

Research on the Impact of Banking Industry Competition on Innovation Output of Manufacturing Enterprises

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Abstract: Using panel data from Chinese listed manufacturing enterprises during the period from 2011 to 2020, this study empirically examines the mechanism by which banking industry competition affects the innovation output of manufacturing enterprises. The results reveal a "inverted U-shaped" relationship between banking industry competition and innovation output of manufacturing enterprises, with different turning points for different levels of innovation. The mechanism analysis demonstrates that banking industry competition affects the innovation output of manufacturing enterprises through financing constraints and channels for research and development (R&D) investment. Furthermore, the development of financial technology (fintech) positively moderates the impact of banking industry competition on innovation output of manufacturing enterprises. In the process of economic operation, it is important to fully consider the impact of fintech development on the real economy and achieve an organic integration of fintech and traditional finance, aiming to establish a modern financial system that effectively supports the development of the real economy.

Keywords: Innovation output of enterprises, Bankin industry competition, Development of financial technology.

1. Introduction

China's economy has transitioned from a high-speed development phase to a high-quality development phase, and accelerating innovation has become a crucial path for China to achieve the transformation of economic growth drivers. From the perspective of industrial chain modernization, innovation is a key element in breaking through "bottleneck" technologies, achieving independent and controllable technological innovation in the industrial chain, and improving industrial foundational capabilities. In 2022, China's total investment in research and experimental development exceeded 3 trillion yuan for the first time, with an R&D intensity (R&D expenditure as a percentage of GDP) reaching 2.55%. However, in critical technologies that restrict the development of China's industries, such as lithography machines, chips, and operating systems, there still exists a certain gap in domestic substitution. Manufacturing enterprises, as the industry that induces innovation and is induced by innovation, serve as incubators for Schumpeter's "creative destruction" and play a key role in addressing "bottleneck technologies." At the same time, innovation activities in manufacturing enterprises exhibit long cycles, high risks, and high investment requirements, with a strong reliance on external financing.

At present, indirect financing remains dominant for Chinese enterprises. According to statistics from the People's Bank of China, in 2021, loans granted by commercial banks to the real economy accounted for 63.6% of the increment in the scale of social financing. Therefore, the banking industry serves as a crucial pillar of China's modern financial sector and represents a significant component of the financial system. However, in reality, the dominance of Chinese banks as sellers of credit still exists. The banking system has long been dominated by state-owned large banks, which allocate a significant portion of credit to government-supported large

enterprises and sectors. As a result, small and medium-sized enterprises (SMEs), which are highly efficient, have long faced difficulties in obtaining credit. In order to improve the quality and efficiency of financial services for the real economy, the government has implemented a series of policies, such as relaxing regulations on bank entry and promoting interest rate liberalization. One of the important objectives is to eliminate "credit discrimination" in the Chinese credit market through the benign transformation of the banking industry structure and effectively guide funds into the high-efficiency sectors of the real economy. Therefore, this paper takes the impact of banking industry competition on innovation in manufacturing enterprises as a starting point to conduct research, aiming to address the aforementioned issues.

2. Literature Review

There are two distinct viewpoints within the academic community regarding whether banking industry competition can promote firm innovation. The majority of scholars believe that banking industry competition breaks the monopoly of large commercial banks, effectively leverages market mechanisms, and enhances firm innovation by alleviating "credit discrimination," restraining corporate financialization, and mitigating underinvestment or overinvestment by firms [1, 2]. However, some scholars argue that banking industry competition weakens the information value of firms, exacerbates information asymmetry between banks and firms, reduces the scale of relationship-based loans in the banking sector, and suppresses firm innovation activities [3]. Additionally, there is also a view that suggests a nonlinear relationship between banking industry competition and firm innovation. For instance, Presbitero and Zazzaro argue that the effect of banking industry competition on firm innovation has a critical threshold, and it only promotes firm innovation when banking industry competition exceeds that threshold

within a region [4]. Chang Qiguo and Hu Guoliu suggest that banking industry competition has a linear impact on firm innovation under different levels of financial development [5]. In summary, existing research confirms the significant role of banking industry competition in firm innovation but does not yield consistent conclusions.

