixed effects gives 0.2159. Adding the expanded controls gives 0.3079. Each estimate remains positive and significant at the 1 percent level.

Dependent variable: Share of invention patents among patent grants

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Table 1. Digital inclusive finance, the invention-patent share, and IPR moderation

	Baseline and robustness				Moderation
Specification	(1) Baseline	(2) Lagged DIF	(3) Province ×year FE	(4) Expanded controls	(5) IPR moderation
Digital inclusive finance	0.2741***	0.2940***	0.2159***	0.3079***	0.2281***
	(0.0581)	(0.0583)	(0.0736)	(0.0619)	(0.0579)
DIF × IPR protection	–	–	–	–	0.0230**
					(0.0094)
IPR protection included	No	No	No	Yes	Yes
Baseline controls	Yes	Yes	Yes	Yes	Yes
City fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	No	Yes	Yes
Province × year fixed effects	No	No	Yes	No	No
Expanded controls	No	No	No	Yes	No
R^2	0.672	0.692	0.818	0.665	0.667
Observations	3,119	2,849	3,119	2,915	2,963

Notes: Standard errors clustered by city appear in parentheses. Column (2) uses a one-year lag of digital inclusive finance. Column (3) replaces year fixed effects with province-by-year fixed effects. Column (4) adds marketization, internet development, human capital, and IPR protection. Column (5) includes the baseline controls and the standardized IPR-protection main effect; the coefficient on that main effect is not shown. Dashes indicate that the interaction is not included. DIF = digital inclusive finance; IPR = intellectual property rights; FE = fixed effects. * p < 0.10; ** p < 0.05; *** p < 0.01.

4.4. Institutional moderation

Column (5) reports a positive interaction between digital inclusive finance and IPR protection. The estimated interaction coefficient is 0.0230, with a standard error of 0.0094 and a p-value of 0.0148. Since IPR protection is standardized, a one-standard-deviation increase in protection raises the estimated slope on digital inclusive finance by 0.023. This result is consistent with H2. Stronger IPR protection may encourage firms to invest in innovation.

5. Conclusion

This paper uses three datasets: the Peking University Digital Financial Inclusion Index, the China Patent Database, and the China City Statistical Yearbook. The results show a positive and statistically significant relationship between digital inclusive finance and the share of invention patents. The baseline coefficient is 0.2741 and is significant at the 1 percent level. The relationship is stronger in cities with better IPR protection.

One possible explanation is that digital finance gives lenders more information about borrowers. This may help them assess risk and make them more willing to lend. At the same time, patent

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protection may give firms more reason to innovate.

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