

Cyclical Dynamics of Trade Credit with Production Networks*

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Abstract

We show that in production and trade networks that characterize the Chinese economy there is an externality that (inefficiently) reduces the supply of trade credit from upstream firms to downstream firms. Since a credit expansion affects more directly firms in upstream industries (due to their closer connection with banks), the credit expansion does not fully propagate to downstream firms through trade credit because of the externality. Manufacturing industry data for the period 2005-2016 supports the theoretical findings. In particular, we observe that during the credit expansion period of 2005-2011, the higher growth of credit received by upstream manufacturing industries was not accompanied by a similar growth of trade lending to downstream industries.

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1 Introduction

A financial expansion may affect certain sectors of the economy or class of borrowers more directly than others. Still, other sectors may be affected indirectly. For instance, a monetary policy expansion may increase the liquidity of banks which then creates the conditions for higher supply of credit to firms that are more connected to banks. Firms that are less connected to banks may not benefit directly from the initial credit expansion. However, they could benefit indirectly through higher supply of ‘trade’ credit from bank-connected firms. Thus, through trade credit, a financial expansion could cascade to the whole economy with significant real macroeconomic effects. However, if the higher credit received by the more connected firms does not cascade to other firms, the financial expansion may not have large macroeconomic effects. This is especially true if the most connected firms are not those facing the most stringent financial conditions. The question we ask in this paper is whether trade credit facilitates the propagation of a financial expansion to the whole economy when financial markets are highly segmented.

We ask this question in the context of the Chinese economy because of the distinct dual economic structure. On the one hand, there are large firms—often state-owned and operating in upstream industries—that have easier access to banking credit. On the other hand, there are smaller firms—often privately owned and operating in downstream industries—with limited access to bank credit. Even though these firms do not have easy access to banks, they can still fund operations through the trade credit channel, that is, by borrowing from suppliers that have easier access to banks. Would then a credit expansion propagate to the whole economy through the trade credit channel?

We first study this question empirically using Chinese data for manufacturing industries over the period 2005-2016. This period is characterized by two distinct phases. During the first phase, spanning from 2005 to 2011, the Chinese economy experienced a liquidity/credit expansion, in part driven by monetary policy (especially during 2009-2010 in response to the global financial crisis). During the second phase, spanning from 2012 to 2016, the Chinese economy experienced a financial slow down with much lower rates of credit growth.

We rank manufacturing industries according to their upstream position within the manufacturing sector. We adopt the definition of upstreamness

used in the production network literature, such as Liu (2017). In brief, an industry is more upstream than another industry if the former is more influential (as supplier of intermediate goods) to other industries than the latter. It turns out that more upstream manufacturing industries have a stronger presence of state-owned and larger enterprises. Because of this, firms operating in upstream industries are more connected to banks which in practice means easier access to bank credit.

We find that during the expansionary phase (2005-2011), upstream manufacturing industries experienced higher rates of credit growth than downstream manufacturing industries. This may be a reflection of the fact that firms operating in upstream manufacturing industries are more connected to banks. However, the higher rate of credit growth in these industries was not accompanied to the same increase in the trade lending of these industries. Effectively, the increase of funds received by more bank-connected manufacturing industries were not re-channeled to other less connected manufacturing industries. Instead, they were used for financial investments outside the manufacturing sector. Therefore, the credit expansion did not generate a full credit cascade to all manufacturing industries. This suggests that the real impact of the credit expansion and, in particular, of the 2009-2010 expansionary monetary policy, may have not achieved its full potential.

In the second part of the paper we develop a model with trade credit network that rationalizes why a credit expansion toward bank-connected firms may not lead to an expansion in ‘trade’ credit, limiting the credit cascade to the rest of the economy.

The model features two sectors, upstream and downstream. In the upstream sector firms choose optimally the amount of credit supplied to downstream firms. However, due to an externality, trade credit is under-supplied. The externality derives from the fact that, when an individual upstream firm increases trade lending to downstream firms, this raises sales not only for this particular upstream firm, but also for other upstream firms. Since an individual firm cares only about its own sales, trade credit is under-supplied in equilibrium. The fact that individual upstream firms do not fully internalize the benefits of trade credit, the equilibrium supply of trade credit is below the socially optimal level. We also show that when the upstream sector is less concentrated, individual upstream firms internalize less the benefits of trade credit. As a result, the equilibrium supply of trade credit is lower.

In the model, a credit expansion increases the amount of credit supplied to upstream firms, that is, firms that have easier access to banks. However,

the extra credit to upstream firms do not necessarily translate into more trade lending to downstream firms. They may simply hoard the extra funds loaned from banks and/or invest in financial assets. In fact, upstream firms only increase trade lending to downstream firms to the point in which the ‘individual’ marginal benefit equalizes the opportunity cost. In the model the opportunity cost is the return on financial assets. Since the ‘individual’ benefit from trade lending is higher for larger upstream firms, the model predicts that a credit expansion tilted toward larger upstream firms generates greater downstream credit cascade through trade lending. This is consistent with our empirical findings.

Related literature Our paper contributes to several strands of literature on trade credit, credit allocation and monetary stimulus policy. First, our paper belongs to the literature that studies the importance of trade credit (as an alternative financial mechanism) in overcoming credit constraint. Using the U.S. firm-level data, Petersen and Rajan (1997) find that firms with closer connection to financial institutions offer more trade credit to credit-constrained firms. Burkart and Ellingsen (2004) present a theory of trade credit where suppliers have relative advantages versus banks in lending to their customers due to the fact that it is more difficult to divert inputs than to divert cash. Allen et al. (2005) find that informal financing channels, such as trade credit, have supported the fast growth of the non-listed private firms in China. Zhu et al. (2007) find that the under-performing state owned firms in China tend to re-channel credit to firms with less access to loans via trade credit. Our paper contributes to this literature by presenting a novel theory of trade credit that features an externality that (inefficiently) reduces the supply of trade credit from bank-connected firms to firms with less access to credit.