In recent years, the vigorous rise of financial technology has created a vast stage for financial innovation, injecting abundant vitality into the digital transformation of finance. The rapid evolution of digital technologies such as big data, cloud computing, artificial intelligence, and blockchain has significantly expanded the coverage of financial services, enriched the supply of high-quality financial products, and facilitated the progression of the digital economy into a stage of high-quality development [6]. In light of these realities, existing literature has also discussed the impact of financial technology on the traditional financial system. Current research indicates that the development of financial technology has both "external competitive effects" and "technology spillover effects" on commercial banks. The "external competitive effects" suggest that the development of financial technology leads to competition with commercial banks, altering their liability structure, exacerbating asset-side risks, and impacting the liquidity creation of commercial banks [7, 8]. On the other hand, the "technology spillover effects" argue that the development of financial technology supports the digital transformation of commercial banks by providing technological and talent support. The digital transformation of commercial banks, in turn, enhances their innovation capabilities and competitiveness, allowing them to reach a broader range of creditworthy borrowers, expand their credit business, and more accurately identify credit risks [9, 10]. Furthermore, some scholars have pointed out that the development of financial technology can lead to structural changes in the banking industry, slowing down the expansion of bank branches and accelerating the transformation and exit of rural cooperative financial institutions [11].

Overall, scholars have extensively discussed the relationship between banking competition, the development of financial technology, and corporate innovation, but there is still room for further expansion in this area. Therefore, this article makes the following two contributions: (1) This article focuses on studying the impact of banking competition on corporate innovation in the manufacturing industry. Innovation is particularly important for manufacturing firms compared to other types of enterprises. The ability of manufacturing firms to achieve "quality improvement and efficiency enhancement" relies on the development of new technologies. Thus, the possession of high-quality patents is an important indicator of the competitive ability of manufacturing firms. (2) This article considers the influence of the development of financial technology on the competitive landscape of the banking industry. Commercial banks can utilize financial technology to achieve digital transformation, reduce information asymmetry between banks and enterprises, and effectively manage lending to high-risk enterprises and projects. By taking into account the impact of financial technology development on commercial banks, this article combines empirical research to examine the effects of financial technology development on banking competition and the innovation output of manufacturing firms. In summary, this article aims to contribute to the existing literature by exploring the relationship between banking competition, the development of financial technology, and corporate

innovation. It specifically focuses on the manufacturing industry and examines the effects of financial technology development on both banking competition and the innovation output of manufacturing firms through empirical analysis.

3. Theoretical Analysis and Research Hypotheses

The information collection and risk diversification functions of a well-functioning financial market are crucial for addressing the financing issues of corporate innovation [12]. Existing theories regarding the impact of banking competition on corporate innovation mainly rely on the traditional structuralist "market power hypothesis" and the "information hypothesis" that emphasizes information asymmetry and agency costs. The market power hypothesis suggests that when banking competition is low, large banks that hold a monopoly position in the market can extract monopoly profits, distort credit pricing, increase the financing costs of corporate innovation, and subject businesses to "credit discrimination" by commercial banks [3]. In such a scenario, only large enterprises with close relationships with banks can obtain credit support. Additionally, banks may further restrict high-risk innovation activities of enterprises to mitigate credit risk [13]. However, when banking regulations are relaxed and competition leads to standardized lending processes and market-based loan rates, the monopoly pricing of large banks is disrupted. This compels them to change the direction, methods, scale, and structure of credit allocation. As a result, funds flow into high-efficiency enterprises based on market supply and demand principles, providing the financial foundation for efficient enterprises to engage in innovation activities.

The information hypothesis suggests that competition can make it more difficult for firms to obtain financing for innovation. According to this hypothesis, a monopolistic banking structure facilitates the establishment of bank-firm relationships. Banks extract information value by having exclusive access to firm-specific information and provide relationship-based loans to the firms [3]. Through ongoing interactions with the firms, banks develop a deeper understanding of their information, enabling them to accurately assess the risks and returns of innovation projects [4]. However, as banking competition intensifies, the monopolistic control of banks over firm-specific information diminishes, reducing the economic rent value of information. Consequently, the scale of relationship-based loans between banks and firms decreases. Moreover, intensified banking competition can lead to the "winner's curse" trap for banks. When banking competition becomes excessive, commercial banks must compete for potential customers in order to meet their credit targets. However, the market for high-quality customers is limited, so the bank that ultimately wins the loan may only obtain the opportunity to lend to lower-quality borrowers [14]. The "winner's curse" trap exacerbates adverse selection and moral hazard risks faced by commercial banks, compelling them to reduce their lending volumes. Therefore, the information hypothesis suggests that increased banking competition can lead to a reduction in the size of relationship-based loans, as banks lose their monopolistic control over firm-specific information and face challenges associated with adverse selection and moral hazard risks.

