10. BANK COMPETITION AND FIRM INNOVATION OUTPUT: THE ROLE OF FINANCING CONSTRAINTS

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Abstract

The economic theory tries to explain the coexistence of China's technological progress and imperfect bank-oriented system. We use data which includes bank branches and manufacturing enterprises information across China over the period 1998-2011 to check how bank competition impacts firm innovation output and the role of firms' financing constraints in bank competition impacting firm innovation output. We find that increased competition among banks can improve the innovation output of enterprises and the positive effect is stronger for firms with more dependence on external financing, high financing cost, and short operating years. The increase in banks branches and decline in assets share of state-owned banks are helpful to promote firm innovation. Moreover, bank competition enables small firms and opacity firms to improve their innovation output in regions with few state-owned banks branches. Promoting bank competition by privatizing state-owned banks or downsizing giant banks would be a way to promote enterprise R&D investment and improve enterprise productivity. This study sheds light on the determinants of innovation in transitional economies.

Keywords: bank competition, innovation output, bank branches, financing constraints

JEL Classification: D20, G21, O31

1. Introduction

Does financial competition promote firm innovation? Financing services provided by financial institutions play an important role in promoting firm growth. Rajan and Zinagales (1998) reveal that financial development alleviates adverse selections and moral hazard problems, thus promoting economic growth. Financial intermediaries improve investment productivity by providing loans to the qualified firms (Greenwood and Jovanovic, 1990). Well-functioning

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financial market could promote resource allocation efficiency and technological progress through monitoring firms' behavior and by matching lenders and borrowers efficiently (King and Levine, 1993).

Some studies investigate the effects of market characteristics on innovation activities of enterprise, such as competition (Aghion *et al.*, 2005), stock market development (Brown, Martinsson, and Petersen, 2013) and financing constraint (Caggese, 2019). Due to the imperfection of financial markets, the innovative activities of firms are constrained by internal financing (Guariglia and Liu, 2014). Innovative entrepreneurs initially face stronger financial constraints under arm's length financing than relationship financing, which reduces social welfare (Spiganti, 2019). Those firms that rely more on the inter-bank market reduced their innovative performance than other firms during the financial crisis (Giebel and Kraft, 2019). On the other hand, Kim, Lee and Kim (2016) find that bank loans have negative impact on technological innovation activities of firms, while stocks and bonds have positive effect on them. Although verifying the determinants of firm innovation is important for policy makers and academics, studies that link bank competition and innovation are sparse.

China has been experiencing an ongoing economic boom for 40 years, but presents a puzzle. The banking sector is the main source of firms financing. Bank competition has increased substantially in China over the past 40 years, while the government acknowledged that small firms face more obstacles than large firms in access to funds from financial institutions. According to the market power hypothesis, the rising competition of banks and the obstruction of enterprise financing should not occur at the same time. Due to theoretically equivocal predictions and endogeneity concerns, the influence of bank competition on firm innovation remains an issue of argument. One possible reason is that the role of financing constraints in bank competition affecting enterprise innovation is not clear.

To this end, this study seeks the micro-channel about how firms make decisions on innovation given local bank competition and firms' characteristics. This study uses a panel data of firms from China to investigate: (1) how bank competition impacts firm innovation output, (2) whether the effect differed relying on the levels of firms' financing constraints, (3) whether bank competition has different influence on innovation output of enterprises of different scale and transparency. The results suggest that bank competition results in an increase in firm innovation output and the effect is greater for financing-dependent enterprises, enterprises with high financing cost and young enterprises. Enterprises that invest more in R&D and small and medium-sized enterprises benefit from the intensified competition of banks.

This study has made some contributions. First, this paper contributes to bank competition measurement. The structural and non-structural approaches are the primary methods to measure bank competition in the previous literature. We use the banking structure around firms to proxy the bank competition, thus distinguishing bank competition faced by firms in different regions. Second, this study contributes to the broader literature on the relationship between bank competition and innovation output, while previous studies neglect the effects of bank competition on firm innovation. We add microscopic evidence to the determinants of innovation from the perspective of competition among financial institutions. Third, previous studies neglect the effects of firm financing constraints in bank competition influencing innovation, while this article clarifies the relation between bank competition and innovation by investigating the influence of bank competition on innovation output under different financing constraints and characteristics of enterprises. China is at a critical stage of promoting innovation-driven economic growth, and the lack of strong evidence of innovation determinants has caused regret for promoting innovation-driven economic development.

Under the background of global economic slowdown caused by COVID-19 epidemic, the conclusions of the study are significant.

Section 2 provides theoretical predictions of how bank competition should influence innovation. Section 3 and Section 4 describe the methodology and data used in the study, respectively. Section 5 and Section 6 discuss the results. Section 7 provides conclusions and suggestions.

2. Literature review and hypotheses

This article draws on previous studies that analyze the factors that impact firm innovation, and then finds out the factors which have effects on firm innovation activities. The theoretical literature presents conflicting conclusions about the effect of bank competition on financial constraints. The market power hypothesis argues a positive relation between bank competition and access to loans, since competitive banking decreases the market power of banks and is less likely to result in credit rationing than is monopoly banking (Santiago, Francisco, and Udell, 2009). Relaxing bank branching restrictions leads to bank branches compete with another and promotes both quantity and quality of manufacturing firm innovation across the US over the period of the 1980s and 1990s (Amore, Schneider, and Žaldokas, 2013). In addition, the effect of bank competition on obtaining loans may depend on the condition of information asymmetry. Higher competition would increase debt availability when there is no asymmetric information (González and González, 2014). Financing constraints hinder the innovation of small and medium-sized enterprises in an unfavorable environment, but the long-term relationship between firms and banks can reduce information asymmetry and alleviate the adverse effects of financing constraints (Antonia, Domingo, and Howard, 2016). Bank competition increases opaque firms' access to loans in homogeneous market with a large amount of small banks and reduces these firms' lending in heterogeneous market. (Heddergott and Laitenberger, 2017).