Second, our paper is closely related to the literature on credit allocation across firms in China. Song et al. (2011) present a theory that features two sectors, namely, private firms that use more productive technologies but have less access to credit, and state-owned firms that have lower productivities but have more access to credit. Their model explains simultaneously the high return to capital and the fast growing foreign surplus observed in China. Chang et al. (2018) show that the adjustments of bank reserve requirement not only affect the supply of bank credit but also have important implications for the credit allocation between state-owned firms (that rely on bank loans) and private firms (that rely on unregulated off-balance sheet financing). Hsieh and Klenow (2009) and Bai et al. (2018) provide evidence on resource and

credit miss-allocation across Chinese firms. Recent works, such as Chen et al. (2016) and Cong et al. (2017), study the credit allocation across sectors and firms in China during the four trillion Yuan economic stimulus of 2009-2010. The former provides evidence that during the economic stimulus period, a major fraction of the newly extended loans are channeled to ‘heavy sectors’, e.g., real estate, infrastructure, and manufacturing industries. The later finds that during the stimulus period, the effect of increases in credit supply on firm borrowing was significantly larger for state-owned firms relative to private firms. While their studies focus on the initial credit allocation, our work focuses on the reallocation of credit from bank-connected firms to firms with less access to credit.

Finally, our work is related to the studies on shock propagation in trade credit network. For example, Kiyotaki et al. (1997) present a theory of default cascade in trade credit network in recessions. Our paper is complementary to this literature as it provides a theory on credit cascade through trade credit channel in credit expansions.

The organization of the paper is as follows. Section 2 provides evidence about some key features of the dynamics of trade credit in China as well as some key features of the Chinese industrial and financial structure. Section 3 presents the model and characterizes its properties. Section 4 derives the efficient allocation and compares it to the competitive allocation. Section 5 analyzes the credit cascade in credit expansions. Section 6 concludes.

2 Empirical analysis

Before presenting the theoretical framework, we present the empirical observations that motivate this paper. We first categorize China’s manufacturing industries into upstream and downstream sectors, and describe their characteristics in Section 2.1. In Section 2.2 we document that, during the expansion period 2005-2011, the financial activities of upstream manufacturing industries grew more than for downstream manufacturing industries. We also show that the higher credit received by upstream manufacturing industries during the credit expansion was re-channeled outside the manufacturing sector rather than being used to increase trade lending to downstream manufacturing industries. Section 2.3 provides further evidences that downstream firms depend on upstream firms for short-term credit but the credit expansion in upstream industries has limited cascade to downstream firms.

2.1 Characteristics of the upstream and downstream industries

To categorize Chinese manufacturing industries into upstream and downstream sectors, we adopt the measure of upstreamness used by Liu (2017). This measure is based on an upstream score constructed from an extended version of the production network model by Acemoglu et al. (2012). In Liu (2017), the upstreamness of an industry is defined as the impact of the industry’s idiosyncratic productivity shock to aggregate net output (via downstream propagation) relative to its sales scale. An industry that, directly or indirectly, supplies more intermediate goods to other industries tend to have higher upstream score. Further details are provided in Appendix C.1.

We compute the upstream scores for all Chinese industries using the 2007 input-output table. We then rank the 26 two-digit manufacturing industries based on their upstream scores. Table 8 in Appendix C.1 lists the 26 two-digit industries of China’s manufacturing sector ordered from top (upstream) to bottom (downstream). We then construct two groups of manufacturing industries based to their upstreamness ranking. Half of the 26 manufacturing industries form the ‘upstream’ group and the remaining half the ‘downstream’ group.

To characterize some of the properties the 26 two-digit manufacturing industries, we use firm-level data from the 2007 survey of manufacturing enterprises conducted by the National Bureau of Statistics of China. For each industry, we compute (i) the average ratio of net trade lending to sales across firms, (ii) the sales share of large-firms, and (iii) the sales share of state-owned firms. Net trade lending is defined as accounts receivable minus accounts payable. Figure 1 plots some characteristics at the industrial level.

The figure shows that the sales shares of large and state-owned firms tend to be larger in upstream manufacturing industries. The first two columns of Table 1 shows that the sales shares of large firms and state-owned firms are respectively 6% and 10% higher than those in downstream manufacturing industries. This suggests that upstream firms have on average better access to loans from banks. In addition, the average ratio of net trade lending (account receivable minus accounts payable) to sales tends to be higher in upstream industries. See Panel (c) of Figure 1 and the third column of Table 1. This indicates that upstream firms lend to downstream firms via trade credit.

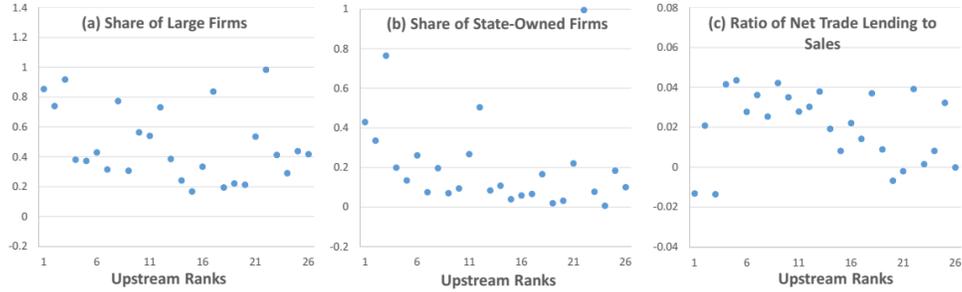


Figure 1: Characteristics of manufacturing industries

Notes: Panel (a) of the above figure shows the sales share of large firms by industry. Panel (b) shows the sales share of state-owned firms by industry. Panel (c) shows the average ratio of net trade lending to sales across firms for each manufacturing industry, where net trade lending refers to accounts receivable minus accounts payable. Each dot represents a two-digit manufacturing industries. Industries are ordered by their upstream ranks from left to right. Large firms are defined as firms with sales higher than 400 million Yuan according to the National Bureau of Statistics of China. All the statistics are computed using the firm-level data from the 2007 survey of manufacturing enterprises conducted by the National Bureau of Statistics of China.

