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Article

Do major customers promote firms' innovation?

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journal homepage: www.elsevier.com/locate/cjarDo major customers promote firms' innovation?[☆]Jinsong Tan^{a,b}, Huijuan Cao^b, Xiangting Kong^{b,*}^a Center for Accounting, Finance and Institutions, Sun Yat-sen University, China^b Business School, Sun Yat-sen University, China

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ABSTRACT

This study examines whether and how a concentrated supply chain relationship affects a firm's innovation decisions. Using data from Chinese listed firms in the manufacturing industry, we find that a concentrated customer base constrains a firm's R&D investment, where a 1% increase in customer concentration is associated with a 0.011% decrease in R&D investment. To establish causality, we use the instrumental variable method, the reverse causality model, and the Granger causality test to re-examine the relationship and arrive at a consistent conclusion. Results from mechanism analysis suggest that a concentrated customer base constrains the internal fund availability and that the negative relationship between customer concentration and firms' innovation is less pronounced for firms with more external financial support. Additional analysis reveals that the negative effect of customer concentration mainly affects R&D investment expenditure and that customer concentration also constrains innovation output in China. Overall, our paper reveals the dark side of close customer-supplier relationships and provides new insights into how supply chain relationships affect firms' innovation decisions.

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1. Introduction

An economy's long-term growth prospects reflect its potential for innovation (Kung and Schmid, 2015). Innovation is especially critical in emerging countries. China is a large manufacturing country and is known as the “world's factory.” However, China is still at the lower end of the value chain. In many cases, only the labor-intensive parts of production, such as processing and packaging, are done in China. For example, with a retail price of US\$1149, the total manufacturing cost of the iPhone X (256G) is US\$412.75. China (excluding Taiwan) mainly provides low-cost components, such as wireless charging receivers, acoustics, RF antennas, and accessories, all of which amount to about US\$75, a price that also includes the artificial remuneration of Chinese workers, estimated at about US\$3.¹ Innovation is thus the guideline for transforming China's manufacturing industry from large to powerful. The promotion of manufacturing innovation thus becomes an important issue, both in practice and in academic research. A growing literature links various factors to innovation, such as the effect of property protection (Long, 2010), financial development (Acharya and Xu, 2017), and industrial policies or corporate governance mechanisms (Manso, 2011; Aghion et al., 2013). However, in a context where the scale of the manufacturing industry is constantly increasing, little is known about whether and how supply chain relationships affect a firm's innovation-related decisions.

In this paper, we focus on the key ingredient of supply chain relationships: the concentration. In a concentrated supply chain relationship, firms often need to meet customized requirements of large customers through specific R&D investments to reap the benefits of supply chain integration, reduce costs, and enhance product competitiveness (Chu et al., forthcoming; Dou et al., 2013; Nunn, 2007). For example, manufacturers of automotive parts must always develop dedicated production lines to provide customized parts, while software companies require dedicated software or operating systems for different platforms, such as Apple iOS and Google Android.

However, like other relationship-specific investments, R&D costs can trigger a classic “hold-up problem.” Firms in countries with inadequate legal protections typically underinvest, as contracts cannot be enforced (Grossman and Hart, 1986; Nunn, 2007; Williamson, 1979). More importantly, financing innovation is a challenge for most firms, because innovation activities are risky, unpredictable, long-term, and multi-stage, all of which leads to severe information asymmetry and high agency costs (Holmstrom, 1989). Hence, R&D activities generally lead to difficulty in obtaining external funding. Previous evidence shows that internal funds are a primary resource for R&D activities (Czarnitzki and Hottenrott, 2011; Hall, 2002). However, having major customers can also limit a firm's internal cash flow. Major customers use their bargaining power to obtain favorable terms, such as lower product pricing or more trade credit, resulting in lower profitability and higher earnings and cash flow volatility (Fabbri and Klapper, 2016; Huang et al., 2016; Itzkowitz, 2013). In short, a concentrated customer base can lead to internal financial constraints and therefore underinvestment in R&D.

We test the above two competing hypotheses by examining whether customer concentration encourages or hinders firms' R&D investment. Using data from Chinese listed firms in the manufacturing industry, we document that a concentrated customer base constrains a firm's R&D investment. A 1% increase in customer concentration is associated with a 0.011% decrease in R&D investment. To establish causality, we use the instrumental variable method, the reverse causality model, and the Granger causality test to re-examine the relationship, and we arrive at a consistent conclusion. However, the relationship is less pronounced for firms with more external financial support. Furthermore, the negative effect of customer concentration mainly affects R&D investment expenditure. We also provide evidence that customer concentration limits R&D output.

This paper contributes to three strands of literature. First, it relates to research examining the real effects of supplier-customer relationships on R&D investment. Most studies focus on how supply chain relationships affect financial decisions, including capital structure (Banerjee et al., 2008), dividend policy (Wang, 2012), equity financing (Dhaliwal et al., 2016), debt financing (Campello and Gao, 2017), and so on. However, there is a literature gap on how supplier-customer relationship affects corporate investment behavior. Chu et al. (forthcoming) and our paper are both related to this topic. Chu et al. (forthcoming) examines the effect of

¹ See the website http://www.sohu.com/a/200592527_100030976.

supplier-customer geographic proximity on R&D output. Proceeding from the notion that being closer to customers makes communication more efficient, they document that the timely feedback and the demand to decrease production costs from the geographically closer customers can motivate suppliers to innovate. Compared to [Chu et al. \(forthcoming\)](#), our paper focuses on a different dimension of supplier-customer relationships and applies a different theoretical framework to examine how supplier-customer relationship affects corporate innovation. We document that concentrated customer bases constrain the availability of internal funds and impede suppliers' R&D input, an outcome that has traditionally been understood to be the product of a poorly functioning legal system where contracts cannot be enforced ([Grossman and Hart, 1986](#); [Nunn, 2007](#); [Williamson, 1979](#)).

Second, our paper contributes to the emerging literature on finance and innovation. R&D investment activity is generally associated with high agency costs. Innovation projects are usually risky, unpredictable, long-term, labor-intensive, and idiosyncratic ([Holmstrom, 1989](#)). Agency problems associated with separate ownership and management may undermine firm incentives to innovate ([Bernstein, 2015](#)). Therefore, determining appropriate mechanisms to motivate or incentivize innovation is an important research topic. [Manso \(2011\)](#) proposes an optimal innovation incentive scheme that favors tolerance for early failure and rewards long-term success. Indeed, analysts often exert too much pressure on managers to meet short-term performance goals, which hinders managers' incentives to create long-term value for the firm ([He and Tian, 2013](#)). Instead, institutional owners motivate managers by reducing career risk ([Aghion et al., 2013](#)). However, while motivation is important, it is not enough. Being heavily dependent on financing, an adequate financial resource is essential for R&D investment. Firms with innovation opportunities often lack capital ([Acharya and Xu, 2017](#)). Therefore, the roles of internal financing, external financing, and in particular, equity and debt financing are also discussed. Our paper supports the hypothesis that internal cash flow plays a leading role in R&D investment.

Third, our paper contributes to research on the consequences of customer-concentration risk. Our study identifies the exact mechanism by which a concentrated customer base influences firm's innovation, thereby helping both firms and investors optimize their strategies by understanding how downstream enterprises influence firm's investment decisions.

The rest of the paper is organized as follows. Section 2 reviews the literature and develops our hypothesis. Section 3 describes the sample and model construction. Section 4 presents the baseline results and various tests to address endogeneity problems, and examines the possible underlying mechanisms. Finally, Section 5 concludes the paper.

2. Theory and hypothesis

In this section, we develop arguments for how downstream businesses influence a firm's R&D investment decisions. We propose two hypotheses: the relationship-specific investment hypothesis and the financial-pressure hypothesis. However, weak legal environments may impede firms' ability to make relationship-specific investments. We therefore predict that in China, the financial-pressure hypothesis dominates and concentrated customers restrict firms' R&D investment. This restricting effect will diminish if the firm has access to external financial resources.