The information hypothesis, in contrast, suggests that lower competition results in the incentive for financial institutions to invest in relationship lending which is useful for them to obtain soft information and alleviate information asymmetry (Berger and Udell, 2002). A higher degree of bank competition reduces relationship lending and increases financial constraints. The phenomenon of inefficiency causes financial constraints to be alleviated in the banking markets dominated by large banks than in the banking markets composed of some small banks. Marquez (2002) observes that competitive bank markets may cause lending to low-quality borrowers, since banks could not screen potential borrowers. On the other hand, Cornaggia *et al.* (2015) argue that the increase in bank competition prevents public corporations' innovations but promotes private firms' innovation which face financing obstacles.

Financial development could increase endogenously with the expectation of technological advance, when there are no constraints for financial system improvement. Enhancing firms' access to credit from banks promotes innovation, while poor access to funds is likely to hinder convergence to the technological frontier for firms. If bank competition directly relieves firms' financial constraints, then bank competition could improve their R&D expenditures and innovation outputs. We expect firm-level innovation to increase following bank competition, since firms can take advantage of the improved supply of loans to invest in R&D projects. The hypotheses are stated as follows.

Hypothesis 1: There is a positive correlation between banking competition and firm innovation output.

Hypothesis 2: The influence of bank competition on innovation output is stronger for firms with financing constraints.

3. Methodology

3.1. Empirical methodology

We develop the following baseline equations to identify the influences of bank competition on firm innovation output and how financing constraints shape the effect:

$$Ln\_Innovation_{j,i,t} = \beta_0 + \beta_1 BranchCR4_{i,t-1} + \beta_2 BranchHHI_{i,t-1} + \beta_3 F_{j,i,t-1} + \omega_i + \eta_t + \mu_k + \varepsilon_{j,i,t} \quad (1)$$

$$Ratio\_Innovation_{j,i,t} = \beta_0 + \beta_1 BranchCR4_{i,t-1} + \beta_2 BranchHHI_{i,t-1} + \beta_3 F_{j,i,t-1} + \omega_i + \eta_t + \mu_k + \varepsilon_{j,i,t} \quad (2)$$

where j indexes the firm, i indexes the prefecture-level city, and t indexes the year.[2] *Ln_Innovation* and *Ratio_Innovation$_j$* denote the innovation output of firm. We use two structural measures, *BankCR4* and *BankHHI*, to measure regional bank competition (Carlson and Mitchener, 2009; Temesvary, 2015).[3] $F_{j,i,t}$ is control variables that impact firms' future innovation output. Table 1 shows the variables definitions.

The residual term of regression includes unobservable both region characteristics and industry characteristics, which are related to both firm innovation and bank competition. Standard Ordinary least squares (OLS) regression is difficult to produce correct statistical inferences with these unobservable characteristics existing. The panel dataset enables us to control region-level effects and industry-level effects, and thus eliminates time-invariant unobservable effects that influence firm innovation. Therefore, we include prefecture-level, year-level, and industry-level effects in the baseline regression. ω_i is the prefecture-level region specific effects and tackle omitted variables from the equations that generate variation in a region's stance toward bank competition may be correlated with innovations activities. Persistent diversities across prefectures could be stripped out when model include prefecture fixed effects. η_t is the year fixed effects. μ_k is the industry specific effects. $\varepsilon_{j,i,t}$ is the error term.

There is debate on the causality between bank competition and firm innovation. Kroszner and Strahan (1999) find obvious differences in state-level characteristics among states that affect the timing of bank competition, and it may be that these differences trigger bank competition. However, bank competition is measured at the prefecture level in this study, whereas the innovation output measures for firm-level information are derived from a different data set. Thus, firms' innovation output measure is unlikely to affect bank competition at the prefecture level.

Region and industry characteristics related to both bank competition and firm innovation may be left in the residual terms and lead to incorrect statistical inferences. We use a panel-based fixed-effect identification method to control the time series and cross-sectional dynamics (Rajan and Zinagales, 1998). The approach addresses the problem of identifying the specific effect mechanisms through which bank competition influences firm innovation.

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[2] *As of June 2018, China has 334 prefecture-level administrative divisions.*

[3] *The big four state-owned commercial banks are the Industrial and Commercial Bank of China, the Bank of China, the Construction Bank of China, and the Agriculture Bank of China.*

To control the potential endogeneity problem and the contemporaneous reverse causality, we exploit the competition of regional banking sector and perform the estimations through lagging the independent variables by one year.

3.2. Variable measurement

3.2.1. Measuring firm innovation

It is hard to measure firm innovation, but patents are easily measured and are usually used as an indicator of innovation. This measurement method has faults. Patents' tendency is different across regions, industries, and processes. Patents measure inventions instead of innovations, and some firms are prone to protect their innovations by other methods rather than applying for patents. Hu, Zhang and Zhao (2017) find that the patents growth comes from the extensive margin of growth-firms in China. They observe that the correlations between patents and labor productivity and that between patents and R&D expenditures are weak, particularly for the extensive margin of patents. Moreover, R&D expenditures measure firm innovation, which may be biased, especially for small firms. R&D expenditures do not necessarily result in innovations and not all innovations result from these expenditures (Archibugi and Sirilli, 2000; Yuriy and Monika, 2013), *i.e.*, R&D expenditures are input rather than output.