	Share of large firms	Share of state-owned firms	Ratio of net lending to sales
Upstream sector	0.5616	0.2614	0.0262
Downstream sector	0.4056	0.1581	0.0139

Table 1: Characteristics of upstream and downstream sectors

Notes: The first column of the above table reports respectively the average ratio of net trade lending to sales across firms within the upstream and downstream sectors, where net trade lending refers to accounts receivable minus accounts payable. The second and third columns report the sales shares of large firms and state-owned firms for the upstream and downstream sectors. All the statistics are computed using the firm-level data from the 2007 survey of manufacturing enterprises conducted by the National Bureau of Statistics of China.

2.2 Short-term financing of manufacturing firms

As shown in the previous section, upstream manufacturing firms tend to be larger and state-owned when compared to downstream firms. Because of

this, upstream manufacturing industries have better access to credit. This special financial structure creates an interesting channel for credit cascade: Upstream industries are more connected to banks and, therefore, they are more directly affected by financial expansions. The impact on downstream industries, instead, relies more on the indirect channel of trade credit from upstream firms. If the extra credit received by upstream industries is used to expand trade lending to downstream industries, the credit expansion cascades to the whole sector. However, if upstream firms do not increase trade lending, the cascade or propagation to the whole economy is limited.

Before investigating the degree of credit cascade, we describe how the financial activities of upstream and downstream manufacturing firms respond to financial expansions. We focus on short-term financing of manufacturing firms, where short-term financing refers to the sum of short-term lending (including both trade and non-trade short-term lending) and borrowing (including both trade and non-trade short-term borrowing).

Data The balance sheet data (aggregated to two-digit industrial level) for Chinese manufacturing industries is from the National Bureau of Statistics, and available annually for the period 2003-2016. Short-term lending is measured by ‘non-inventory current assets’, namely, ‘current assets’ minus ‘inventory’. Short-term borrowing is measured by ‘current liabilities’. Trade lending is measured by ‘accounts receivable’. Trade borrowing is measured by ‘accounts payable’. Non-trade lending corresponds to short-term lending minus trade lending. Non-trade borrowing corresponds to short-term borrowing minus trade borrowing. All nominal variables are deflated by CPI and expressed in 2000 Chinese Yuan.

2.2.1 Short-term borrowing and lending: Upstream v.s. downstream industries

Short-term financing of manufacturing firms is significantly affected by the monetary policy of the People’s Bank of China (PBOC), the central bank of China. The PBOC ended its expansionary monetary policy and started to tighten its money supply in 2012. See Figure 17 in Appendix C.3. As a result of this policy change, the growth of short-term financing of manufacturing firms started to slow down. Therefore, we divide the sample period in two phases: the credit expansion period, 2005-2011, and the contraction period, 2012-2016. To investigate how upstream and downstream industries respond to this monetary policy changes, we first compare their short-term borrow-

ing and lending during the expansion phase, 2005-2011, and the contraction phase, 2012-2016.

Fact 1: During the credit expansion period (2005-2011), upstream industries experienced higher growth of short-term borrowing and lending.

Figure 2 shows that during the credit expansion phase (2005-2011), short-term borrowing and lending of upstream industries have grown faster than for the downstream industries. These results are significant even after taking into account the different trends in upstream and downstream industries. As shown in Columns 2 and 4 of Table 2, the coefficients associated with the dummy ‘expansion’ are statistically significant only for upstream industries. This indicates that only upstream industries have experienced significant expansions of short-term financing (i.e., the sum of short-term lending and borrowing). In contrast, there is no significant expansion of short-term financing for the downstream industries.

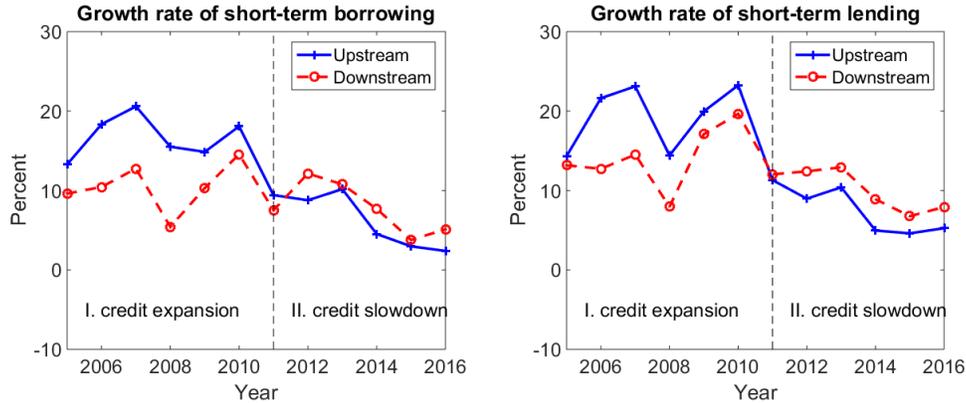


Figure 2: Growth rates of short-term borrowing and lending of upstream and downstream industries

Notes: The above figure plots the average growth rates of short-term borrowing (i.e., non-inventory current assets) and lending (i.e., current liabilities) for the upstream and downstream industries.