2.1. The positive relationship between customer concentration and R&D input: the relationship-specific investment hypothesis

In a close supply chain relationship, a firm's dealings with its major customers often entails relationship-specific investments, including R&D ([Bowen et al., 1995](#); [Chu et al., forthcoming](#); [Raman and Shahrur, 2008](#)). Relationship-specific investments support transactions between the firm and its stakeholders. These investments are relationship-specific because the value derived from their use outside the relationship is less than within the relationship ([Bowen et al., 1995](#)). Such specialized investments are usually customized to meet customers' proprietary needs. Relationship-specific investments also contribute to products' uniqueness, which makes it difficult for downstream enterprises to obtain substitute products from the market ([Holmstrom and Roberts, 1998](#)). Close cooperation along the supply chain increases the customer's

stickiness. Further, the stable customer-base will improve efficiency and create more value for the firm (Patatoukas, 2012; Irvine et al., 2015).

R&D investment is necessary to meet customers' proprietary needs, increase products' uniqueness, and improve market competitiveness (Chu et al., forthcoming; Dou et al., 2013; Nunn, 2007). Indeed, the intensity of R&D expenditure is often used in the empirical literature as a proxy for asset specificity (Kale and Shahrur, 2007). Bowen et al. (1995) use R&D expenses to measure this kind of investment. Raman and Shahrur (2008) use R&D intensity of a firm's suppliers and customers to measure the importance of relationship-specific investments. In the automotive industry, auto part suppliers often customize production lines to supply specific car parts, depending on their customers' requirements, and in the mobile phone industry, Foxconn announced plans to invest US\$270 million in R&D for specialized optical lens, glass, and metal processing equipment to complete Apple's orders of iPhone 8 and iPhone X.

To maintain stable and integrated relationships with major customers, firms have an incentive to produce customized products and improve product uniqueness, and R&D investment is essential to achieving these outcomes. This is what we refer to as the **relationship-specific investment hypothesis**. Under this hypothesis, having a concentrated customer base motivates firms to invest more in R&D.

2.2. The negative relationship between customer concentration and R&D input: the financial-pressure hypothesis

By the same token, a concentrated customer base also constrains firms' internal finances. First, faced with major customers, the firm has weak bargaining power. Hence, the firm is more likely to make a series of concessions during business negotiations, such as providing a lower product price and extending trade credit (Fabbri and Klapper, 2016; Porter, 1989). Second, the firm risks losing anticipated cash flows if the customer goes bankrupt (Dhaliwal et al., 2016). If one customer represents a large portion of a firm's sales, then the loss of that customer will result in a large adverse cash flow shock and cause severe financial distress (Itzkowitz, 2013). Third, firms with concentrated customer base also face contagion risk along the supply chain, when downstream distress "spills over" and transmits real costs to upstream businesses (Jorion et al., 2009; Kolay et al., 2016; Pandit et al., 2011). For instance, Kolay et al. (2016) find that firms with economically distressed customers experience large losses in market value and increased sales, general, and administrative expenses. Jorion et al. (2009) further provide evidence of credit contagion from counterparty risk. After a counterparty goes bankrupt, the credit rating of the firm also declines at the same time, and the probability of bankruptcy increases. As a result, firms in such relationships are likely to hold onto additional cash as a precautionary measure (Itzkowitz, 2013; Huang et al., 2016), rather than make risky R&D investments.

R&D investment depends on abundant financial support. Compared with general investment, the external financing costs associated with R&D are higher (Czarnitzki and Hottenrott, 2011; Hall, 2002; Holmstrom, 1989). First, the R&D process is long and has uncertain outputs. Considerable input does not necessarily lead to equal advantageous outcomes. Establishing an R&D program may involve significant sunk costs and trigger additional adjustment spending. Second, the collateral value of R&D investment is low, as most input consists of wages for R&D employees rather than tangible assets. Third, to protect asset specificity, the R&D process must be kept secret. Information asymmetries between investors and managers create additional uncertainties. Moreover, high external financing costs lead to financing gaps and underinvestment. As a result, internal financing becomes the principal determinant of R&D investment (Himmelberg and Petersen, 1994), with cash flow volatility resulting in decreased R&D expenditure (Minton and Schrand, 1999).

From the discussion above, financial pressure from a concentrated customer base limits firms' R&D investment. This is the **financial-pressure hypothesis**.

2.3. China: the financial-pressure hypothesis dominates

Relationship-specific investment can trigger a "hold-up problem" for firms in countries with inadequate legal protections. Given that the value of specialized investment decreases outside of the supplier-customer relationship (Dou et al., 2013), if that relationship breaks down, then the investment becomes a sunk cost. When a contract is incomplete in a context where contract enforceability is weak, customers are likely to have more bargaining power. To protect and maintain the relationship, supplier firms must accept more oppressive

clauses. In the economics literature, this is commonly referred to as the hold-up problem, as underinvestment occurs when contracts cannot be enforced (Grossman and Hart, 1986; Nunn, 2007; Williamson, 1979). Nunn (2007) finds that the intensity of relationship-specific investment is positively associated with judicial quality and contract enforcement. In the case of China, legal institutions are weak. In fact, until recently, many important economic laws were missing or incomplete. More importantly, current laws are rarely enforced effectively. The absence of judicial independence and a lack of qualified legal professionals are the major causes. In 2005, there was one lawyer for every 9000 people, while this ratio is 1:300 in the United States. According to the World Bank's 2001 Investment Climate Survey on 1500 Chinese firms, most disputes with customers are settled through negotiations between firms rather than through the formal court system (Long, 2010). In such a legal environment, Chinese firms have little incentive to engage in relationship-specific R&D investment because of the hold-up problem.

In summary, a well-functioning legal system and abundant financial resources are both prerequisites for R&D investment. In China, legal institutions are still weak. Moreover, in a close supply chain, the financial resources necessary for investing in R&D activities are restricted both by the pressure from downstream businesses and by the precautionary incentive to hold onto more cash. The above discussion leads to our baseline hypothesis.

Hypothesis 1. There is a negative relationship between customer concentration and firm's R&D investment.

3. Data and methodology

3.1. Data and sample

Our sample consists of manufacturing industry firms listed on the main board of the Chinese A-share market during the period from 2011 to 2015. We limit our sample to the manufacturing industry because the characteristic of the supply chain is more evident than service industries. To measure innovation activities, we collect firm-year R&D investment data from the Wind database. In addition, financial data are obtained from the China Security Market and Accounting Research (CSMAR) database.

We implement the following process for sample selection. First, we exclude firms that suffer from financial losses in two consecutive fiscal years (ST firms). Second, we drop firms listed in the current year. Finally, we eliminate samples with missing values in the model estimation. Our final sample includes 1984 firm-year observations. All continuous variables are winsorized at the 1st and 99th percentile.

3.2. Model and variable definition

We construct model (1) to assess whether customer concentration affects R&D investment.

$$RD_{i,t} = \alpha_0 + \alpha_1 Concentration_{i,t} + \sum \alpha_j Control_{i,t} + \theta_{i,t} \quad (1)$$

where i indexes firm and t indexes year. RD is the R&D input deflated by the total assets. *Concentration* is the sales fraction of a firm's top 5 customers. *Control* variables include finance- and governance-related variables that influence both the firm's R&D investment and customer concentration. The set of control variables includes firm size (*Size*), debt levels (*Lev*), operating performance (*ROA*), cash holding (*Cash*), revenue growth (*Growth*), growth prospect (*TobinQ*), listed years (*Age*), analyst following (*Analyst*), and institutional ownership (*Ins*). We also control the industry and year-fixed effect in the model. Our key variable of interest is *Concentration*. Based on Hypothesis 1, we expect the coefficient of *Concentration* in model (1), α_1 , to be negative. The definitions of all variables are presented in Appendix A.

3.3. Descriptive statistics

Panel A of Table 1 presents the summary statistics. The average sales to top-five customers account for 25.440% of firms' total revenue. The ratio of R&D spending over the total assets is 1.722%. Panel B shows

Table 1
Descriptive statistics of main variables.