This study constructs two measures for firm-year innovation output: the logarithm of the firm's value of new product (*Ln_Innovation*), the ratio of the firm's value of new product divided by its output value (*Ratio_Innovation*). The new product used in this article belongs to the innovation category defined by Schumpeter.

3.2.2. Measuring bank competition

The studies about industrial organization provide different methodological ways to measure competition. The traditional structure-conduct-performance (SCP) model argues that low industry concentration is positively related to competitive business and leads to low profitability.

This study relies on aggregate measures of bank competition. Following previous studies (Carlson and Mitchener, 2006; Temesvary, 2015; Degl'Innocenti, Mishra, and Wolfe, 2017; Liu, Li, and Huang, 2018), we use concentration ratio (*BankCR4*) and Herfindahl index (*BankHHI*) as the proxies of bank competition. The calculated results show that the banking sector of China prefecture-level regions is fairly concentrated.

3.2.3. Measuring control variables

The models control for firm characteristics that may impact innovation output. Specifically, they use the firm's assets (*Size*) to alleviate the deviation of firm size. The argument on including firm size is that large firms could put more resources into innovative projects. The firm's age (*Age*) is used to control for the dependence of the operating period, the firm's capital-labor ratio (*K_L*) to control for the capital intensity (Aghion, Van Reenen, and Zingales, 2013). The firm's leverage ratio (*Leverage*) is used to eliminate the impact of financial leverage, the firm's return on assets (*ROA*) to control for the effect of internal funds in supporting firms' innovation activities, the amount of subsidies received from the government (*Subsidy*) to control the government's support for firms. The firm's asset tangibility (*Tangibility*) is used to control for the mortgage of a firm's assets, and lower ratio of tangible assets could result in few opportunities for firms to obtain external financing (Fungáčová, Shamshur, and Weill, 2017). Finally, the Herfindahl index of industries (*Industry-HHI*) is used to control for the influence of industry concentration.

Table 1 reports the variables definitions used in this paper, including dependent and independent variables.

Table 1

Definition of variables used in the study

Variable	Definition
Ln_Innovation	The firm's value of new product.
Ratio_Innovation	The ratio of the firm's value of new product divided by its output value (%).
BankCR4	The ratio of the big four state-owned commercial bank branches to commercial bank branches.
BankHHI	The Herfindahl index of the big four state-owned commercial bank branches to commercial bank branches.
AssetCR4	The proportion of assets of the big four state-owned commercial banks.
Branches	The logarithm of the number of commercial bank branches.
Size	The firm's total assets.
Age	The number of years the firm has existed since its founding year.
K_L	The firm's fixed assets divided by the number of employees.
Leverage	The firm's debt divided by its total assets.
ROA	The ratio of the firm's profit to its total assets.
Subsidy	Subsidies received by the firm from the government.
Tangibility	The ratio of the firm's tangible fixed assets to its total assets.
Industry-HHI	The Herfindahl index of sales values with four-digit SIC codes between 1310 and 4290.

Note: The data of variable Ln_Innovation, Size, K_L, and Subsidy are logarithmic in the regressions.

4. Data

The sample contains 1279650 firm-year observations for 323871 manufacturing enterprises in China during the period 1998-2011. We obtain the firm-level data from the *Annual Survey of Industrial Enterprise* and the bank branches information from *China Banking and Insurance Regulatory Commission*. Table 2 shows the summary statistics of the variables. Correlation coefficients among independent variables are lower than 0.51, and multi-collinearity is not an issue.

China's banking concentration has decreased substantially in the financial market over the past 30 years, but it remains dominated by state-owned commercial banks. Statistics show that the concentration ratio of banking industry was higher than 0.4 in the most prefecture-level regions in 1994, while the ratio experienced a significant drop until 2017. In 1994, the value of *BranchCR4* was above 0.6 in half of the prefecture-level cities. By 2017, the value of *BranchCR4* was less than 35% in half of the prefecture-level cities.

Table 2

Summary statistics

Variable	Min	Mean	Max	S. D
Ln_Innovation	0.000	12631.610	1.32e+08	352183.700
Ratio_Innovation	0.000	3.329	100.000	14.308
BankCR4	0.000	0.488	0.988	0.181
BankHHI	0.000	0.079	0.923	0.059
AssetCR4	0.000	0.576	1.000	653.062

Variable	Min	Mean	Max	S. D
Branches	0.000	668.940	3400.000	0.244
Size	18.000	99830.200	2.23e+08	944293.200
Age	1.000	9.821	62.000	9.989
K_L	0.226	104.783	1290906.000	1122.495
Leverage	0.000	0.557	0.999	0.257
ROA	-0.399	0.088	0.100	0.153
Subsidy	0.000	221.861	4811285.000	7323.165
Tangibility	0.000	0.336	1.000	0.219
Industry-HHI	0.001	0.035	0.421	0.075

Note: The statistics of Ln_Innovation, Branches, Size, K_L, and Subsidy are the original values.