Therefore, while banking competition can enhance firm innovation output, excessive competition can also have

negative effects. In the early stages of banking deregulation, the long-standing monopoly of large state-owned banks gradually diminishes, allowing credit funds to flow in the market based on pricing, thus improving the accessibility of credit for efficient manufacturing firms. However, as competition deepens, the diminishing returns of banking competition and negative effects such as the reduction in information value begin to dominate. On the one hand, excessive competition significantly reduces the monopolistic control of information in the banking industry, making it difficult for banks to generate sufficient profits from information collection. As a result, banks are less inclined to establish long-term stable relationships with manufacturing firms, leading to a reduction in relationship-based loans provided to these firms. On the other hand, the "winner's curse" trap resulting from excessive competition undermines banks' enthusiasm for lending to manufacturing firms. This leads to a decrease in the scale of credit for manufacturing firms, higher loan interest rates, stricter loan restrictions, and further constraints on firm innovation activities. In summary, while banking competition initially benefits firm innovation by improving credit availability, excessive competition erodes the positive effects. The diminishing information value and the "winner's curse" trap associated with excessive competition reduce the availability of relationship-based loans and constrain the credit and innovation activities of manufacturing firms.

Hypothesis 1: There is an inverted U-shaped relationship between the degree of banking competition and innovation output of manufacturing firms.

Resources always exhibit scarcity, and therefore, optimal resource allocation requires individuals to allocate limited and relatively scarce resources in a rational manner to produce the most suitable goods and services with minimal resource consumption. However, during the period of banking monopoly, the long-standing phenomenon of credit discrimination directed financial resources primarily towards large state-owned enterprises, resulting in distorted resource allocation in the credit market [15]. Competition breaks the banking monopoly, alleviating the financing constraints of enterprises and effectively improving their innovation output. Firstly, from the supply side, banking competition compels commercial banks to enhance their professional capabilities, thus improving resource allocation efficiency. To compete for limited high-quality clients, commercial banks have to improve their information mining capabilities, enhance their risk assessment systems, maintain appropriate risk exposures, and obtain reasonable risk premiums when granting loans. At the same time, the participation of small and medium-sized banks enhances the ability of "division of labor by scale" among banks [16]. Due to their smaller asset size, small and medium-sized banks find it challenging to meet the high loan demand of large enterprises, making it difficult to compete with large banks in the large-scale credit market. However, small and medium-sized banks can leverage their regional advantages to serve small and medium-sized enterprises that are difficult for large banks to reach. Compared to large banks, small and medium-sized banks are more flexible and localized, possessing a natural advantage in collecting information about local small and medium-sized enterprises. They can tailor financial products based on the local industrial ecosystem, playing a collaborative support role in the industrial chain. This improves the efficiency of resource allocation and alleviates the financing constraints of local

small and medium-sized enterprises. Secondly, from the demand side, banking competition enhances the bargaining power of enterprises, further leveraging the market's resource allocation function. During the period of banking monopoly, the relationship-based loans made it difficult for enterprises to switch between different commercial banks. However, with intensified competition among commercial banks, the value of relationship-based loans decreases, and enterprises can compare the credit conditions of different banks to choose the most suitable credit products. This effectively utilizes the market supply-demand mechanism from the demand side, enabling enterprises to obtain reasonable loan collateral values and interest rates, alleviate financing constraints, and reduce their innovation costs.

Hypothesis 2: With the intensification of banking competition, the financing constraints on manufacturing firms exhibit a process of initial relaxation followed by tightening, which subsequently affects the firms' innovation output.

Banking competition can stimulate manufacturing firms to increase their research and development investment, thereby enhancing their innovation output. Firstly, banking competition can effectively select and encourage high-efficiency firms, compelling manufacturing firms to focus more on quality enhancement and increasing their likelihood of entering the innovation sector. Banking competition improves the screening and evaluation capabilities of commercial banks, helping to identify more potential firms and provide them with credit support while reducing credit supply to low-efficiency and high-risk firms [15]. In order to maintain a leading market position, firms are motivated to invest in new equipment, hire R&D personnel, and incur initial innovation costs. By entering the innovation sector and intensifying their innovation efforts, firms can improve their efficiency, thereby solidifying their competitive advantage. In this process, banking competition acts as a catalyst: high-efficiency firms receive greater credit allocation, enhancing their production and R&D capabilities, significantly increasing the probability of successful innovation and achieving higher innovation output [17, 18]. Meanwhile, credit allocation to low-efficiency firms decreases, accelerating their elimination.