Variables	N	Mean	Median	P25	P50	P75
Panel A: Total sample						
<i>RD (%)</i>	1984	1.722	1.419	0.598	1.442	2.483
<i>Concentration (%)</i>	1984	25.440	17.830	12.640	20.380	32.660
<i>AR (%)</i>	1984	10.810	9.504	3.627	8.261	15.120
<i>TurnPeriod</i>	1984	62.970	66.630	18.450	45.090	82.860
<i>PM</i>	1984	0.232	0.162	0.128	0.194	0.289
<i>OCF (%)</i>	1984	4.984	6.458	0.988	4.560	8.874
<i>Size</i>	1984	22.530	1.161	21.740	22.350	23.220
<i>Lev (%)</i>	1984	48.820	18.100	35.960	49.180	62.720
<i>ROA (%)</i>	1984	4.200	5.449	0.897	2.975	6.676
<i>Age</i>	1984	2.455	0.642	2.398	2.639	2.833
<i>Cash (%)</i>	1984	14.410	10.260	7.185	11.980	18.860
<i>Growth (%)</i>	1984	9.510	26.950	−4.943	6.149	18.480
<i>Analyst</i>	1984	1.633	1.181	0.693	1.609	2.639
<i>Ins (%)</i>	1984	46.020	20.420	31.450	46.380	61.530
<i>TobinQ</i>	1984	1.996	1.114	1.250	1.653	2.343
	Low concentration		High concentration		Difference	
	N	Mean	N	Mean		
Panel B: Comparison of firms with different level of customer concentration						
<i>RD (%)</i>	990	1.845	994	1.601	0.244 ^{***}	
<i>Concentration (%)</i>	990	13.062	994	37.766	−24.705 ^{***}	
<i>AR (%)</i>	990	10.312	994	11.305	−0.993 ^{**}	
<i>TurnPeriod</i>	990	58.372	994	67.555	−9.183 ^{***}	
<i>PM</i>	990	0.242	994	0.221	0.021 ^{***}	
<i>OCF (%)</i>	990	5.411	994	4.560	0.852 ^{***}	
<i>Size</i>	990	22.828	994	22.232	0.597 ^{***}	
<i>Lev (%)</i>	990	50.265	994	47.380	2.885 ^{***}	
<i>ROA (%)</i>	990	4.718	994	3.683	1.035 ^{***}	
<i>Age</i>	990	2.446	994	2.463	−0.017	
<i>Cash (%)</i>	990	14.258	994	14.566	−0.309	
<i>Growth (%)</i>	990	9.152	994	9.867	−0.715	
<i>Analyst</i>	990	1.834	994	1.432	0.403 ^{***}	
<i>Ins (%)</i>	990	48.019	994	44.032	3.987 ^{***}	
<i>TobinQ</i>	990	1.847	994	2.145	−0.298 ^{***}	

This table presents summary statistics for variables. Panels A and B present summary statistics for the total sample and subsample. The *Low concentration* and *High concentration* subsamples are determined by whether the ratio of sales to top-five customers over the total sales (which is the definition of *Concentration*) is higher the median value in the same 2-digit CSRC industry in the same year. If the ratio is higher, then the firm-year observation belongs to the *High concentration* subsample; otherwise, it belongs to the *Low concentration* subsample. Continuous variables are winsorized at their 1st and 99th percentiles. See [Appendix A](#) for definitions of all variables. The superscripts ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

that firms with more concentrated customer bases invest less in R&D. However, these firms provide about 0.993% more trade credit (*AR*) to their downstream enterprises and have a longer collection period (*TurnPeriod*), around 9 days on average. The average profit margin (*PM*) decreases from 24.200% to 22.100% as customer concentration increases. *ROA* and the ratio of operating cash flow over the total assets (*OCF*) are also significantly reduced by 1.035% and 0.852%, respectively. Overall, firms with more concentrated customers have lower operating profits. To reduce concentrated customers' operating risk, firms prefer to maintain lower leverage ([Banerjee et al., 2008](#)). In our sample, the average leverage (*Lev*) for high-customer-concentration firms is 47.380%, while this ratio is 50.265% for low-customer-concentration firms.

[Fig. 1](#) shows the evident relationship between customer concentration and R&D investment. In [Fig. 1](#), the horizontal axis represents the decile of customer concentration. A higher value means a more concentrated

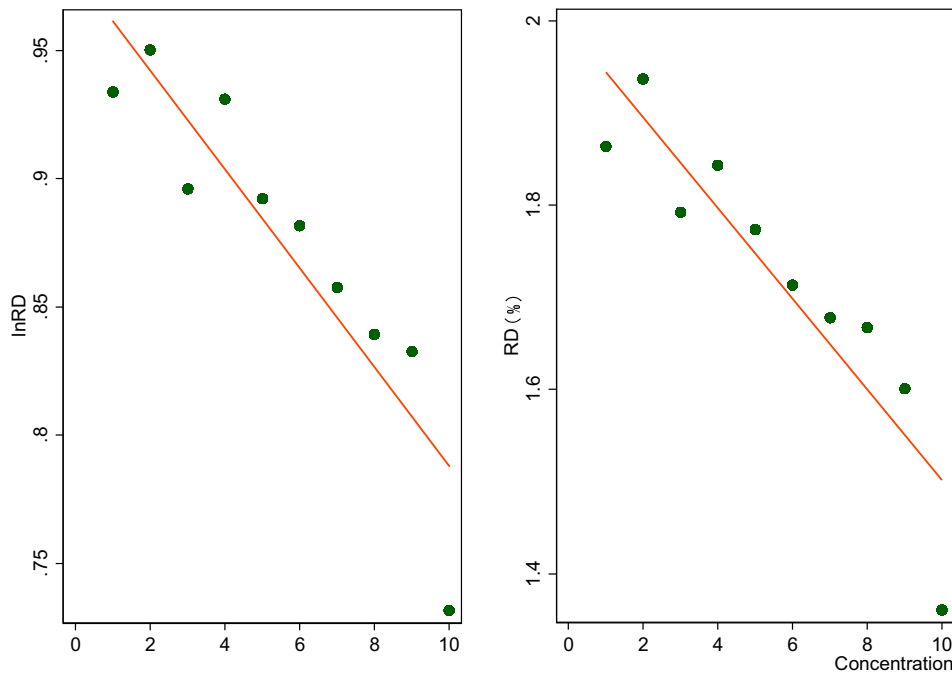


Fig. 1. Customer concentration and R&D investment.

customer base. The vertical axis represents absolute R&D spending and asset-adjusted R&D spending. With an increase in customer concentration, R&D investment shows a significant downward trend. When customer concentration reaches its highest level, R&D spending is at its lowest. This provides preliminary statistical evidence to support Hypothesis 1.

Fig. 2 reveals the mechanism by which a concentrated customer base negatively influences firms' R&D investment; this represents the internal financial pressure exerted by a concentrated customer base. Fig. 2 illustrates that several aspects closely related to the customer base, such as profit margin (*PM*), credit policies (*AR* and *TurnPeriod*), and operating cash flow (*OCF*), exert a negative influence on R&D expenditure. First, lower product prices for major customers directly reduce firms' profits and potential cash flow. As customer concentration increases, the profit margin decreases. Moreover, major customers not only benefit from preferential product prices, but also from a flexible credit policy, further affecting firms' current cash flow. The higher the customer concentration, the more trade credit for customers and the longer the collection period. When concentration is at its highest, corporate accounts receivable accounts for up to 11.5% of total assets. Firms not only provide major customers a large amount of commercial credit, but also extend their credit collection period. For major customers, the collection period can last up to 75 days at the highest level. Finally, both preferential prices and flexible credit policies lead to limited operating cash flow. Fig. 2 shows that the higher the customer concentration, the less cash flow from operating activities. In summary, Fig. 2 indicates that the presence of major customers constrains firms' internal financing ability, thereby limiting R&D investment.

Table 2 provides the correlations between variables. The negative correlation between *Concentration* and *RD* shows that firms with high customer concentration make less R&D investment, as hypothesized earlier. In addition, consistent with prior research findings, customer concentration is negatively correlated with liability level (Banerjee et al., 2008) and positively correlated with trade credit (Fabbri and Klapper, 2016). The correlation coefficients of explanatory variables in the regression model remain below 0.5, which suggests that our regression model presents no serious multicollinearity problem.