5. Empirical results

There are three dimensions to measure firms' financing constraints: the dependence of firms on external financing, the cost of firms paying for external financing, and the number of years firms have been operating (Beck *et al.*, 2006; Yuriy and Monika, 2013). If access to loans is a channel through which bank competition impacts firms' innovation activities, the effects of bank competition are more predominant for firms with severe financing constraints. Therefore, we expect that firms that are more external finance dependent and have higher debt cost experience an increase, instead of a decrease, in innovation output when bank competition rises.

5.1. The role of external finance dependence in bank competition affecting innovation output

To test whether firms' dependence on external financing as an underlying mechanism by which bank competition impacts firm innovation, the study investigates this notion through classifying firms relying on whether their external finance dependence exceeds that of firms in the same industry. Specifically, following the measures of external finance dependence provided by previous studies (Bertrand, Antoinette, and David, 2007; Duchin, Ozbas, and Sensoy, 2010; Cornaggia, Mao, Tian, and Wolfe, 2015), we divide the firms into two groups according to whether their dependence on external financing is higher than the median of firms' debt ratio in each four digit-industry, and each group is equal in size. Table 3 presents the results.

The coefficients of *BankCR4* and *BankHHI* on high external finance dependent firms are significantly negative at the 1% and higher in absolute values than these results for low external finance dependent firms. For instance, every 1% decrease in the proportion of big four state-owned commercial bank branches raises innovation outputs by RMB20.442 for high external finance dependence firms in column 1, and every 1% decrease in the proportion of big four state-owned commercial bank branches increases innovation outputs by RMB15.746 for low external finance dependence firms in column 5. Bank competition is positively associated with firm innovation output and this relationship is stronger for high external finance dependent firms than for low external finance dependent firms.

These conclusions are in line with findings of Amore, Schneider and Žaldokas (2013), who observe banking deregulation is beneficial to innovation activities. The effects of bank competition are driven by the relaxation of financing constraints. However, these results do not necessarily indicate that, following bank competition, firms invest in innovation activities directly with bank financing. Firms can use bank funds to invest in non-innovation projects,

and thus these firms could allocate more internal funds to innovation projects. Although financing constraints have significant negative effects on R&D expenditures and innovative sales (Xiang *et al.*, 2019), bank competition promotes firm innovation by promoting their financing capacity.

Table 3

The role of external finance dependence

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Group	High external finance dependence firms				Low external finance dependence firms			
Dependent variable	Ln_Innovation		Ratio_Innovation		Ln_Innovation		Ratio_Innovation	
BankCR4	-0.715***		-2.006***		-0.454***		-1.669***	
	(0.108)		(0.481)		(0.118)		(0.418)	
BankHHI		-1.619***		-4.411***		-1.179***		-4.180***
		(0.313)		(1.203)		(0.348)		(1.339)
Size	0.622***	0.622***	1.695***	1.695***	0.572***	0.572***	1.513***	1.514***
	(0.008)	(0.008)	(0.033)	(0.033)	(0.008)	(0.008)	(0.030)	(0.030)
Age	0.121***	0.121***	0.184***	0.184***	0.085***	0.085***	0.048	0.048
	(0.006)	(0.006)	(0.028)	(0.028)	(0.006)	(0.006)	(0.029)	(0.029)
K_L	-0.199***	-0.199***	-0.260***	-0.260***	-0.189***	-0.189***	-0.217***	-0.217***
	(0.008)	(0.008)	(0.038)	(0.038)	(0.007)	(0.007)	(0.033)	(0.033)
Leverage	-0.300***	-0.300***	-1.289***	-1.288***	0.119***	0.118***	0.148*	0.147*
	(0.020)	(0.020)	(0.104)	(0.104)	(0.018)	(0.018)	(0.086)	(0.086)
ROA	0.434***	0.430***	1.469***	1.458***	0.339***	0.339***	1.464***	1.462***
	(0.033)	(0.033)	(0.149)	(0.149)	(0.025)	(0.025)	(0.114)	(0.114)
Subsidy	0.094***	0.094***	0.306***	0.306***	0.082***	0.082***	0.294***	0.294***
	(0.003)	(0.003)	(0.014)	(0.014)	(0.003)	(0.003)	(0.016)	(0.016)
Tangibility	0.540***	0.540***	0.238	0.236	0.273***	0.273***	-0.857***	-0.857***
	(0.037)	(0.037)	(0.178)	(0.178)	(0.030)	(0.030)	(0.148)	(0.148)
Industry-HHI	0.386***	0.384***	1.298***	1.290***	0.178***	0.177***	0.559**	0.555**
	(0.059)	(0.059)	(0.286)	(0.286)	(0.056)	(0.056)	(0.266)	(0.266)
Regional FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	639825	639825	639825	639825	639825	639825	639825	639825
R²	0.174	0.174	0.093	0.093	0.171	0.171	0.098	0.098

*Note: The statistical inferences are based on standard errors (reported in brackets) clustered by prefecture-level region and four-digit SIC industry. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.*

5.2. The role of debt cost in bank competition affecting innovation output

Competition among banks reduces the borrowing cost of enterprises (Lian, 2018; Li *et al.*, 2020). We expect the effects of bank competition should be stronger for firms with high cost of external financing. We check this notion by classifying firms relying on whether their debt cost is higher than their industry peers. Specifically, we divide the firms into two groups according to whether their debt cost (*i.e.*, the firm's interest expense divided by its total debt) is higher than the median of firms' debt cost: high debt cost firms, and low debt cost firms. Table 4 presents the results.