Secondly, banking competition can facilitate the transmission of monetary policy and innovation incentive policies, leading to increased R&D investment by manufacturing firms and subsequently improving their innovation level. In the transmission channel of monetary policy, commercial banks play a crucial role as intermediaries in transmitting policy measures to real interest rates. The effectiveness of interest rate transmission in China relies on the adjustment of bank system liquidity through monetary policy tools, thereby releasing policy signals [19]. In this process, the pricing ability of commercial banks is a key factor influencing the efficiency of monetary policy transmission [20]. However, in reality, banks operating under long-term monopolistic conditions exhibit lower efficiency, and some institutions lack scientific models for pricing deposits and loans, resulting in low levels of differentiated and refined pricing. Furthermore, not implementing full fund management and the presence of multiple management and internal division in different business pricing make it difficult to accurately measure funding costs and risk exposure. These factors partially affect the effectiveness of interest rate transmission [21]. With the intensification of banking

competition and the entry of numerous small and medium-sized banks, the dominance of banking monopolies decreases, and market pricing mechanisms begin to replace the monopolistic pricing of large commercial banks. The market's mechanism of survival of the fittest will further increase the market share of efficient banks and reduce the business scale of inefficient banks, pressuring the latter to improve their pricing capabilities and enhancing the overall pricing service capabilities of commercial banks in the market. The pricing capabilities of an efficient banking system can effectively transmit monetary policies that support independent innovation, further guiding firms to enter the innovation sector and improving the overall innovation output of firms at the market level.

Hypothesis 3: With the intensification of banking competition, there is a process of initially increasing and then decreasing research and development investment by manufacturing firms, which subsequently affects their innovation output.

4. Model Design and Data Sources

4.1. Model Design

To examine the impact of banking competition on innovation output of manufacturing firms, this study employs a fixed effects panel data econometric model, taking into account industry and time fixed effects. This approach is consistent with previous research and allows for rigorous empirical analysis.

$$Innovation_{it} = \beta_0 + \beta_1 HHI_{ct} + \beta_2 HHI_{ct}^2 + \sum \beta_k Controls_{it} + u_i + v_t + \varepsilon_{it} \quad (1)$$

In this study, patent applications (*Apply*, *Apply1*, *Apply2*) are used as proxy variables to measure innovation output of manufacturing firms (*Innovation_{it}*). The core explanatory variable is the banking competition index, and *Controls_{it}* represents a set of control variables. *u_i* represents industry fixed effects, *v_t* represents time fixed effects, and *ε_{it}* represents the random disturbance term. Here, *i* represents individual manufacturing firms, *c* represents different provinces, and *t* represents time.

To further investigate the mechanism through which banking competition affects innovation in the manufacturing sector, the following mediation effect model is constructed.

$$M_{it} = \alpha_0 + \alpha_1 HHI_{ct} + \alpha_2 HHI_{ct}^2 + \sum \alpha_k Controls_{it} + u_i + v_t + \varepsilon_{it} \quad (2)$$

$$Y_{it} = \gamma_0 + \gamma_1 HHI_{ct} + \gamma_2 HHI_{ct}^2 + \gamma_3 M_{it} + \sum \gamma_k Controls_{it} + u_i + v_t + \varepsilon_{it} \quad (3)$$

Where *M_{it}* represents the mediating variable, which represents the specific channel through which banking competition influences innovation output of manufacturing firms. γ_1 (or γ_2) and γ_3 respectively measure the direct effects and mediation effects of banking competition on innovation output of manufacturing firms.

4.2. Indicator Selection and Data Sources

4.2.1. Dependent Variable

Innovation Output (*Innovation_{it}*): The innovation output of manufacturing firms is measured using the number of patent applications. In this study, the following indicators are used to quantify different aspects of innovation output: Total Patent Applications (*Apply*): It represents the overall innovation output of the company. The natural logarithm of the total number of patent applications in a given year, plus 1, is used as the proxy variable. Invention Patent Applications (*Apply1*): It captures the innovation output related to methods and products. The natural logarithm of the total number of invention patent applications in a given year, plus 1, is used as the proxy variable. Utility Model and Design Patent Applications (*Apply2*): It measures the innovation output related to structural and design innovations. The natural logarithm of the sum of utility model and design patent applications in a given year, plus 1, is used as the proxy variable.

4.2.2. Explanatory Variables

Banking Competition Level (*HHI*): Drawing on the work of Si Dengkui [2], the establishment of banking competition level is based on the financial license information of national financial institutions published by the China Banking and Insurance Regulatory Commission. By examining the establishment and closure records of branch institutions, the number of bank branches is calculated for each city and year. The level of competition is then measured by calculating the sum of squares of the proportions of bank branches in each city to the total number of bank branches in that city.

$$HHI = \sum_{r=1}^{N_m} (branch_{rm} / \sum_{r=1}^{N_m} branch_{rm})^2 \quad (4)$$

Where *branch_{rm}* represents the number of branches of the *r*-th bank in city *m*, and *N_m* represents the total number of banks of all types in city *m*. A higher Herfindahl-Hirschman Index (*HHI*) for the banking sector indicates lower levels of banking competition.