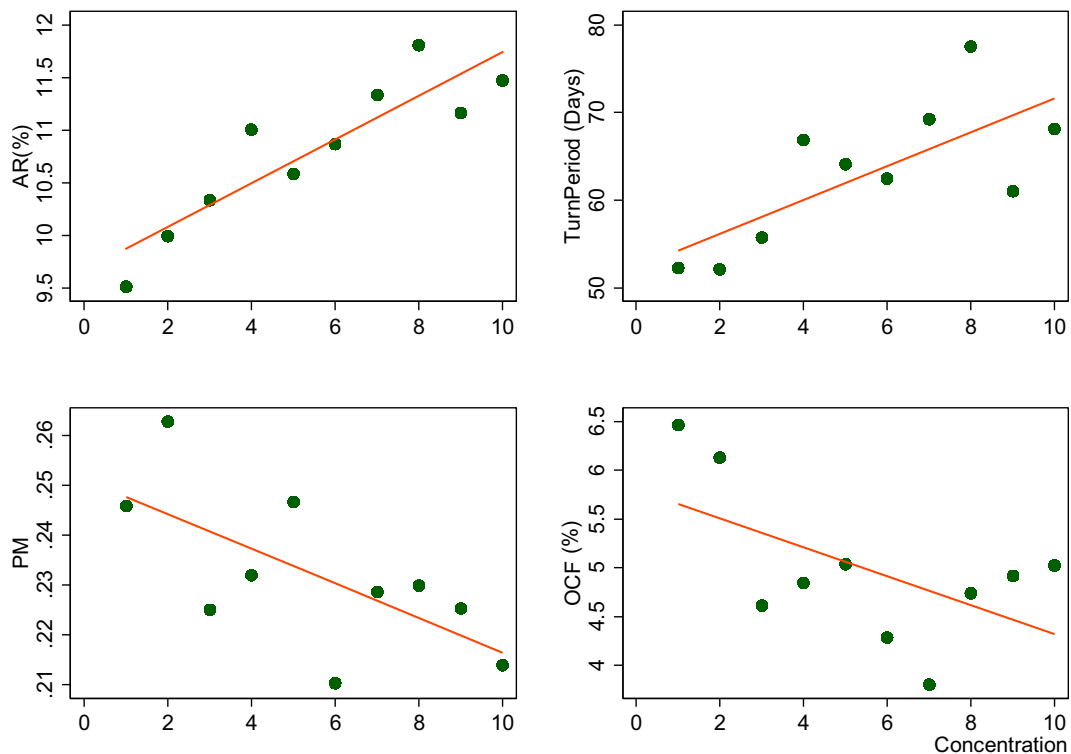


Fig. 2. Customer concentration and internal finance of firm.

4. Empirical results

4.1. Baseline empirical results: customer concentration and R&D investment

We begin our empirical analysis by examining whether a concentrated customer base affects a firm's R&D investment. Table 3 presents the results of this analysis.

Column (1) shows that there is a negative and statistically significant relationship between customer concentration and R&D investment. Column (2) considers all of the control variables in model (1). The relationship remains significantly negative. In terms of economic significance, the coefficient estimate of *Concentration* in Column (2) implies that a 1% increase in customer concentration is associated with a 0.011% decrease in R&D investment.

Regarding control variables, firms that are smaller, institutionally owned, more profitable, and have more analysts following them are more innovative. Consistent with previous findings, analyst coverage decreases information asymmetry and thus increases the firm's R&D investment (Derrien and Kecskes, 2013). Institutions are sophisticated investors that play a monitoring role in reducing pressure for myopic performance (Bushee, 1998; Aghion et al., 2013).

4.2. Test of causality

We argue that the direction of causality is from the customer concentration to the firm's decision to invest in R&D. Nevertheless, it is possible that the lack of market competitiveness due to less R&D investment leads to a more concentrated customer base. Also, there may be some unobservable variables that affect both customer concentration and corporate R&D investment. To establish the causal relation between customer concentration and R&D investment, we use three methods to re-examine the relation: the instrumental variable method, the reverse causality test, and the Granger test.

Table 2
Correlation matrix.

	<i>RD</i>	<i>Concentration</i>	<i>AR</i>	<i>TurnPeriod</i>	<i>PM</i>	<i>OCF</i>	<i>Size</i>	<i>Lev</i>	<i>ROA</i>	<i>Age</i>	<i>Cash</i>	<i>Growth</i>	<i>Analyst</i>	<i>Ins</i>
<i>RD</i>	1.000													
<i>Concentration</i>	−0.033	1.000												
<i>AR</i>	0.297***	0.063***	1.000											
<i>TurnPeriod</i>	0.099***	0.083***	0.787***	1.000										
<i>PM</i>	0.083***	−0.062***	0.005	0.057**	1.000									
<i>OCF</i>	0.121***	−0.066***	−0.200***	−0.273***	0.289***	1.000								
<i>Size</i>	−0.058***	−0.283***	−0.120***	−0.104***	−0.118***	0.060***	1.000							
<i>Lev</i>	−0.140***	−0.087***	0.083***	0.028	−0.398***	−0.185***	0.408***	1.000						
<i>ROA</i>	0.192***	−0.090***	0.001	−0.151***	0.618***	0.469***	0.027	−0.433***	1.000					
<i>Age</i>	−0.058***	0.004	−0.075***	−0.128***	−0.007	0.021	0.012	0.155***	−0.072***	1.000				
<i>Cash</i>	0.098***	0.028	−0.059***	−0.051**	0.164***	0.174***	−0.047**	−0.273***	0.258***	−0.105***	1.000			
<i>Growth</i>	0.015	0.015	0.045**	−0.102***	0.144***	0.042*	0.051**	0.028	0.295***	0.002	−0.003	1.000		
<i>Analyst</i>	0.146***	−0.190***	−0.065***	−0.153***	0.288***	0.258***	0.483***	−0.045**	0.508***	−0.097***	0.080***	0.180***	1.000	
<i>Ins</i>	0.057**	−0.101***	−0.072***	−0.134***	0.125***	0.150***	0.301***	0.088***	0.230***	0.157***	0.062***	0.059***	0.351***	1.000
<i>TobinQ</i>	0.109***	0.163***	0.050**	0.036	0.462***	0.182***	−0.390***	−0.409***	0.385***	0.030	0.189***	0.072***	0.060***	0.088***

This table reports the Pearson correlations between variables. Continuous variables are winsorized at their 1st and 99th percentiles. See [Appendix A](#) for definitions of all variables. The superscripts ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 3
Customer concentration and R&D investment.

	<i>RD_{i,t}</i>	
	(1)	(2)
<i>Concentration_{i,t}</i>	−0.010*** (−5.624)	−0.011*** (−6.600)
<i>Size_{i,t}</i>		−0.310*** (−8.118)
<i>Lev_{i,t}</i>		−0.001 (−0.640)
<i>ROA_{i,t}</i>		0.038*** (5.041)
<i>Age_{i,t}</i>		−0.056 (−1.199)
<i>Cash_{i,t}</i>		−0.003 (−1.003)
<i>Growth_{i,t}</i>		−0.000 (−0.318)
<i>Analyst_{i,t}</i>		0.235*** (6.837)
<i>Ins_{i,t}</i>		0.005*** (2.820)
<i>TobinQ_{i,t}</i>		−0.057 (−1.325)
<i>Constant</i>	1.785*** (8.930)	8.400*** (9.495)
Observations	1984	1984
Adjusted R ²	0.154	0.235
F	37.34	33.53

This table reports results from OLS regressions relating R&D investment to customer concentration and control variables. *Concentration* is the ratio of sales to top-five customers over the total sales. *RD* is R&D investment scaled by total assets at the end of the year. Continuous variables are winsorized at their 1st and 99th percentiles. Robust t-statistics are in parentheses. See [Appendix A](#) for definitions of all variables. The superscripts ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

4.2.1. Instrumental variable method

Specifically, instrumental variables must satisfy two conditions to be considered valid instruments ([Larcker and Rusticus, 2010](#)). First, the relevance condition requires instrumental variables to be correlated with customer concentration measures. Second, the exclusion restriction stipulates that these variables should be uncorrelated with the error term after controlling for the set of control variables in our main model specification. As a result, instruments are correlated with a firm's R&D investment only through their correlations with customer concentration measures.