To further investigate the extent to which the credit expansion of manufacturing firms during 2005-2011 is driven by monetary policy, we regress the industrial-level growth of short-term financing (i.e., the sum of short-term

	I. Short-term finance growth				II. Sales growth	
	Upstream		Downstream		Upstream	Downstream
	(1)	(2)	(3)	(4)	(5)	(6)
Time	-0.013*** (0.002)	-0.008*** (0.003)	-0.006*** (0.002)	-0.009*** (0.003)	-0.015*** (0.004)	-0.017*** (0.002)
M2 growth (lagged)	0.894*** (0.283)		0.089 (0.317)			
Expansion		0.056*** (0.020)		-0.025 (0.021)	0.072*** (0.026)	0.001 (0.016)
Constant	0.088** (0.040)	0.140*** (0.030)	0.124*** (0.044)	0.176*** (0.031)	0.190*** (0.038)	0.255*** (0.024)
Industry F.E.	YES	YES	YES	YES	YES	YES
R-squared	0.532	0.487	0.209	0.219	0.577	0.651

Table 2: Short-term financing and sales: upstream v.s. downstream industries

Notes: For the regressions reported in Panel I, the dependent variable is the growth rate of short-term financing (i.e., the sum of non-inventory current assets and current liabilities). For the regressions reported in Panel II, the dependent variable is the growth rate of sales. “Time” is the time index, and equals 1, ..., T . “M2” is the growth rate of real M2 balance lagged by one year. “Expansion” is the dummy for the credit expansion period, and equals 1 for the years during 2005-2011, and 0 otherwise. The regressions reported in Columns (1), (2) and (5) use the subsample that contains only the upstream industries, and the regressions reported in Columns (3), (4) and (6) use the subsample that contains only the downstream industries.

lending and borrowing) on a time index and lagged M2 growth. M2 growth is often used as a proxy for the tightness of monetary policy in China. This is justified by the fact that China’s monetary policy is mostly quantity based and M2 growth is typically used as an intermediate target.

Table 2 shows that short-term financing of upstream industries are significantly correlated with lagged M2 growth. A one percent growth in M2 is associated with 0.9% growth in short-term financing of upstream industries in the following year. Instead, there is no significant correlation between short-term financing of downstream industries and M2 growth (see Column 3 in Table 2). Notice that M2 increased by more than 30% in 2009 as a result of the four trillion economic stimulus. This is often considered an outlier and,

therefore, the year 2009 is excluded from the estimation reported in Columns 1 and 3.

Figure 3 shows that the sales of upstream industries have also grown faster than downstream firms during the expansion phase (2005-2011). By contrast, during the slowdown phase (2012-2016), the sales growth of upstream industries is not significantly different from the growth of downstream industries. In addition, only the upstream industries have experienced faster sales growth during the expansion phase than during the contraction phase. As shown in Columns 5 and 6 of Table 2, the coefficients associated with the dummy ‘expansion’ are statistically significant only for the upstream industries.

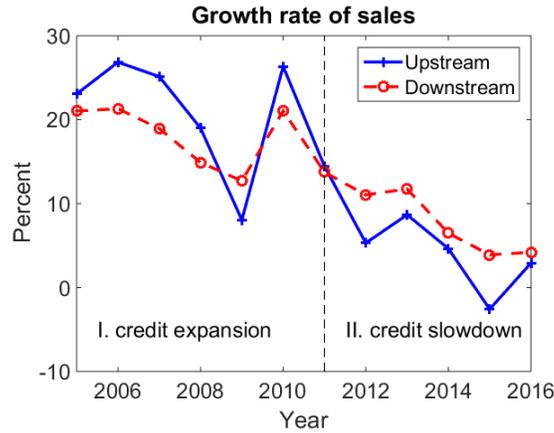


Figure 3: Growth rates of sales of upstream downstream industries

Notes: The above figure plots the average growth rates of sales for the upstream and downstream industries.

2.2.2 Trade vs. non-trade lending of upstream industries

As observed above, during the credit expansion phase (2005-2011), short-term borrowing and lending of upstream industries expanded more than for downstream industries. To investigate the extent to which the extra credit received by upstream firms induced higher trade credit to downstream industries, we compare the trade and non-trade lending of upstream industries.

Fact 2: *During the credit expansion period (2005-2011), upstream industries expanded their non-trade lending more than their supplies of trade credit.*

Figure 4 shows that during the credit expansion phase (2005-2011), non-trade lending of upstream industries expanded more than their trade lending. As shown by Column 1 of Table 3, the growth rate of non-trade lending relative to trade lending is significantly higher during the credit expansion phase as the coefficient associated with the ‘expansion’ dummy is positive and statistically significant.

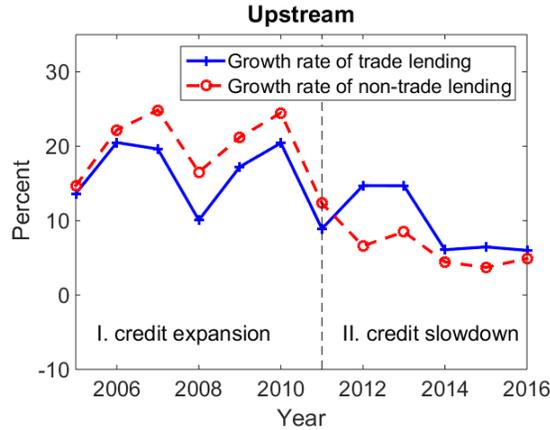


Figure 4: Growth rates of trade and non-trade lending of upstream industries

Notes: The above figure shows the average growth rates of trade and non-trade lending of the upstream industries. Trade lending is measured by accounts receivable and non-trade lending is measured by non-inventory current assets excluding accounts receivable.

The fact that upstream industries did not use the extra credit to expand their trade lending suggests that the origin of the credit expansion is unlikely to be the result of the real expansion (i.e., higher growth in sales driving higher growth of credit). Instead, it is more likely caused by financial factors such as expansionary monetary and credit policies. In fact, if the credit expansion was simply the result of the real expansion, we should have seen a higher growth in trade lending. The facts illustrated in Figures 2, 3 and 4 also indicate that the credit expansion during 2005-2011 did not fully cascade to downstream firms through the trade credit channel.