The coefficients of *BankCR4* and *BankHHI* are significantly negative, thereby suggesting that bank competition has a positive influence on firm innovation output. The finding is consistent with the result showed in Table 3 and is consistent with Tian, Han and Mi (2019), who argue that the intensification of bank competition is related to the innovation efficiency in R&D investment and output. We note that the effect is stronger for firms with high borrowing costs than for firms with low borrowing costs. Compared with the results in columns 5 to 8, the results in columns 1 to 4 show that firms with high debt cost have a higher elasticity of innovation output with respect to bank competition than the elasticity of low debt cost firms. As shown in column 1, every 1% decrease in the proportion of big four state-owned commercial bank branches increases innovation outputs by RMB22.569 for firms with high debt cost. Every 1% decrease in the proportion of big four state-owned commercial bank branches increases innovation outputs by RMB12.523 for firms with low debt cost as shown in column 5. These results suggest that financing costs play an important role in bank competition impacting firms' innovative performance, especially for firms who suffer high financing costs.

Table 4

The role of debt cost

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Group	High debt cost firms				Low debt cost firms			
Dependent variable	Ln_Innovation		Ratio_Innovation		Ln_Innovation		Ratio_Innovation	
BankCR4	-0.814***		-2.657***		-0.225***		-0.754**	
	(0.132)		(0.513)		(0.078)		(0.326)	
BankHHI		-1.953***		-6.057***		-0.555***		-1.964**
		(0.396)		(1.483)		(0.213)		(0.890)
Size	0.691***	0.691***	1.821***	1.821***	0.447***	0.447***	1.233***	1.233***
	(0.009)	(0.009)	(0.033)	(0.033)	(0.007)	(0.007)	(0.029)	(0.029)
Age	0.136***	0.136***	0.235***	0.235***	0.048***	0.048***	-0.064**	-0.064**
	(0.006)	(0.006)	(0.030)	(0.030)	(0.005)	(0.005)	(0.026)	(0.026)
K_L	-0.235***	-0.235***	-0.266***	-0.266***	-0.135***	-0.135***	-0.167***	-0.167***
	(0.009)	(0.009)	(0.039)	(0.039)	(0.006)	(0.006)	(0.030)	(0.030)
Leverage	-0.079***	-0.079***	-0.513***	-0.512***	-0.124***	-0.124***	-0.792***	-0.792***
	(0.020)	(0.020)	(0.103)	(0.103)	(0.015)	(0.015)	(0.078)	(0.078)
ROA	0.453***	0.451***	1.751***	1.744***	0.309***	0.308***	1.313***	1.312***
	(0.032)	(0.032)	(0.134)	(0.134)	(0.025)	(0.025)	(0.121)	(0.121)
Subsidy	0.099***	0.099***	0.348***	0.348***	0.059***	0.059***	0.186***	0.186***
	(0.003)	(0.003)	(0.015)	(0.015)	(0.003)	(0.003)	(0.014)	(0.014)
Tangibility	0.514***	0.513***	-0.198	-0.201	0.191***	0.191***	-0.774***	-0.774***
	(0.038)	(0.038)	(0.178)	(0.178)	(0.026)	(0.026)	(0.135)	(0.135)
Industry-HHI	0.350***	0.346***	1.046***	1.031***	0.187***	0.186***	0.768***	0.767***
	(0.061)	(0.061)	(0.281)	(0.281)	(0.050)	(0.050)	(0.267)	(0.267)
Regional FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	639825	639825	639825	639825	639825	639825	639825	639825
R^2	0.191	0.191	0.104	0.104	0.136	0.136	0.079	0.079

*Note: The statistical inferences are based on standard errors (reported in brackets) clustered by prefecture-level region and four-digit SIC industry. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.*

A possible explanation is that small banks are more willing to provide lower cost loans to firms than large banks in a competitive lending market (Lian, 2018; Li, Fu, Wen, and Chang, 2020), which is conducive to firm innovation. However, some studies argue that increased bank competition increases the external financing costs of firms (Fungáčová, Shamshur, and Weill, 2017).

5.3. The role of firm age in bank competition affecting innovation output

Firms' age provides information about the firms' entry into the market and adjusts the relationship between knowledge maturity and innovation activity. There are two opposite views about the effect of firm age on innovation. Some people argue that old firms are prone to innovate due to the accumulation of knowledge. Others suggest that old firms are less likely to innovate than young firms, since old firms tend to develop a routine. The benefits of R&D expenditures of young firms to firm development are higher than those of old firms (Coad, Segarra, and Teruel, 2016). Young firms can use new knowledge better than old ones (Messeni Petruzzelli, Ardito, and Savino, 2018; Petruzzelli, Ardito, and Savino, 2018). Young firms are effective in transforming R&D into product innovation, while old firms are more effective in translating technological acquisitions into process innovation (Pellegrino and Piva, 2019).

The regressions interpret the potential effect of firms' entry on innovation output, since the time for firms to enter the market may affect their external financing and innovation ability. Therefore, we check whether the effects of bank competition on innovation output differed between old firms and young firms. Specifically, we define firms with no more than 6 years of establishment as young firms and the others as old firms. Note that the median operating life of the sample enterprises is 6 years. Table 5 reports the results.