We select two-year (*Concentration_{i,t-2}*) and three-year (*Concentration_{i,t-3}*) lagged variables as our instrumental variables. First, customer concentration remains relatively stable, to some extent. Therefore, there is a correlation between current customer concentration and previous levels. Furthermore, the two-year and three-year lagged customer concentration maybe irrelevant to the current R&D investment. Therefore, *Concentration_{i,t-2}* and *Concentration_{i,t-3}* are uncorrelated with $\theta_{i,t}$ in model (1).

Column (1) in [Table 4](#) presents the first-stage results obtained by regressing customer concentration measures on our selected instrumental variables and the set of control variables used in model (1). We perform various tests that demonstrate that our selected instrumental variables are valid. First, the high Shea's partial R² of our instruments implies that our results do not suffer from the weak instrument problem. Then, the Hansen J test shows that the null hypothesis that our selected instruments are uncorrelated with the error term cannot be rejected, which implies that the instruments meet the exclusion restriction requirement. The second-stage results in Column (2) show a negative relation between customer concentration and firm's

Table 4
Instrumental variables regression.

Dependent Variable=	First stage $Concentration_{i,t}$ (1)	Second stage $RD_{i,t}$ (2)
$Concentration_{i,t-2}$	0.712*** (17.778)	
$Concentration_{i,t-3}$	0.152*** (3.939)	
$Fit_Concentration_{i,t}$		−0.014*** (−5.831)
$Size_{i,t}$	−1.020*** (−2.922)	−0.333*** (−7.056)
$Lev_{i,t}$	0.039** (2.044)	−0.003 (−1.222)
$ROA_{i,t}$	−0.105 (−1.456)	0.043*** (4.692)
$Age_{i,t}$	0.196 (0.252)	−0.373*** (−3.135)
$Cash_{i,t}$	0.001 (0.044)	−0.008** (−2.044)
$Growth_{i,t}$	−0.013 (−0.907)	0.000 (0.147)
$Analyst_{i,t}$	0.235 (0.663)	0.199*** (4.485)
$Ins_{i,t}$	0.038** (2.399)	0.004* (1.831)
$TobinQ_{i,t}$	0.134 (0.392)	−0.010 (−0.176)
Constant	17.008** (2.185)	9.313*** (8.208)
Observations	1286	1286
Adjusted R2	0.736	0.247
F	107.2	22.86
Weak identification test		
Shea's partial R2		0.690
Hansen J Test		
Chi-sq(1) P-value		0.117
Wu-Hausman F-statistic		48.420 (p = 0.002)

This table reports results from 2-Stage Least Squares regressions relating R&D investment to customer concentration using instrumental variables. The instrumental variables for $Concentration_{i,t}$ are the two-year ($Concentration_{i,t-2}$) and three-year ($Concentration_{i,t-3}$) lagged values of $Concentration_{i,t}$. The first-stage regression results are presented in column (1), and the second-stage results are in column (2). Continuous variables are winsorized at their 1st and 99th percentiles. Robust z-statistics and t-statistics are in parentheses in column (1) and (2) respectively. See [Appendix A](#) for definitions of all variables. The superscripts ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

R&D investment. Specifically, to the extent that our instruments are valid, the Wu-Hausman test rejects the null hypothesis that our customer concentration measures are exogenous. As a result, the instrumental variable method is required, and we obtain a consistent reference with previous OLS regressions. Thus, the results in [Table 4](#) suggest that higher customer concentration causally decreases a firm's R&D investment.

4.2.2. Reverse causality test

Following [Lennox and Park \(2006\)](#), to further examine the robustness of the causal relationship between customer concentration and R&D investment, we construct model (2).

$$Concentration_{i,t} = \theta_0 + \theta_1 RD_{i,t-1} + \theta_2 RD_{i,t+1} + \sum \theta_j Control_{i,t} + \phi_{i,t} \quad (2)$$

where the explained variable is customer concentration. Control variables include *Size*, *Lev*, *ROA*, *Age*, *Cash*, *Growth*, and *TobinQ*. If there is a significant relation between $RD_{i,t+1}$ and $Concentration_{i,t}$ (not vice versa), meaning that θ_2 (not θ_1) is significantly negative, then the results provide statistical evidence that customer concentration influences R&D investment, as hypothesized. Table 5 shows the regression results. As we predict, the coefficient of $RD_{i,t+1}$ ($RD_{i,t-1}$) is significantly (not significantly) negative, which supports our conclusion.

4.2.3. Granger causality test

Following Lev et al. (2010), we use the Granger causality test (Granger, 1969) to establish temporal causality between customer concentration and R&D investment. If customer concentration is the “cause” of R&D investment, then previous customer concentration will be a significant predictor of R&D investment in the current period. Conversely, previous R&D investment should not predict customer concentration in the current period. Specially, we construct model (3a) and (3b). The control variables in model (3a) are the same as in model (1), while the controls in model (3b) are the same as in model (2). We use the first-order difference method to reduce the serial correlation problem.

$$\Delta RD_{i,t} = \gamma_0 + \gamma_1 \Delta RD_{i,t-1} + \gamma_2 \Delta RD_{i,t-2} + \gamma_3 \Delta Concentration_{i,t-1} + \gamma_4 \Delta Concentration_{i,t-2} + \sum \gamma_j Control_{i,t-1} + \pi_{i,t} \quad (3a)$$

$$\Delta Concentration_{i,t} = \psi_0 + \psi_1 \Delta RD_{i,t-1} + \psi_2 \Delta RD_{i,t-2} + \psi_3 \Delta Concentration_{i,t-1} + \psi_4 \Delta Concentration_{i,t-2} + \sum \psi_j Control_{i,t-1} + \eta_{i,t} \quad (3b)$$

Table 5
Reverse causality regression.

Dependent Variable=	<i>Concentration_{i,t}</i>	
	(1)	(2)
<i>RD_{i,t-1}</i>	−0.534 (−0.797)	−0.560 (−0.867)
<i>RD_{i,t+1}</i>	−1.267** (−2.120)	−1.564*** (−2.732)
<i>Size_{i,t}</i>		−2.729*** (−4.730)
<i>Lev_{i,t}</i>		−0.065 (−1.607)
<i>ROA_{i,t}</i>		−0.251* (−1.664)
<i>Age_{i,t}</i>		0.004 (0.004)
<i>Cash_{i,t}</i>		0.016 (0.260)
<i>Growth_{i,t}</i>		0.035 (1.440)
<i>TobinQ_{i,t}</i>		2.129*** (2.810)
<i>Constant</i>	27.449*** (11.665)	90.467*** (7.070)
Observations	982	982
Adjusted R2	0.101	0.160
F	10.44	12.09

This table reports the reverse causality test results from OLS regressions relating customer concentration to R&D investment. Continuous variables are winsorized at their 1st and 99th percentiles. Robust t-statistics are in parentheses. See Appendix A for definitions of all variables. The superscripts ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 6 presents the results. The explained variable in column (1) is R&D investment. The coefficients of lag-one and lag-two period customer concentration are -0.136 (robust t statistics = -2.178) and -0.258 (robust t statistics = -1.642), respectively. The results of model (3b) are shown in Column (2). Previous R&D investment ($\Delta RD_{i,t-1}$, $\Delta RD_{i,t-2}$) cannot predict customer concentration in the current period. Overall, our causality tests show that customer concentration limits firms' R&D investment, at least at the empirical level.

4.3. Mechanism analysis

Our evidence thus far is consistent with the financial-pressure hypothesis, which predicts customer concentrations to impede firm's R&D input. In this section, we provide evidence for the mechanism underlying this hypothesis. In Section 4.3.1, we show direct evidence that customer concentration is positively associated with

Table 6
Granger causality test.