Fact 3: *During the credit expansion phase (2005-2011), large upstream firms expanded their supplies of trade credit more than small upstream firms.*

Figure 5 shows that during the credit expansion phase (2005-2011), the

	I. Non-trade lending from all firms in excess of their trade lending	II. Trade lending from large firms in excess of industrial average	III. Non-trade lending from large firms in excess of industrial average	II - III
	Upstream industries			
	(1)	(2)	(3)	(4)
Time	0.011*** (0.003)	0.005** (0.002)	0.003 (0.002)	0.002 (0.002)
Expansion	0.145*** (0.024)	0.062*** (0.015)	0.030* (0.016)	0.032** (0.016)
Constant	-0.142*** (0.036)	-0.058*** (0.022)	-0.027 (0.023)	-0.031 (0.024)
Industry F.E.	YES	YES	YES	YES
R-squared	0.295	0.147	0.047	0.069

Table 3: Lending of the upstream industries: Trade v.s. Non-trade lending and Large firms v.s. Industry average

Notes: For the regression reported in Column (1), the dependent variable is the industrial-level growth rate of non-trade lending from all firms in excess of the growth rate of their trade lending (i.e., the growth rate of non-trade lending minus the growth rate of trade lending). For the regressions reported in Columns (2) and (3), the two dependent variables are the industrial-level growth rates of trade(non-trade) lending from large firms in excess of the corresponding industry averages (i.e., the growth rate of trade(non-trade) lending from large firms minus the growth rate of trade(non-trade) lending from all firms), and the dependent variable for the regression reported in Column (4) is the former minus the latter (i.e., the excess trade lending growth of large firms minus their excess non-trade lending growth). “Time” is the time index, and equals 1, ..., T . “Expansion” is the dummy for the credit expansion period, and equals 1 for the years during 2005-2011, and 0 otherwise. The regressions reported in all columns use the panel for the upstream industries over the period of 2005-2016. Large firms refer to firms with sales higher than 400 million Chinese Yuan according to the National Bureau of Statistics of China.

growth rates of trade and non-trade lending from large upstream firms exceeded the industry averages. This may indicate that large upstream firms have better access to credit than smaller upstream firms within the same industry. However, the excess growth of trade lending of large upstream firms (i.e., the growth rate of trade lending of large firms minus the corresponding industry average) is even higher than the excess growth of non-trade lending

as shown by the right panel of Figure 5. These results indicate that more of the extra credit to large upstream firms are used for trade lending compared to the industry average. As shown by Columns 2-4 of Table 3, these results are significant as the coefficients associated with the dummy ‘expansion’ are positive and statistically significant. We will come back to this finding when we present the theoretical model.

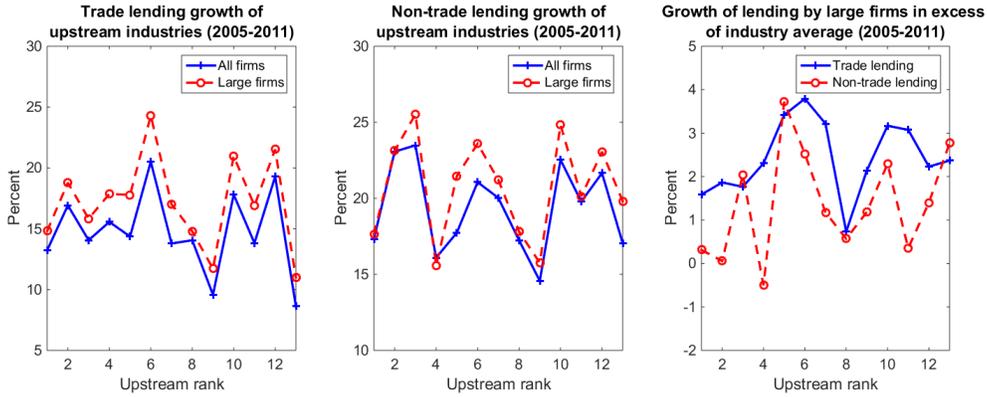


Figure 5: Growth rates of trade and non-trade lending of upstream industries: Large firms v.s. Industry average

Notes: The left and middle panels show the industrial-level growth rates of trade and non-trade lending from large firms (dashed-red) and the corresponding industry averages (solid-blue) for the period noted above. Trade lending is measured by accounts receivable and non-trade lending is measured by non-inventory current assets excluding accounts receivable. The right panel shows the industrial-level growth rates of trade(non-trade) lending from large firms in excess of the corresponding industry averages (i.e., the growth rate of trade(non-trade) lending of large firms minus the growth rate of trade(non-trade) lending of the entire industry) for the period noted above. Each dot represents an upstream industry. Industries are ordered by their upstream rank from left to right. For all the panels, only the upstream industries are plotted.

2.3 Credit cascade

We have seen that during the credit expansion phase of 2005-2011, upstream firms did not use all the extra credit to expand their trade lending. This suggests that the credit expansion did not fully cascade to downstream firms through the trade credit channel. Here, we further investigate the degree of credit cascade and how it varies over time.

To investigate the extent to which downstream firms depend on upstream firms for credit and how the dependence varies over time, we consider the following regression model:

$$b_{it} = c - \mu_t + ex_t (\rho_{ex}^{up} \psi_{it}^{up} + \rho_{ex}^{dw} \psi_{it}^{dw}) + (1 - ex_t) (\rho_{sl}^{up} \psi_{it}^{up} + \rho_{sl}^{dw} \psi_{it}^{dw}) + e_{it}, \text{ with } i \in I^{dw}, \quad (1)$$

where b_{it} is the growth rate of short-term borrowing (i.e., the sum of trade and non-trade borrowing) by industry i . Coefficient μ_t captures the time fixed effects, ex_t is the dummy for the credit expansion period, taking the value of 1 for 2005-2011 and 0 otherwise. The variables ψ_{it}^{up} and ψ_{it}^{dw} are short-term lending of upstream and downstream industries. They are defined as

$$\psi_{it}^{up} \equiv \sum_{j=I^{up}} \sigma_{ij} l_{jt} \quad \text{and} \quad \psi_{it}^{dw} \equiv \sum_{j=I^{dw}} \sigma_{ij} l_{jt}, \quad (2)$$

where l_{jt} is the growth rate of short-term lending (i.e., the sum of trade and non-trade lending) by industry j . Coefficients σ_{ij} , with $\sum_{j \in I^{up} \cup I^{dw}} \sigma_{ij} = 1$, captures the strength of supply-use linkages between industries i and j (and are estimated as the share of input j in the total value of intermediate good inputs of industry i), and $\sigma_i \equiv (\sigma_{i,1}, \dots, \sigma_{i,N})$ are industry-specific.