The coefficients of *BankCR4* and *BankHHI* are significantly negative, which imply that bank competition improves firm innovation output and the effect varies with different firms' age. Specifically, the coefficients of *BankCR4* and *BankHHI* have higher absolute values for young firms than for old firms and reveal that firm innovation is more driven by the increase in firms' entry. Young firms have a higher elasticity of innovation with respect to bank competition than the elasticity of old firms, which aligns with the view that young firms have few opportunities to accumulate internal funds than old firms and thus rely more on external financing.

Table 5

The role of firm age

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Group	Young firms				Old firms			
Dependent variable	Ln_Innovation		Ratio_Innovation		Ln_Innovation		Ratio_Innovation	
BankCR4	-0.604***		-2.086***		-0.527***		-1.696***	
	(0.116)		(0.476)		(0.108)		(0.421)	
BankHHI		-1.464***		-5.237***		-1.315***		-3.747***
		(0.346)		(1.296)		(0.305)		(1.221)
Size	0.427***	0.427***	1.222***	1.222***	0.698***	0.698***	1.827***	1.827***
	(0.007)	(0.007)	(0.032)	(0.032)	(0.008)	(0.008)	(0.031)	(0.031)
Age	0.001	0.001	-0.138***	-0.139***	0.244***	0.244***	0.411***	0.411***
	(0.006)	(0.006)	(0.034)	(0.034)	(0.010)	(0.010)	(0.044)	(0.044)
K_L	-0.137***	-0.137***	-0.179***	-0.179***	-0.203***	-0.203***	-0.183***	-0.183***

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	(0.007)	(0.007)	(0.036)	(0.036)	(0.008)	(0.008)	(0.035)	(0.035)
Leverage	-0.083***	-0.082***	-0.561***	-0.560***	-0.085***	-0.085***	-0.597***	-0.597***
	(0.016)	(0.016)	(0.088)	(0.088)	(0.019)	(0.0194)	(0.093)	(0.093)
ROA	0.289***	0.288***	1.287***	1.280***	0.498***	0.496***	1.777***	1.774***
	(0.024)	(0.024)	(0.122)	(0.122)	(0.034)	(0.034)	(0.133)	(0.133)
Subsidy	0.075***	0.075***	0.272***	0.272***	0.092***	0.092***	0.306***	0.306***
	(0.003)	(0.003)	(0.017)	(0.017)	(0.003)	(0.003)	(0.014)	(0.014)
Tangibility	0.196***	0.196***	-0.567***	-0.569***	0.454***	0.454***	-0.413**	-0.413**
	(0.032)	(0.032)	(0.163)	(0.163)	(0.035)	(0.035)	(0.162)	(0.162)
Industry-HHI	0.225***	0.224***	0.823***	0.816***	0.303***	0.301***	0.960***	0.954***
	(0.052)	(0.052)	(0.272)	(0.272)	(0.064)	(0.064)	(0.284)	(0.284)
Regional FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	610527	610527	610527	610527	669123	669123	669123	669123
R^2	0.130	0.130	0.081	0.081	0.200	0.200	0.108	0.108

Note: The statistical inferences are based on standard errors (reported in brackets) clustered by prefecture-level region and four-digit SIC industry. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

The results might be explained by the fact that obtaining loans is easier in areas where bank competition is high, young firms thus are able to access bank loans easily. Old firms can have easier access to external funds, and they are expected to less respond to changes in bank competition than young firms. By contrast, young firms have shorter loan history than old firms, which decreases young firms' access to external funding from financial institutions. Due to information asymmetry problems, young firms are more likely to suffer financing constraints, which have both direct and indirect effects on firm innovation (Caggese, 2019). On the other hand, Cucculelli (2017) finds that the highly innovative activities of newly entered firms are mainly driven by the innovative tendency of the new chief executive officers.

5.4. The role of firm R&D expenditures in bank competition affecting innovation output

If firm innovate more due to the decline in financial constraints and the intensified competition among banks, we should expect higher R&D expenditures and higher innovation output in which bank competition is intense. We check this notion by classifying firms relying on whether they input more R&D expenditures than their industry peers. We use firms' median of R&D expenditures ratio (*i.e.*, the firms' R&D expenditures divided by its sales) to classify firms into two groups. Table 6 presents the results.

The coefficient estimates of *BankCR4* and *BankHHI* in the observations of innovation output produced by high R&D expenditures firms are negative and significant at 1% or 5% level (in columns 1 to 4), while those in the observations of innovation output generated by low R&D expenditures firms is negative (in columns 5 to 8) and significant (in column 5). The increase in bank competition is stronger for firms with higher R&D expenditures but does not have an impact on innovation output for firms with low R&D expenditures.