4.2.3. SMediating Variable and Moderating Variable

Firm Financing Constraints (*SA*): In this study, the *SA* index is used as a proxy variable for firm financing constraints. The *SA* index incorporates two exogenous indicators, namely firm age and firm size, to reflect the level of financing constraints faced by the firms.

$$SA = -0.737 * Size + 0.043 * Size^2 - 0.04 * Age \quad (5)$$

Firm Financing Constraints (*SA*): The *SA* index is calculated and all values are negative. The absolute value of the *SA* index indicates the severity of financing constraints faced by the firms, with larger absolute values indicating more severe constraints.

Research and Development Expenditure (*RD*): In this study, the natural logarithm of the amount of research and development expenditure reported in the firm's financial statements is used as a proxy variable for firm's research and development investment. A higher value of *RD* indicates higher research and development expenditure by the firm.

Financial Technology Development (*Index*): In this study, the Peking University Digital Inclusive Finance Index [22] is used as a proxy variable for financial technology development. This index measures the development of digital inclusive finance at the provincial, municipal, and county levels based

on three dimensions: coverage breadth, usage depth, and digital support services. In this study, the digital inclusive finance index at the municipal level is employed.

4.2.4. Controlling Variables

Based on theoretical analysis and existing literature on firm innovation levels, this study introduces the following control variables: Firm Age (*Age*): Represented by the logarithm of the firm's founding time. Firm Size (*Size*): Represented by the logarithm of total assets. Shareholder Concentration (SHRCR): Measured by the proportion of ownership held by the largest shareholder. Financial Indicators: Reflecting the impact of firm's financial performance on innovation behavior, including: Return on Assets (*ROA*): Ratio of net profit to average assets. Total Asset Turnover (*TAT*): Ratio of net sales to total assets. Cash Ratio (*Cash*): Ratio of cash assets to current liabilities. Leverage (*LEV*): Ratio of total liabilities to total assets. Firm Growth (*Growth*): Measured by the growth rate of sales revenue. Long-Term Debt-to-Capital Ratio: Ratio of long-term debt to long-term assets. City Gross Domestic Product (*GDP*): Represented by the logarithm of the GDP of the city where the firm is located.

4.2.5. Data Source

This study selects manufacturing firms listed on the Shanghai and Shenzhen stock exchanges in China from 2011

to 2020 as the research sample. The sample data is processed as follows: (1) Exclusion of ST and *ST firms, (2) Imputation of missing values for certain samples using interpolation. The innovation data for this study is sourced from the WIND database, while the financial data is obtained from the CSMAR database. The financial data is supplemented with information from the annual reports of the listed companies. To ensure data validity, robust standard errors are used for all data analysis in this study.

5. Empirical Analysis: Results of Bank Competition

5.1. Baseline Regression

In order to examine the impact of bank competition on firm innovation output, a fixed effects model is employed to regress panel data. The regression results are presented in Table 1. To demonstrate the heterogeneity of the effects of bank competition on different types of firm innovation output, columns (1) to (3) in Table (1) display the regression results for total patent applications, invention patent applications, and the sum of utility model and design patent applications, respectively, affected by bank competition.

Table 1. Baseline Regression Results

| Variables | (1) Apply | (2) Apply1 | (3) Apply2 |
|------------------|-----------------------|-----------------------|-----------------------|
| HHI | 6.015*** (1.837) | 6.540*** (1.899) | 5.150*** (1.852) |
| HHI ² | -15.580*** (3.938) | -17.110*** (4.109) | -12.530*** (4.023) |
| Size | 7.533*** (0.192) | 7.346*** (0.197) | 6.913*** (0.186) |
| Age | -1.809*** (0.321) | -0.981*** (0.328) | -1.445*** (0.333) |
| SHRCR | -3.498*** (1.317) | -4.990*** (1.330) | -1.256 (1.287) |
| TAT | 4.154* (2.151) | 1.340 (2.163) | 3.673* (2.090) |
| LEV | -1.630 (5.932) | 4.563 (4.196) | -0.194 (5.974) |
| Growth | -6.649 (11.54) | -7.236 (13.30) | -5.231 (10.97) |
| ROA | 5.330*** (1.344) | 4.910*** (1.413) | 4.247*** (1.266) |
| CAT | 3.327 (2.865) | 1.097 (2.887) | 3.581 (2.782) |
| Cash | 5.368 (5.268) | 14.07** (6.064) | -4.584 (4.390) |
| GDP | 1.533*** (0.449) | 2.317*** (0.427) | 0.963** (0.446) |
| Constant | -6.058*** (0.964) | -8.269*** (0.921) | -5.062*** (0.965) |
| Observations | 4,540 | 4,540 | 4,540 |
| R ² | 0.594 | 0.538 | 0.585 |

Note: ***, **, * represent the significance levels of 1%, 5%, and 10%, respectively. Standard errors are shown in parentheses. The same notation applies to the following table.