Dependent Variable=	$\Delta RD_{i,t}$ (1)	$\Delta Concentration_{i,t}$ (2)
$\Delta RD_{i,t-1}$	-0.210^{**} (-2.422)	0.026 (0.586)
$\Delta RD_{i,t-2}$	-0.071^{***} (-2.915)	0.006 (0.690)
$\Delta Concentration_{i,t-1}$	-0.136^{**} (-2.178)	-0.327^{***} (-4.192)
$\Delta Concentration_{i,t-2}$	-0.258 (-1.642)	-0.133^{**} (-2.107)
$Size_{i,t-1}$	-0.005 (-0.235)	-0.000 (-0.000)
$Lev_{i,t-1}$	0.002^{**} (2.119)	0.001^* (1.725)
$ROA_{i,t-1}$	-0.006 (-1.238)	-0.001 (-0.733)
$Age_{i,t-1}$	-0.004 (-0.170)	-0.009 (-0.470)
$Cash_{i,t-1}$	0.004 (1.402)	0.000 (0.220)
$Growth_{i,t-1}$	-0.000 (-1.263)	-0.000 (-0.709)
$TobinQ_{i,t-1}$	-0.015 (-0.901)	-0.006 (-0.596)
$Analyst_{i,t-1}$	-0.000 (-0.290)	
$Ins_{i,t-1}$	0.042 (1.542)	
Constant	0.987^{***} (2.821)	0.910^{***} (2.816)
Observations	535	535
Adjusted R2	0.086	0.062
F	1.959	1.437

This table reports Granger causality test results. The dependent variable in column (1) is the change-value of R&D investment ($\Delta RD_{i,t}$). The dependent variable in column (2) is the change-value of customer concentration ($\Delta Concentration_{i,t}$). Continuous variables are winsorized at their 1st and 99th percentiles. Robust t-statistics are in parentheses. See Appendix A for definitions of all variables. The superscripts ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

weakened internal finance. Section 4.3.2 argues that if it is the financial pressure mechanism that drives our findings, then we should expect to observe significant cross-sectional heterogeneity in the results when financial pressure varies across firms.

4.3.1. Customer concentration and internal finance

When a customer's purchases account for a large share of a firm's profits, the firm's bargaining power is low (Porter, 1989), which has a negative effect on its internal financing. Customers can exert bargaining power on firms by acquiring extended trade credit or reducing the product price. First, firms with weak bargaining power are more likely to have a larger share of goods sold on credit and offer longer payment periods (Fabbri and Klapper, 2016). Extended trade credit policies can reduce the current operating cash flow. Second, product prices for major customers are relatively lower so that the firm's profit margins are lower.

Following Fabbri and Klapper (2016), we examine the direct effect that a concentrated customer base has on internal finances, including the turnover period of accounts receivable (*TurnPeriod*), the ratio of accounts receivable over assets (*AR*), the profit margin of products (*PM*) and the operating cash flow (*OCF*). Control variables include whether the firm is exporting (*Export*), the industry competition index (*Herfindal*), the firm's age and size (*Age*, *Size*), the percentage of the firm owned by foreign institutions (*Foreign*), and whether the firm is owned by state (*SOE*). Consistent with the intuitive and visual evidence shown in Fig. 1, the multiple regressions provide even stronger evidence. We report the results in Table 7. The regression results suggest that when a firm's customer base is more concentrated, it provides longer payment periods, more accounts receivable, lower product prices, and experiences a decrease in operating cash flow, all signs that its internal financing ability is weakened.

4.3.2. The moderating effect of external finance

We next conduct cross-sectional tests to examine whether the effect of having a concentrated customer base on R&D investment varies in (1) firms with different levels of external financing resources, including trade credit from upstream firms (*Credit*), equity financing cash flow (*Equity*), and debt financing cash flow (*Debt*),

Table 7
Customer concentration and internal financing.

Dependent Variable=	<i>TurnPeriod_{i,t}</i> (1)	<i>AR_{i,t}</i> (2)	<i>PM_{i,t}</i> (3)	<i>OCF_{i,t}</i> (4)
<i>Concentration_{i,t}</i>	0.623*** (7.017)	0.093*** (6.669)	−0.002*** (−8.533)	−0.019** (−2.029)
<i>Age_{i,t}</i>	−12.026*** (−4.048)	−0.775** (−2.401)	−0.003 (−0.655)	0.363* (1.653)
<i>Size_{i,t}</i>	−5.172*** (−3.953)	−0.911*** (−5.334)	−0.019*** (−6.428)	0.291** (2.395)
<i>Freign_{i,t}</i>	−6.459*** (−3.028)	−0.042 (−0.094)	0.063*** (6.354)	2.265*** (6.394)
<i>SOE_{i,t}</i>	−3.537 (−1.191)	−0.447 (−1.062)	−0.034*** (−4.632)	−1.394*** (−4.630)
<i>Export_{i,t}</i>	18.210*** (5.103)	3.803*** (7.619)	−0.098*** (−9.306)	−1.061*** (−3.065)
<i>Herfindal_{i,t}</i>	−118.248*** (−7.234)	−20.452*** (−7.642)	−0.142*** (−4.555)	5.751** (2.408)
<i>Constant</i>	202.025*** (6.417)	30.558*** (7.456)	0.832*** (11.526)	−0.617 (−0.214)
Observations	1984	1984	1984	1984
Adjusted R2	0.089	0.096	0.149	0.056
F	20.480	20.400	25.910	10.830

This table reports results of the relationship between customer concentration and firm's internal financing. Continuous variables are winsorized at their 1st and 99th percentiles. Robust t-statistics are in parentheses. See Appendix A for definitions of all variables. The superscripts ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

and (2) firms in different external financing environments, such as those located in districts with more developed financial markets (*Market*),² operating in high-tech industries (*Tech*), and with higher levels of state ownership (*SOE*).

If internal finances are insufficient to promote innovation, then adequate external financing resources may serve as substitutes and alleviate the problem. Equity financing is a main source of external financing for R&D investment (Acharya and Xu, 2017; Brown et al., 2009; Hall, 2002; Hsu et al., 2014). Compared with equity financing, the credit market plays only a limited role (Brown et al., 2009; Hsu et al., 2014). Creditors are risk averse and only obtain fixed interest from borrowers. However, recent evidence shows the development of banking sectors contributes to innovation activity due to the stronger ability of banks to diversify credit risk (Amore et al., 2013). In the manufacturing industry, trade credit along the supply chain has gradually become a means for firms to ease financing constraints (Fisman and Love, 2003). As such, in addition to direct external financial resources, a developed external financing environment can play a key role in reducing the costs associated with external financing, such as evaluating innovative projects, managing risk, and monitoring managers (Khurana et al., 2006; Hsu et al., 2014). In China, the government plays an important role in allocating financial resources (Firth et al., 2008; Mukherjee et al., 2017). To accelerate technological upgrading, the Chinese government supports and subsidizes firms in various ways, for instance, through tax reductions and exemptions (Mukherjee et al., 2017). State-owned enterprises have more flexible financing channels and lower financing constraints (Firth et al., 2008).

To examine the moderating effect that external financing might have on innovation, we include *Financing* and its interaction with *Concentration* in model (1). Table 8 reports the regression results. Columns (1) and (2) show that when firms have more trade credit from suppliers or equity financing resources, the constraint effect of customer concentration on R&D investment is lower. However, debt financing seems to have no positive effect on R&D investment. This might be attributable to the high-risk nature of R&D investment, which is antithetical to creditors' risk-averseness (Hsu et al., 2014). Columns (4), (5), and (6) in Table 8 also support our predictions that the negative relationship between customer concentration and R&D input is less pronounced in firms with more external financing.

4.4. Further analysis

4.4.1. Expense R&D and capital R&D

According to Chinese accounting standards, the treatment of R&D input is based on the stage of R&D activities. Total R&D input consists of an expense at the research stage and a capitalization in the development stage. In the initial stage of R&D activity, output is uncertain and input can only be expensed. As the application value gradually develops and the R&D activity enters the development stage, uncertainty decreases and R&D expenditure is capitalized.

Research-stage R&D input is more sensitive to customer concentration, because a concentrated customer base leads to internal funds pressures, which directly affect whether the firm will invest in R&D. The capitalization part of R&D input is only transformed from the previous expense part when the certainty of the program increases. As a result, sensitivity to customer concentration decreases. We therefore predict that the negative impact of customer concentration on corporate R&D investment will mainly occur at the research stage of R&D input.