The role of firm R&D expenditures

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Group	High R&D expenditures firms				Low R&D expenditures firms			
Dependent variable	Ln_Innovation		Ratio_Innovation		Ln_Innovation		Ratio_Innovation	
BranchCR4	-0.222**		-1.509***		-0.208***		-0.416	
	(0.104)		(0.536)		(0.077)		(0.313)	
BranchHHI		-0.807***		-4.468***		-0.098		-0.284
		(0.291)		(1.377)		(0.198)		(0.874)
Size	0.592***	0.592***	1.654***	1.654***	0.612***	0.612***	1.555***	1.554***
	(0.009)	(0.009)	(0.034)	(0.034)	(0.007)	(0.007)	(0.025)	(0.025)
Age	0.075***	0.075***	0.038	0.037	0.123***	0.123***	0.165***	0.164***
	(0.006)	(0.006)	(0.032)	(0.032)	(0.005)	(0.005)	(0.024)	(0.024)
K_L	-0.187***	-0.187***	-0.293***	-0.292***	-0.199***	-0.199***	-0.136***	-0.135***
	(0.009)	(0.009)	(0.040)	(0.040)	(0.006)	(0.006)	(0.02)	(0.027)
Leverage	-0.076***	-0.076***	-0.626***	-0.627***	-0.113***	-0.114***	-0.572***	-0.573***
	(0.018)	(0.018)	(0.094)	(0.094)	(0.016)	(0.016)	(0.076)	(0.076)
ROA	0.443***	0.443***	1.764***	1.763***	0.431***	0.430***	1.620***	1.621***
	(0.029)	(0.029)	(0.133)	(0.133)	(0.028)	(0.028)	(0.114)	(0.114)
Subsidy	0.095***	0.095***	0.342***	0.342***	0.074***	0.074***	0.214***	0.214***
	(0.003)	(0.003)	(0.015)	(0.015)	(0.003)	(0.003)	(0.013)	(0.013)
Tangibility	0.418***	0.418***	-0.051	-0.051	0.375***	0.375***	-0.675***	-0.676***
	(0.037)	(0.037)	(0.184)	(0.184)	(0.026)	(0.026)	(0.123)	(0.123)
Industry-HHI	0.221***	0.223***	0.745***	0.749***	0.426***	0.426***	1.689***	1.691***
	(0.047)	(0.047)	(0.229)	(0.229)	(0.093)	(0.093)	(0.431)	(0.431)
Regional FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	766124	766124	766124	766124	513526	513526	513526	513526
R^2	0.180	0.180	0.105	0.105	0.169	0.169	0.085	0.085

*Note: The statistical inferences are based on standard errors (reported in brackets) clustered by prefecture-level region and four-digit SIC industry. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.*

5.5. Endogenous test

In order to verify the duration of bank competition to promote firm innovation, this study puts the explanatory variables of lagging two periods and three periods into the models. Table 7 shows that the coefficients of the two-stage lag bank competition variables (*L2.BankCR4* and *L2.BankHHI*) are significantly negative, which indicates that the changes in bank competition still affect the innovation output of enterprises. The estimated coefficients of the three-stage lag bank competition variables (*L3.BankCR4* and *L3.BankHHI*) in column (1) to column (3) failed the significance tests. These results show that the influence of the change in bank competition on the innovation output of enterprises can last for two years, but the effect ceased to exist in the third year.

Relevant agencies disclose the assets data of the state-owned banks at the provincial level in China, but the data on prefecture-level cities were not disclosed. The study investigates whether the main results are robust when the asset concentration, *AssetCR4*, is used as an alternative index of bank competition. In Table 7, the estimation coefficients of *AssetCR4*

are significantly negative, which imply that intensified competition among banks will increase the innovation output of enterprises.

Moreover, this study uses the number of bank branches in each region to measure bank competition. Specifically, *Branches* is the logarithm of the number of commercial bank branches at the prefecture level. Higher value for this competition indicator suggests higher bank competition. The positive coefficients of *Branches* in columns (6) and (8) reveal that setting up branches of banks can promote firm innovation output. Thus, the number of bank branches around firms has positive effect on corporate innovation.

Table 7

Bank competition and firm innovation output

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable	*Ln_Innovation*		*Ratio_Innovation*		*Ln_Innovation*		*Ratio_Innovation*	
L2.BankCR4	-0.084*** (0.041)		-0.627*** (0.204)					
L3.BankCR4	-0.041 (0.042)		0.257 (0.181)					
L2.BankHHI		-0.449*** (0.067)		-1.769*** (0.313)				
L3.BankHHI		0.061 (0.059)		0.528* (0.285)				
AssetCR4					-0.786*** (0.123)		-2.719*** (0.690)	
Branches						0.069*** (0.009)		0.202*** (0.042)
Obs.	756022	756022	756022	756022	1279650	1279650	1279650	1279650
R^2	0.191	0.192	0.109	0.110	0.177	0.172	0.101	0.095

*Note: We do not show the coefficients of control variables. The statistical inferences are based on standard errors (reported in brackets) clustered by prefecture-level region and four-digit SIC industry. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.*

6. Heterogeneity test

6.1. The role of firm size in bank competition affecting innovation output

In order to test whether the impact of bank competition on the innovation output of firms is different among firms of different sizes, we bring the interaction terms of firm size and bank competition into the models.

As shown in Table 8, the coefficients for *BranchCR4×Medium* and *BranchHHI×Medium* are significantly negative, suggesting a higher innovation output in more competitive areas for medium-sized firms as compared to small firms. The coefficients for *BranchCR4×Large* and *BranchHHI×Large* are significantly positive, implying a low innovation output in more competitive areas for large firms as compared to small and medium-sized enterprises. These results reveal that the effect of increasing bank competition on innovation output is stronger for small and medium-sized enterprises than for large enterprises.