Table (1) shows that the coefficient of HHI is 6.015, and the coefficient of HHI squared is -15.58, both of which are significant. This indicates a "inverted U-shaped" relationship between bank competition and firm patent applications,

validating Hypothesis 1. However, the turning points for different levels of patent applications vary. Specifically, the results in column (1) indicate that the turning point of bank competition is around HHI = 0.193. A lower HHI value

indicates higher bank competition. Thus, below this turning point, there is a negative relationship between bank competition and firm patent applications, implying that increased bank competition leads to a decrease in firm patent applications. On the other hand, when bank competition exceeds this turning point, intensified bank competition promotes an increase in firm patent applications.

The regression results for invention patent applications (*Apply1*) indicate that as bank competition level increases, firm patent applications first increase and then decrease, with a turning point around HHI = 0.191. The turning point for invention patent applications occurs later than that of total patent applications. Similarly, there is a non-linear relationship between bank competition and utility model and design patent applications (*Apply2*), with a turning point around HHI = 0.205. This may be because when banks face excessive competition, they may increase their selection criteria for high-quality projects and reduce credit supply, especially for utility model and design patents that have less commercial value. Therefore, banks are more likely to prioritize reducing credit supply for utility model and design patents, leading to an earlier turning point.

5.2. Mechanism Analysis of the Impact of Bank Competition on Manufacturing Firms' Innovation Output

Based on the specifications of models (2) and (3), empirical

models are constructed to examine the relationship between bank competition and the mediating variables. Table 2 presents the regression results of bank competition, corporate financing constraints, and manufacturing firms' innovation output, while Table 3 presents the regression results of bank competition, corporate research and development investment, and manufacturing firms' innovation output.

The results in Table 2 indicate a significant "U-shaped" relationship between bank competition and financing constraints, and the nonlinear impact of bank competition on innovation output in the manufacturing sector remains significant after incorporating the mediating variable. Financing constraints significantly reduce innovation output in manufacturing firms, suggesting that bank competition not only directly enhances innovation output but also influences it through the channel of "financing constraints." Hypothesis 2 is supported. Furthermore, the coefficient (SA) for the number of firms' invention patent applications is -0.554, while for the number of design patents and utility model patents, it is -0.498. This indicates that after reducing financing constraints (SA) through bank competition, the impact on firms' invention patent applications is greater, resulting in a more pronounced improvement in the structure of innovation in the manufacturing sector and mitigating "innovation bubbles" in firms.

Table 2. Bank Competition, Financing Constraints, and Firm Innovation Output

| Variables | (1) SA | (2) Apply | (3) Apply1 | (4) Apply2 |
|------------------|-------------------|-----------------------|----------------------|----------------------|
| SA | | -0.574*** (0.0708) | -0.554*** (0.076) | -0.498*** (0.072) |
| HHI | -0.655 (0.413) | 5.889*** (1.819) | 6.312*** (1.883) | 5.024*** (1.838) |
| HHI ² | 1.636* (0.892) | -15.15*** (3.911) | -16.48*** (4.081) | -12.12*** (4.006) |
| Controls | YES | YES | YES | YES |
| Observations | 4,540 | 4,540 | 4,540 | 4,540 |
| R ² | 0.306 | 0.596 | 0.542 | 0.587 |

The results in Table 3 indicate a significant inverted "U-shaped" relationship between bank competition and the mediator variable RD. Furthermore, after incorporating the mediator variable, the non-linear impact of bank competition on firm innovation output remains significant. Specifically, an increase in R&D expenditure significantly enhances firm innovation output, suggesting that bank competition not only directly promotes firm innovation output but also influences

it through the channel of R&D investment, thus supporting Hypothesis 3. Moreover, the RD coefficient for firm invention patent applications is 0.162, while the RD coefficient for firm design patent applications and utility model patent applications is 0.090. This implies that bank competition, through the channel of R&D investment, improves the structure of firm innovation output, leading to a greater emphasis on high-level innovation.