Coefficients ρ_x^z , where $z \in \{up, dw\}$ and $x \in \{ex, sl\}$, capture the sensitivities of b_{it} to the lending of upstream industries (ψ_{it}^{up}) and the lending of downstream industries (ψ_{it}^{dw}) during the credit expansion ($ex_t = 1$) and slowdown ($ex_t = 0$) phases. For example, consider one percent growth in the lending of upstream industry j (i.e., l_{jt} with $j \in I^{up}$). This translates into $\rho_{ex}^{up} \sigma_{ij}$ per cent increase in the borrowing of industry i , for all $i \in I^{dw}$, during the credit expansion phase, and $\rho_{sl}^{up} \sigma_{ij}$ percent increase in borrowing during the credit slowdown phase. In addition, its impact on a specific downstream industry depends also on the supply-use connection between downstream industry i and upstream industry j . Given the values of ρ_x^{up} , with $x \in \{ex, sl\}$, one percent growth in l_{jt} induces more increase in b_{it} if σ_{ij} is bigger.

We expect that $\rho_{ex}^{up} < \rho_{sl}^{up}$. This is because during the credit expansion phase, upstream industries did not use the extra credit to expand their trade lending to downstream industries. This implies that one percent growth in the lending of upstream industries translates into less growth of borrowing from downstream industries.

		Short-term borrowing of downstream industries							
		I.		II.		III.		IV.	
		Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Lending of all industries									
	All periods	1.102*** (0.109)							
	Expansion								
	Slowdown								
Lending of upstream industries									
	All periods			0.864*** (0.185)					
	Expansion					0.821*** (0.218)		0.795** (0.316)	
	Slowdown					1.681*** (0.443)		1.538** (0.591)	
Lending of downstream industries									
	All periods			1.105*** (0.108)					
	Expansion					1.187*** (0.144)		1.311*** (0.162)	
	Slowdown					0.959*** (0.160)		1.035*** (0.174)	
	Constant	-0.053*** (0.019)		-0.042** (0.020)		-0.046* (0.024)		-0.054** (0.027)	
	Time F.E.	YES		YES		YES		YES	
	Industry F.E.	No		No		No		YES	
	R-squared	0.578		0.585		0.603		0.647	

Table 4: Sensitivities of borrowing by downstream industries w.r.t. lending from upstream and downstream industries

Notes: The above table reports the estimates of ρ_x^z , where $z \in \{up, dw\}$ and $x \in \{ex, sl\}$, from regression (1). Column I corresponds the regression with constraint $\rho_{ex}^{up} = \rho_{ex}^{dw} = \rho_{sl}^{up} = \rho_{sl}^{dw} = \rho$. Column II corresponds the regression with constraints $\rho_{ex}^{up} = \rho_{sl}^{up} = \rho^{up}$, and $\rho_{ex}^{dw} = \rho_{sl}^{dw} = \rho^{dw}$. Column III and IV correspond to the regressions with no additional constraint.

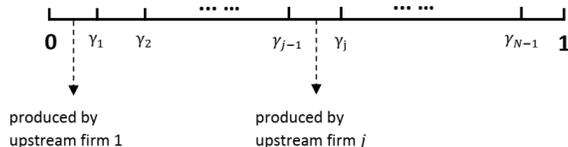
The regression results are reported in Table 4. As can be seen in Column III, the sensitivity of downstream industries' borrowing to upstream industries' lending (i.e., ρ^{up}) is 1.681 during the credit slowdown phase but only 0.821 during the credit expansion phase. This indicates that a one percent growth in the lending of upstream industries translates into less than one percent increase in the borrowing of downstream industries during the credit expansion phase.

In the next section we present a theoretical model that can generate the empirical facts outlined here.

3 Model

We extend the monopolistic competition model developed by Dixit and Stiglitz (1977) by allowing for trade credit. In the model, there are two sectors in the economy: the upstream sector and the downstream sector. The upstream sector has N firms indexed by $j = 1, \dots, N$. Each upstream firm produces

a mass of intermediate inputs sold to the downstream sector. Intermediate goods are indexed by i . More specifically, upstream firm j produces intermediate goods of variety $i \in [\gamma_{j-1}, \gamma_j] \equiv \mathbf{I}_j$, with $\gamma_0 = 0$, $\gamma_N = 1$, and $\gamma_{j-1} < \gamma_j$ for $j = 1, 2, \dots, N$.



In the downstream sector there is a continuum of competitive firms. They produce a composite good by combining intermediate goods produced by upstream firms. There is only one period in the model. Figure 6 provides a schematic illustration of the production network.

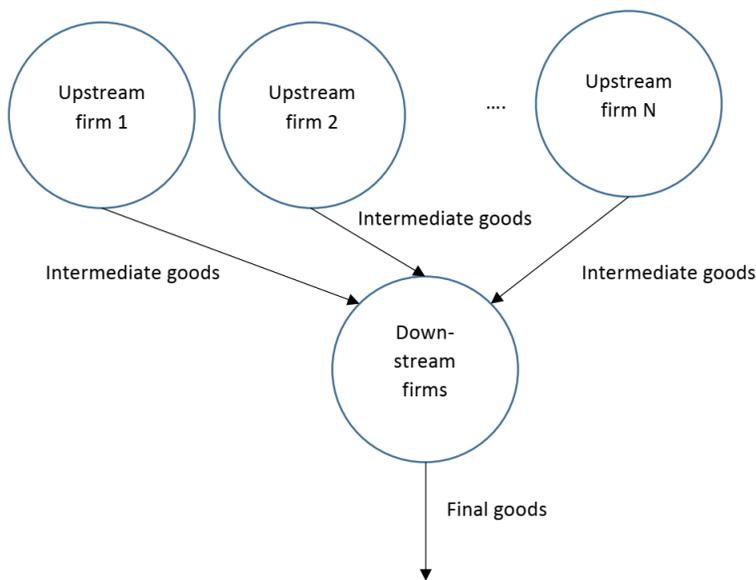


Figure 6: Structure of the production sector

3.1 Production technology

Upstream firms incur an increasing marginal cost of production in terms of the composite good (numeraire). Denoting by x_i the quantity produced of

intermediate good i , the total production cost for firm j is

$$\int_{i \in \mathbf{I}_j} c(x_i), \quad (3)$$

where $c(\cdot)$ is strictly increasing and convex.