The results of the comparison are presented in Table 9. In Column (1), a 1% increase in customer concentration is associated with a 0.010% decrease in R&D expenditure, while the effect is only 0.001% in R&D capitalization. In other words, the constraint effect of customer concentration on R&D expenditure is almost 10 times higher than R&D capitalization.

² The financial market development index for Chinese provinces is calculated from Wang et al. (2017). This index is commonly used in Chinese research (Guan et al., 2016; Fang et al., 2017). The index is calculated based on authority statistics and survey data through the investigation of enterprises in China. Higher values indicate a more developed financial market.

Table 8

Customer concentration, external financing and R&D investment.

Dependent Variable=	$RD_{i,t}$					
	External financing resource			External financing environment		
$Financing_{i,t} =$	<i>Credit</i>	<i>Equity</i>	<i>Debt</i>	<i>Market</i>	<i>Tech</i>	<i>SOE</i>
	(1)	(2)	(3)	(4)	(5)	(6)
$Concentration_{i,t}$	−0.014*** (−5.926)	−0.014*** (−6.511)	−0.013*** (−6.023)	−0.014*** (−6.545)	−0.012*** (−6.826)	−0.015*** (−5.614)
$Concentration_{i,t} * Financing_{i,t}$	0.005* (1.706)	0.006* (1.831)	0.004 (1.441)	0.005* (1.682)	0.016*** (2.729)	0.006* (1.814)
$Financing_{i,t}$	0.148 (1.481)	−0.197* (−1.928)	−0.166* (−1.665)	−0.080 (−0.789)	−0.929*** (−4.442)	−0.027 (−0.266)
$Size_{i,t}$	−0.302*** (−7.812)	−0.313*** (−8.201)	−0.297*** (−7.828)	−0.305*** (−7.970)	−0.304*** (−7.957)	−0.315*** (−8.213)
$Lev_{i,t}$	−0.001 (−0.630)	−0.001 (−0.354)	−0.003* (−1.649)	−0.002 (−0.739)	−0.001 (−0.580)	−0.001 (−0.578)
$ROA_{i,t}$	0.038*** (5.038)	0.037*** (4.916)	0.035*** (4.659)	0.037*** (4.957)	0.037*** (4.931)	0.041*** (5.348)
$Age_{i,t}$	−0.060 (−1.284)	−0.060 (−1.279)	−0.070 (−1.506)	−0.056 (−1.218)	−0.052 (−1.123)	−0.081* (−1.677)
$Cash_{i,t}$	−0.003 (−1.044)	−0.003 (−1.075)	−0.003 (−1.086)	−0.003 (−1.009)	−0.003 (−1.096)	−0.004 (−1.133)
$Growth_{i,t}$	−0.000 (−0.370)	−0.000 (−0.366)	−0.000 (−0.087)	−0.000 (−0.378)	0.000 (0.126)	−0.000 (−0.298)
$Analyst_{i,t}$	0.005*** (2.715)	0.005*** (2.735)	0.004*** (2.579)	0.005*** (2.762)	0.005*** (3.003)	0.004** (2.324)
$Ins_{i,t}$	−0.056 (−1.307)	−0.058 (−1.354)	−0.042 (−0.993)	−0.053 (−1.229)	−0.054 (−1.257)	−0.057 (−1.329)
$TobinQ_{i,t}$	0.238*** (6.879)	0.238*** (6.874)	0.229*** (6.657)	0.233*** (6.743)	0.233*** (6.806)	0.234*** (6.820)
$Constant_{i,t}$	6.872*** (7.943)	7.069*** (8.157)	6.707*** (7.739)	6.873*** (7.831)	6.783*** (7.832)	7.108*** (8.170)
Observations	1984	1984	1984	1984	1984	1984
Adjusted R2	0.235	0.235	0.245	0.235	0.241	0.237
F	31.150	31.670	33.300	31.270	31.390	32.470

This table reports results for the moderating effect of external financing. Columns (1)–(3) use direct external financing resources as the interaction term, $Financing_{i,t}$. Columns (4)–(6) use indirect external financing environment to measure $Financing_{i,t}$. Continuous variables are winsorized at their 1st and 99th percentiles. Robust t-statistics are in parentheses. See Appendix A for definitions of all variables. The superscripts ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

4.4.2. Customer concentration and R&D output

Given that innovation correlates with levels of R&D investment, if customer concentration limits R&D input, then we can reasonably predict that R&D output will be negatively influenced.

We use a firm's total number of patent applications filed in a given year to gauge its R&D output. As previous studies show (He and Tian, 2013), using patent applications rather than patent grants captures the actual timeframe of innovation. There is an administrative approval process before patents are finally granted and this can involve factors that are not controlled by firms. Because innovation generally takes longer than a single year, we examine the effect of customer concentration on firms' patenting two or three years ahead (He and Tian, 2013). To assess how customer concentration affects innovation, we replace the dependent variable $RD_{i,t}$ in model (1) with $Patent_{i,t+2}$ and $Patent_{i,t+3}$. The value of $Patent$ is the natural logarithm of one plus the number of patent applications.

Results in Table 10 support our predictions. Firms with a concentrated customer base have fewer patents in the following two and three years.

Table 9
Customer concentration and R&D investment in different stages.

Dependent Variable=	$RD_FEE_{i,t}$ (1)	$RD_CAPITAL_{i,t}$ (2)
$Concentration_{i,t}$	−0.010*** (−5.981)	−0.001** (−2.249)
$Size_{i,t}$	−0.305*** (−8.207)	−0.014 (−1.340)
$Lev_{i,t}$	−0.001 (−0.596)	0.000 (0.795)
$ROA_{i,t}$	0.045*** (6.147)	−0.007*** (−3.297)
$Age_{i,t}$	−0.039 (−0.838)	−0.024* (−1.898)
$Cash_{i,t}$	−0.003 (−1.157)	−0.000 (−0.036)
$Growth_{i,t}$	−0.001 (−0.758)	0.001* (1.733)
$Analyst_{i,t}$	0.210*** (6.262)	0.027** (2.484)
$Ins_{i,t}$	0.004** (2.297)	0.001* (1.802)
$TobinQ_{i,t}$	−0.074* (−1.779)	0.006 (0.649)
Constant	8.340*** (9.699)	0.297 (1.341)
Observations	1984	1984
Adjusted R2	0.215	0.040
F	29.060	8.193

This table reports results of the effect of customer concentration on R&D investment at different stages of the R&D process. Column (1) presents results for the research stage; column (2) presents results for the development stage. Continuous variables are winsorized at their 1st and 99th percentiles. Robust t-statistics are in parentheses. See [Appendix A](#) for definitions of all variables. The superscripts ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

4.5. Robustness tests

To verify the robustness of our findings, we replace the measurement of key variables in our model and re-examine the relationship between customer concentration and R&D investment. The results are presented in [Table 11](#).

First, we replace customer concentration measures. Following [Patatoukas \(2012\)](#), to reduce the potential measurement error of our proxy variables, we measure customer concentration ($HHICongcentration$) with the customer sales-based Herfindahl-Hirschman Index. The regression results are presented in Column (1) of [Table 11](#). The results remain consistent. Next, rather than using the raw values of customer concentration measures ($Concentration$), we use their decile rank transformations ($DeConcentration$). Firms are ranked annually in different industries and assigned to deciles based on $Concentration$. Therefore, the raw values of $Concentration$ are replaced by the corresponding annual decile ranks ($DeConcentration$).

We also replace the dependent variable R&D investment with R_RD or RE_RD . R_RD is the ratio of a firm's R&D investment over its sales, while RE_RD is the ratio of a firm's R&D investment over its equity. The regression results are presented in Columns (3) and (4). The results hold.

Table 10
Customer concentration and R&D output.