Table 3. Bank Competition, Research and Development, and Firm Innovation Output

| Variables | (1) RD | (2) Apply | (3) Apply1 | (4) Apply2 |
|------------------|--------------------|----------------------|----------------------|---------------------|
| RD | | 0.143*** (0.022) | 0.162*** (0.024) | 0.090*** (0.017) |
| HHI | 2.585 (2.259) | 4.054** (1.784) | 4.987*** (1.916) | 3.259* (1.865) |
| HHI ² | -8.680* (4.884) | -13.20*** (3.919) | -14.71*** (4.216) | -10.46** (4.122) |
| Controls | YES | YES | YES | YES |
| Observations | 4,173 | 4,173 | 4,173 | 4,173 |
| R ² | 0.411 | 0.576 | 0.534 | 0.570 |

5.3. Further Analysis

According to the aforementioned results, it is evident that banking sector competition has a significant impact on innovation output in the manufacturing industry. Meanwhile, financial technology, as a new development model, has brought profound changes to traditional finance and also has important implications for the relationship between banking sector competition and innovation output in the manufacturing industry. Therefore, to identify the impact of financial technology on the innovation effect of banking sector competition, an interaction term between banking

sector competition and the digital inclusive finance index is constructed based on Model (1). The model is set as follows:

$$Y_{it} = \delta_0 + \delta_1 HHI_{ct} + \delta_2 HHI_{ct}^2 + \delta_3 Index_{kt} + \delta_4 Index_{kt} \times HHI_{ct} + \sum \delta_k Controls_{it} + u_i + v_t + \varepsilon_{it} \quad (6)$$

the coefficient δ_4 represents the moderating effect of financial technology development on the relationship between banking sector competition and innovation output in the manufacturing industry.

Table 4. Banking Sector Competition, Financial Technology Development, and Innovation Output of Enterprises

| Variables | (1) Apply | (2) Apply1 | (3) Apply2 |
|------------------|----------------------|-----------------------|--------------------|
| HHI | 4.741** (2.020) | 5.986*** (2.113) | 3.366 (2.053) |
| HHI ² | -10.830** (4.295) | -12.580*** (4.505) | -7.817* (4.434) |
| Index | 0.210 (0.265) | 0.590** (0.271) | -0.0972 (0.269) |
| Index_HHI | 1.382*** (0.452) | 1.664*** (0.462) | 1.101** (0.458) |
| Controls | YES | YES | YES |
| Observations | 4,540 | 4,540 | 4,540 |
| R ² | 0.595 | 0.539 | 0.586 |

According to the table, the inverted U-shaped non-linear relationship between banking sector competition and innovation output of manufacturing enterprises still exists. The coefficient of the digital financial index is positive but not significant. This may be due to the fact that the data used in this study mainly consists of listed manufacturing companies, which are predominantly large-scale enterprises. Existing research indicates that the development of financial technology has a greater impact on technological innovation in small and medium-sized enterprises, while its impact on large enterprises is not significant [23]. Therefore, the innovation effects of financial technology development may not be fully reflected among listed manufacturing companies. The significant positive coefficient of the interaction term between the digital financial index and the level of banking sector competition indicates that the development of financial technology can significantly moderate the relationship between banking sector competition and innovation output of manufacturing enterprises. It strengthens the role of banking sector competition in driving innovation output while also increasing the inflection point of the inverted U-shaped relationship between banking sector competition and innovation output, thereby enhancing the tolerance of innovation output to banking sector competition. Further analysis reveals that the development of financial technology primarily has a direct impact on product and process innovation represented by the number of invention patent applications. However, its impact on structural and appearance innovation represented by utility model and design patent applications is not significant.

5.4. Robustness Testing

5.4.1. Replacement of Explanatory Variable

Considering the uniqueness of policy banks, rural cooperative banks, and other types of financial institutions,

this study conducts a robustness test by replacing the banking competition variable (HHI) with the ratio of the five major state-owned commercial banks to the total number of banks in the region (CR5). The five major state-owned banks include Bank of China, Agricultural Bank of China, Industrial and Commercial Bank of China, China Construction Bank, and Bank of Communications. The regression results, as shown in Table 10, demonstrate a significant "inverted U-shaped" relationship between CR5 and patent applications, consistent with the previous findings, further indicating the robustness of the test results in this study.

5.4.2. Instrumental Variable Regression

In the aforementioned regression, there might be an endogeneity issue between bank competition and firm innovation. It is possible that bank competition promotes firm innovation, which in turn enhances urban competitiveness, attracting more banks to enter the city. This potential bidirectional causal relationship can lead to endogeneity problems in the model. Therefore, this study adopts the approach of Cai Jing and Dong Yan [24] to construct instrumental variables.