The composite goods is produced in the downstream sector by a unitary mass of homogeneous and competitive firms. Production takes places by combining the intermediate goods produced by upstream firms according to the technology

$$y = \left(\sum_{j=1}^N \int_{i \in \mathbf{I}_j} x_i^{\frac{\varepsilon-1}{\varepsilon}} \right)^{\frac{\varepsilon}{\varepsilon-1}}, \quad (4)$$

where x_i is the quantity of intermediate good i used as an input of production by a representative downstream firm and $\varepsilon > 1$ is the elasticity of substitution between intermediate goods.

The production of the composite good y is in part used as an intermediate input for the production of intermediate goods in the upstream industry and the remaining part is used for consumption (final usage). Effectively, the cost $c(x_i)$ represents the quantity of the composite good used to produce x_i units of intermediate good i in the upstream sector. The remaining part of y is used for consumption. The assumption that y is used as an intermediate input for the production of intermediate goods needed to produce itself may seem counterintuitive. However, this is an artifact of the assumption that there is only one period in the model. In a dynamic setting, the part of y that is not used for consumption will form intermediate inventory that will be used for production in the next period.

3.2 Downstream firms

Bank financing of downstream firms is limited by \bar{b} . Because of their limited access to external financing, downstream firms may have an incentive to borrow from upstream firms (trade credit). However, due to enforcement problems, downstream firms can only partially fund the purchase from upstream firms with trade credit. Denoting by ϕ_j the down payment fraction required by upstream firms, the fraction of purchases funded with trade credit is $1 - \phi_j$. The down payment fraction ϕ_j is chosen optimally by upstream firm j as described below.

We assume that downstream firms do not have own funds and, therefore, the down payments has to be funded with bank loans. The borrowing constraint for bank credit can then be written as

$$\sum_{j=1}^N \phi_j \int_{i \in \mathbf{I}_j} q_i x_i \leq \bar{b}, \quad (5)$$

where q_i and x_i are, respectively, the price and quantity purchased of intermediate good i . The left-hand-side is the total borrowing from banks necessary to cover the total down payments to upstream firms: Given the purchases of x_i units of intermediate goods $i \in \mathbf{I}_j$ from upstream firm j , the down payment to firm j is $\phi_j \int_{i \in \mathbf{I}_j} q_i x_i$. Since there are N upstream firms, the total down payment is $\sum_{j=1}^N \phi_j \int_{i \in \mathbf{I}_j} q_i x_i$. This must be financed with loans from banks, which is bounded by the borrowing limit \bar{b} . Trade credit is the difference between the purchased value of intermediate goods and the down payments.

The representative downstream firm chooses intermediate inputs x_i to maximize profits, that is,

$$\max_{\{x_i\}_{i \in [0,1]}} y - \sum_{j=1}^N \int_{i \in \mathbf{I}_j} q_i x_i - r \sum_{j=1}^N \phi_j \int_{i \in \mathbf{I}_j} q_i x_i \quad (6)$$

subject to (4) and (5).

The firm maximizes the revenues from production, y , minus the cost of the intermediate inputs. The cost has two components. The first is the direct purchasing cost while the second is the cost of financing the down payment with bank loans, which depends on the interest rate r charged by banks.

The first order condition with respect to x_i is

$$\frac{\partial y}{\partial x_i} = \left[1 + (r + \lambda) \phi_j \right] q_i, \quad (7)$$

for all $i \in \mathbf{I}_j$ and $j = 1, \dots, N$. The variable λ is the Lagrange multiplier associated with the borrowing constraint for bank credit. This is the shadow price of liquidity for the downstream firm and it is positive only if the constraint is binding. For the analysis that follows we assume that \bar{b} is sufficiently small so that the borrowing constraint is always binding in equilibrium. Therefore, $\lambda > 0$.

Using the first order conditions we derive the demand for intermediate good i as a function of q_i , ϕ_j , λ and y ,

$$x_i = D_i(q_i, \phi_j, y, \lambda) \equiv \frac{y}{[1 + (r + \lambda)\phi_j]^\varepsilon q_i^\varepsilon}, \quad \text{for } i \in \mathbf{I}_j, \text{ and } j = 1, 2, \dots, N. \quad (8)$$

The demand function is the same as in the standard Dixit-Stiglitz monopolistic competition model except that the cost of purchasing the intermediate good i is augmented by the financing and shadow cost $(r + \lambda)q_i\phi_j$. In absence of down payment, that is, $\phi_j = 0$, the cost reduces to the price q_i and we obtain the standard demand function.