Dependent Variable=	<i>Patent</i> _{<i>t</i>+2} (1)	<i>Patent</i> _{<i>t</i>+3} (2)
<i>Concentration</i> _{<i>i,t</i>}	−0.009*** (−3.169)	−0.009** (−2.326)
<i>Size</i> _{<i>i,t</i>}	0.434*** (6.813)	0.342*** (4.139)
<i>Lev</i> _{<i>i,t</i>}	0.003 (0.964)	0.003 (0.609)
<i>ROA</i> _{<i>i,t</i>}	0.018 (1.520)	0.008 (0.483)
<i>Age</i> _{<i>i,t</i>}	−0.032 (−0.423)	−0.094 (−0.787)
<i>Cash</i> _{<i>i,t</i>}	−0.002 (−0.547)	−0.002 (−0.309)
<i>Growth</i> _{<i>i,t</i>}	0.003 (1.462)	0.001 (0.312)
<i>Analyst</i> _{<i>i,t</i>}	0.001 (0.473)	0.001 (0.214)
<i>Ins</i> _{<i>i,t</i>}	0.016 (0.238)	−0.046 (−0.486)
<i>TobinQ</i> _{<i>i,t</i>}	0.176*** (3.472)	0.234*** (3.067)
<i>Constant</i>	−8.349*** (−5.520)	−5.294*** (−2.920)
Observations	710	383
Adjusted R2	0.375	0.342
F	19.76	14.33

This table reports results of the effect of customer concentration on R&D output. We use the number of patent applications to measure R&D output. *Patent* is the natural logarithm of one plus the number of patent applications. Continuous variables are winsorized at their 1st and 99th percentiles. Robust t-statistics are in parentheses. See [Appendix A](#) for definitions of all variables. The superscripts ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

5. Conclusion

We examine the effect of customer concentration on firms' R&D investment. We document that a concentrated customer base restricts firms' internal financing and thus constrains its R&D investment. A 1% increase in customer concentration is associated with a 0.011% decrease in R&D investment. To establish causality, we use the instrumental variable method, the reverse causality model, and the Granger causality test to re-examine the relationship and obtain consistent results. However, this relationship is less pronounced for firms with more external financial support. Furthermore, the negative effect of customer concentration is more pronounced for the early stages of R&D. We also provide evidence that customer concentration constrains R&D output. Overall, our paper reveals the dark side of close customer-supplier relationships from the perspective of innovation. We extend the traditional risk view of customer concentration ([Banerjee et al., 2008](#); [Campello and Gao, 2017](#); [Dhaliwal et al., 2016](#)) to the real effect view ([Chu et al., forthcoming](#)).

We focus on manufacturing enterprises' innovation behaviors. Based on the unique supply chain relationship in the manufacturing industry, we identify the mechanism that influences firms' innovation behaviors, thereby enriching the literature on customer concentration risk in the supply chain field. Moreover, we contribute to research on the determinants of innovation behavior. Overall, our findings should help firms and investors better understand the influence of downstream businesses and thus optimize their strategies.

Table 11
Robustness tests.

Dependent Variable=	$RD_{i,t}$		$R_RD_{i,t}$	$RE_RD_{i,t}$
	(1)	(2)	(3)	(4)
$HHIConcentration_{i,t}$	−0.0003*** (−5.336)			
$DeConcentration_{i,t}$		−0.054*** (−5.068)		
$Concentration_{i,t}$			−0.013*** (−5.389)	−0.022*** (−4.844)
$Size_{i,t}$	−0.340*** (−6.930)	−0.309*** (−8.068)	−0.180*** (−3.431)	−0.613*** (−6.062)
$Lev_{i,t}$	0.001 (0.262)	−0.001 (−0.611)	−0.012*** (−4.147)	0.080*** (12.880)
$ROA_{i,t}$	0.034*** (3.451)	0.036*** (4.783)	−0.016 (−1.555)	0.143*** (6.759)
$Age_{i,t}$	0.021 (0.347)	−0.055 (−1.170)	−0.358*** (−4.699)	−0.042 (−0.394)
$Cash_{i,t}$	−0.005 (−1.355)	−0.003 (−0.866)	−0.005 (−1.316)	−0.010 (−1.314)
$Growth_{i,t}$	−0.001 (−0.710)	−0.000 (−0.450)	−0.002 (−1.177)	−0.002 (−0.845)
$Analyst_{i,t}$	0.304*** (6.771)	0.235*** (6.778)	0.222*** (4.574)	0.327*** (3.653)
$Ins_{i,t}$	0.003 (1.343)	0.005*** (2.745)	−0.000 (−0.075)	0.013*** (3.059)
$TobinQ_{i,t}$	−0.041 (−0.769)	−0.058 (−1.359)	0.081 (1.313)	−0.133 (−1.487)
Constant	8.103*** (7.096)	8.360*** (9.296)	7.641*** (6.232)	13.556*** (6.186)
Observations	1278	1984	1984	1984
Adjusted R2	0.212	0.228	0.299	0.241
F	21.290	32.770	41.920	29.930

This table reports results from OLS regressions relating R&D investment to customer concentration and control variables. We replace the previous customer concentration measure, $Concentration_{i,t}$, with $HHIConcentration_{i,t}$ and $DeConcentration_{i,t}$. $HHIConcentration_{i,t}$ is the customer sales-based Herfindahl-Hirschman Index. $DeConcentration_{i,t}$ is the decile rank transformations of $Concentration_{i,t}$ in the same 2-digit CSRC industry and the same year. Continuous variables are winsorized at their 1st and 99th percentiles. Robust t-statistics are in parentheses. See [Appendix A](#) for definitions of all variables. The superscripts ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Appendix A. Variable definitions

Variable	Definition
<i>RD</i>	Ratio of R&D investment over the total assets at the end of the year
<i>Concentration</i>	Ratio of sales to top-five customers over total sales
<i>Credit</i>	An indicator variable equal to 1 if ratio of the difference between accounts payable and prepaid over the total assets in the previous year is higher than the median value in the same 2-digit CSRC industry and year; equal to 0 otherwise
<i>Equity</i>	An indicator variable equal to 1 if ratio of the equity financing cash flow over total assets in the previous year is higher than the median value in the same 2-digit CSRC industry and year; equal to 0 otherwise

<i>Debt</i>	An indicator variable equal to 1 if ratio of the debt financing cash flow over total assets in the previous year is higher than the median value in the same 2-digit CSRC industry and year; equal to 0 otherwise
<i>Market</i>	An indicator variable equal to 1 if the financial development index of place of incorporation is higher than the median value in the same year; equal to 0 otherwise. The financial development index is from Wang et al. (2017)
<i>Tech</i>	An indicator variable equal to 1 if the firm belongs to the high-tech industry classification in manufacturing industry; equal to 0 otherwise. The high-tech industry classification is prepared by the State Statistics Bureau, specifically including pharmaceutical manufacturing, aviation, spacecraft equipment manufacturing, electronics and communications equipment manufacturing, computer and office equipment manufacturing, medical equipment and instrumentation manufacturing and information chemicals manufacturing
<i>SOE</i>	An indicator variable equal to 1 if the firm is ultimately controlled by government and equal to 0 otherwise
<i>AR</i>	Ratio of accounts receivable over the total assets at the end of the year
<i>TurnPeriod</i>	365 days, scaled by turnover of accounts receivable
<i>PM</i>	The difference of sales and operating costs, scaled by sales
<i>OCF</i>	Net operating cash flow, scaled by total assets
<i>Size</i>	Natural logarithm of total assets at the end of the year
<i>Lev</i>	Ratio of total liabilities over the total assets at the end of the year
<i>Age</i>	Natural logarithm of one plus the number of years a company has been listed
<i>ROA</i>	Ratio of net income over the total assets at the end of the year
<i>Cash</i>	Ratio of cash, short-term investment, and trading financial assets over the total assets at the end of the year
<i>Growth</i>	Annual percentage sales growth of the firm
<i>Analyst</i>	Natural logarithm of one plus the number of analysts following the company
<i>TobinQ</i>	The sum of the book value of total debts and market value of shareholder equity over the total assets at the end of the year
<i>Ins</i>	The institutional ownership in the firm
<i>Export</i>	An indicator variable equal to 1 if the firm is exporting and equal to 0 otherwise
<i>Herfindal</i>	Herfindal Index of revenues in the 2-digit CSRC industry
<i>Foreign</i>	The foreign institutional ownership of the firm

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