In constructing the instrumental variables, all cities are divided into three categories: municipalities directly under the central government, sub-provincial cities, and cities within the same province. The average level of bank competition in the same category of cities (excluding the bank competition level of the focal city) is used as the instrumental variable. The rationale behind this construction is that when companies borrow across regions, they need to consider transaction costs and information costs. Therefore, the distribution of banks in other cities of the same category is unlikely to affect local firms' research and development financing. However, cities of the same category share geographic proximity or similar economic characteristics, and when banks establish branches, they may consider cities of the same category as alternative

locations. Hence, there is a correlation in the distribution of banks among cities of the same category.

The table below presents the results of the two-stage regression using instrumental variables. The coefficients are consistent with the previous analysis and are all statistically significant, indicating the robustness of the results.

5.4.3. Replacement of Dependent Variable

Due to the possibility that companies engage in a

significant amount of low-end innovation in order to obtain "support" from the government and commercial banks, thereby overestimating their level of innovation, using the number of patent applications as a measure of firm innovation output may not accurately capture the true level of innovation. Therefore, in this study, the natural logarithm of the number of patents obtained by companies (Get) is used as a replacement for the dependent variable, and the resulting test results remain robust.

Table 5: Robustness Test

| Variables | (1) Apply | (2) Apply | (3) Get |
|-------------------------|----------------------|----------------------|----------------------|
| Cr5 | 4.890*** (1.685) | | |
| Cr5 ² | -5.003*** (1.938) | | |
| fitted_HHI | | 4.785*** (1.587) | |
| fitted_HHI ² | | -41.41*** (12.14) | |
| HHI | | | 4.012** (1.812) |
| HHI ² | | | -10.59*** (3.959) |
| Controls | YES | YES | YSE |
| Observations | 4,540 | 4,540 | 4,540 |
| R ² | 0.594 | 0.594 | 0.598 |

6. Conclusion

Based on a comprehensive review of the existing literature, this study has constructed a theoretical framework to analyze the relationship and mechanisms between bank competition, financial technology, and innovation output of manufacturing firms. Using panel data from listed manufacturing companies in the Shanghai and Shenzhen stock markets for the period 2010-2020, the empirical analysis has examined the relationship between bank competition and innovation output of manufacturing firms, as well as the moderating effect of fintech represented by the digital inclusive finance index. The main findings and policy implications are as follows: (1) There is an inverted U-shaped relationship between bank competition and innovation output of manufacturing firms. Increased bank competition promotes innovation output up to a certain point. However, excessive competition beyond the turning point has a negative impact on innovation output. Moreover, the turning point differs across different levels of innovation. (2) Further analysis reveals that bank competition primarily affects innovation output of manufacturing firms through two channels: the financing constraint channel and the R&D investment channel. Specifically, bank competition can reduce firms' financing constraints and increase their R&D investment, thereby enhancing innovation output of manufacturing firms. (3) The development of fintech plays a positive moderating role in the relationship between bank competition and innovation output of manufacturing firms. Fintech amplifies the positive effect of bank competition on innovation output, increases the threshold for the negative impact of bank competition on different levels of innovation, and enhances the tolerance of manufacturing firms towards bank competition. Table 10: Robustness Test

The conclusions of this study have certain policy implications for China's goal of achieving a financial system

that serves the real economy. As an important component of China's financial system, the banking industry has a significant relationship with the development and stability of the financial system. On one hand, in order to effectively support the development of the real economy and enhance the independent innovation capabilities of Chinese enterprises, a modern financial system that is highly adaptable, competitive, and inclusive is indispensable. This requires the banking-led financial system to proactively adapt to the requirements of high-quality development, the construction of a high-level socialist market economy, and the deepening of supply-side structural reforms in finance. Therefore, relaxing regulations on the entry of commercial banks and effectively utilizing market mechanisms are key to constructing a modern financial system that is highly adaptable, competitive, and inclusive. However, on the other hand, an overly competitive banking industry can fall into the trap of the "winner's curse," thereby reducing innovation output of enterprises. Therefore, while relaxing regulations, attention should also be paid to mitigating the potential risks in the financial industry and constructing a rational competition system to prevent commercial banks from causing financial misconduct in pursuit of profits. Simultaneously, effectively leveraging financial technology to empower traditional commercial banks in their digital transformation can help expand their service coverage, reduce credit risks, and improve operating profits. This, in turn, increases the tolerance of the real sector towards banking competition and enhances the support of the banking industry for innovative sectors.

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