The role of firm size

	(1)	(2)	(3)	(4)
Dependent variable	Ln_Innovation		Ratio_Innovation	
BranchCR4	-0.545*** (0.109)		-1.762*** (0.408)	
BranchHHI		-1.363*** (0.320)		-4.259*** (1.171)
Medium	0.320*** (0.013)	0.317*** (0.013)	0.872*** (0.062)	0.863*** (0.062)
Large	2.182*** (0.053)	2.181*** (0.053)	4.951*** (0.211)	4.951*** (0.210)
BranchCR4×Medium	-0.256*** (0.068)		-0.946*** (0.295)	
BranchCR4×Large	0.873*** (0.289)		3.257*** (1.161)	
BranchHHI×Medium		-0.476*** (0.187)		-1.949*** (0.796)
BranchHHI×Large		3.714*** (0.833)		12.88*** (3.313)
Obs.	1279650	1279650	1279650	1279650
R^2	0.178	0.178	0.095	0.095

Note: We do not show the coefficients of control variables. The statistical inferences are based on standard errors (reported in brackets) clustered by prefecture-level region and four-digit SIC industry. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. Medium takes the value of one if a firm is medium-sized firm (assets between 40 million and 400 million yuan) and zero otherwise. Large takes the value of one if a firm is large firm (assets over 400 million yuan) and zero otherwise. This classification standard comes from the "Statistical Method for Dividing Large, Medium and Small Enterprises (Provisional)" (Guo Tong Zi [2003] No.17).

6.2. The role of firm opacity in bank competition affecting innovation output

Another study point is to examine whether the innovation output of enterprises with high opacity is rising when competition among banks increases. Information hypothesis argues that bank competition results in lower innovation for opaque firms, such as small firms. If the information hypothesis applies, the coefficients for the interaction terms between bank competition and firm opacity would be negative and significant. We measure the opacity of the firm by dividing the total assets of the firm by the fixed assets. The higher the index, the opaquer the enterprise is. According to the opacity level of the firm, we classify firms of the sample into three groups of equal size: low opacity firms, medium opacity firms and high opacity firms.

In columns (1) and (2) of Table 9, the coefficients of the interaction terms are significantly negative, which prove that higher innovation output in more competition areas for more opacity firms than for less opacity firms. As high transparency enterprises have easier access to funds, and they face fewer financial constraints and are less affected by bank competition than low transparency enterprises. As shown in columns (3) and (4), the coefficients for interaction terms are negative, but not significant, suggesting the role of bank

competition in promoting the innovation intensity of low-transparency enterprises needs further verification. As competition in the bank market intensifies, banks provide more loans to the opaque firms than before. These results are inconsistent with the finding of Tian and Han (2019); they argue that the innovation of low opacity firms are more sensitive to local bank competition than that of high opacity firms.

<div align="right">**Table 9**</div>

The role of firm opacity

	(1)	(2)	(3)	(4)
Dependent variable	Ln_Innovation		Ratio_Innovation	
BranchCR4	-0.388*** (0.102)		-1.544*** (0.395)	
BranchHHI		-0.865*** (0.303)		-3.417*** (1.127)
Opacity_m	0.256*** (0.008)	0.256*** (0.008)	0.916*** (0.039)	0.913*** (0.039)
Opacity_h	0.420*** (0.012)	0.420*** (0.012)	1.751*** (0.060)	1.756*** (0.059)
BranchCR4×Opacity_m	-0.176*** (0.040)		-0.337* (0.192)	
BranchCR4×Opacity_h	-0.254*** (0.050)		-0.143 (0.252)	
BranchHHI×Opacity_m		-0.390*** (0.107)		-0.650 (0.498)
BranchHHI×Opacity_h		-0.798*** (0.136)		-0.821 (0.666)
Obs.	1279650	1279650	1279650	1279650
R^2	0.126	0.126	0.080	0.080

Note: We do not show the coefficients of control variables. The statistical inferences are based on standard errors (reported in brackets) clustered by prefecture-level region and four-digit SIC industry. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. *Opacity_m* takes the value of one if the firm belongs to medium opacity firms and zero otherwise. *Opacity_h* takes the value of one if the firm belongs to high opacity firms and zero otherwise.

7. Conclusions

In this study, we use a cross-prefecture-level regions sample of firms from China over the period 1998 to 2011 and investigate the effect on firm innovation of the changes in branches market shares resulted from bank competition. We find a positive relation between bank competition and firm innovation output. Specifically, the effect is stronger for firms with high dependence on financing, high financing cost, and short time since establishment. As expected, dependence on external finance and borrowing costs are underlying mechanisms via which bank competition impacts firms' innovation performance. The decline in market share of state-owned banks and the establishment of banks branches increase the innovation output of enterprises. The influence is driven by small enterprises, opaque enterprises and enterprises with large R&D investment. These results reveal that firms facing severe financing constraints benefit more from bank competition than firms that have easier access to funds. Similarly, Lian (2018) find that the effect of bank competition on firms facing more financial constraints is higher than that of firms with less financial constraints.

These conclusions have important policy implications, especially for the current slowing down of economic growth in the developing countries. Bank competition expands access to credit for these firms and alleviates their financing constraints, which promotes firms to invest in innovation projects. Moreover, the high non-performing loan ratio of state-owned banks, which still dominate China's financial market, is a thorny issue (Berger, Hasan, and Zhou, 2009). Therefore, promoting bank competition is a prerequisite to increasing firm innovation and reducing credit discrimination at both macro and micro levels. First, it strengthens the competition among banks and reduces the operating threshold and industry barriers of small and medium-sized financial institutions. Secondly, building a fair business environment is the institutional guarantee to improve enterprise's willingness and ability to innovate, which requires strengthening the transparency of enterprise information and the construction of the rule of law, and eliminating the unfair treatment of small and micro enterprises and private enterprises in the financing market.

In addition, state ownership may result in low innovation performance as a result of debt guarantee and inefficient incentive mechanism, suggesting that the effect of state ownership on credit allocation and firm innovation may be a new research issue.

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