We can now use (8) to replace x_i in the production function (4) to obtain,

$$1 = \sum_{j=1}^N \left[1 + (r + \lambda)\phi_j\right]^{1-\varepsilon} \int_{i \in \mathbf{I}_j} q_i^{1-\varepsilon}. \quad (9)$$

This equation defines the shadow price λ as a function of intermediate prices $\mathbf{Q} \equiv \{q_i\}_{i \in [0,1]}$ and down payments requirements $\mathbf{\Phi} = \{\phi_1, \dots, \phi_N\}$ chosen by the N upstream firms. Also, under the assumption that the borrowing constraint is binding, we can use (8) to replace x_i in the borrowing constraint (5) to obtain,

$$y = \frac{\bar{b}}{\sum_{j=1}^N \phi_j [1 + (r + \lambda)\phi_j]^{-\varepsilon} \int_{i \in \mathbf{I}_j} q_i^{1-\varepsilon}}. \quad (10)$$

This equation defines final output y as a function of intermediate prices $\mathbf{Q} \equiv \{q_i\}_{i \in [0,1]}$, down payments requirements $\mathbf{\Phi} = \{\phi_1, \dots, \phi_N\}$, and shadow price λ . Since equation (9) defines λ as a function of \mathbf{Q} and $\mathbf{\Phi}$, final output is also a function of \mathbf{Q} and $\mathbf{\Phi}$. The next step is to derive the prices of intermediate inputs and down payments chosen by upstream firms.

3.3 Upstream firms

Upstream firms have the financial capability of providing trade credit (lending) to downstream firms. Each upstream firm j chooses the fraction of sales that needs to be paid in advance by the purchasing firms, ϕ_j . The remaining fraction, $1 - \phi_j$, is paid at the end of the period and represents trade credit. There is no interests on trade credit, although the prices chosen by upstream firms may reflect, implicitly, interest charges.

We assume that an upstream firm cannot differentiate the trade lending policy ϕ_j across goods and costumer firms in the downstream sector. Since there is a finite number of upstream firms, this assumption implies that the optimal choice of ϕ_j takes into account the aggregate implications of this policy. On the other hand, the production and pricing policies are specific to each of the continuum of goods produced by the upstream firm. Therefore, the production and price choice of a single intermediate good i , with $i \in \mathbf{I}_j$, has negligible aggregate consequences.

In addition, upstream firm j is endowed with e_j units of the composite goods, and needs working capital equal to its sales $\int_{i \in \mathbf{I}_j} x_i q_i$. The firm can fund working capital with the endowed funds, c_j , and the down payments from its customers, $\phi_j \int_{i \in \mathbf{I}_j} x_i q_i$. The firm can also invest on a financial asset that has a risk-free return of r_f . The flow of funds constraint for upstream firm j , before production, is

$$\phi_j \int_{i \in \mathbf{I}_j} x_i q_i + e_j = \int_{i \in \mathbf{I}_j} x_i q_i + a_j, \quad (11)$$

where $a_j \geq 0$, is the amount of funds invested on financial assets. The above equation can also be re-written as

$$e_j = (1 - \phi_j) \int_{i \in \mathbf{I}_j} x_i q_i + a_j, \quad (12)$$

which says that the endowed funds, e_j , are allocated between trade lending and financial investments. Lower down payment requirements imply that the upstream firms is left with less funds for financial investments. Thus, r_f is the opportunity cost of trade lending for upstream firms when the non-negative constraint for financial investments does not bind, that is, $a_j > 0$.

Upstream firms set prices and down payment ratios and choose their holdings of financial assets taking as given the demand function from downstream firms and the policies of other upstream firms (prices and down payments). The optimization problem is

$$\max_{\{q_i\}_{i \in \mathbf{I}_j}, \phi_j} \int_{i \in \mathbf{I}_j} q_i x_i - \int_{i \in \mathbf{I}_j} c(x_i) - g(\phi_j) \int_{i \in \mathbf{I}_j} q_i x_i + a_j r_f \quad (13)$$

subject to (8).

The first term in the objective function is the revenue from sales; the second term is the direct cost of production; the third term is the monitoring cost. Providing more trade credit may increase the sales of upstream firms. However, this also increases the risk of not being paid by the purchasing firms. To avoid this risk, upstream firms have to incur a monitoring cost that increases with the fraction of sales funded with trade credit (or, equivalently, decreases with the down payment fraction). To use a compact notation we define the down payment net of the monitoring cost as $g(\phi_j) \int_{i \in \mathbf{I}_j} x_i q_i$, where $g'(\phi_j) < 0$ and $g''(\phi_j) > 0$. The monitoring cost decreases in ϕ_j because $g'(\phi_j) < 0$ but the rate of decrease declines with ϕ_j because $g''(\phi_j) > 0$. This captures the idea that increasing the down payment rate is especially beneficial when ϕ_j is low because agency problems are more severe.

The problem solved by the upstream firm is subject to the demand for its products, equation (8). The demand depends not only on its policies, \mathbf{Q}_j and ϕ_j , but also on the policies of other upstream firms through the shadow price λ which, according to equation (9), is a function of $\mathbf{Q} = \{\mathbf{Q}_1, \dots, \mathbf{Q}_N\}$ and $\Phi = \{\phi_1, \dots, \phi_N\}$.

The strategic interaction between upstream firms takes the form of a Nash game where each upstream firm takes as given the policies chosen by other upstream firms, that is, prices and down payments. This allows us to derive the optimal response functions which will be used to define the equilibrium.

The optimality conditions for the choice of prices and down payment can be derived by differentiating problem (13) with respect to q_i and ϕ_j . The resulting conditions are,

$$\left[q_i f(\phi_j, \mu_j) - c'(x_i) \right] \frac{\partial x_i}{\partial q_i} + f(\phi_j, \mu_j) x_i = 0, \quad (14)$$

$$\int_{i \in \mathbf{I}_j} \left[f(\phi_j, \mu_j) q_i - c'(x_i) \right] \frac{\partial x_i}{\partial \phi_j} + f'_{\phi_j}(\phi_j, \mu_j) \int_{i \in \mathbf{I}_j} q_i x_i = 0, \quad (15)$$

where we have defined the function

$$f(\phi_j, \mu_j) \equiv 1 - (1 - \phi_j) \mu_j - g(\phi_j), \quad (16)$$

with μ_j being the Lagrangian multiplier associated with constraint (11). Thus, μ_j is the shadow value of endowed funds e_j . Note that the endowed funds can also be used for financial investment a_j . Thus, μ_j is bounded below by r_f , and $\mu_j > r_f$ when $a_j = 0$ and $\mu_j = r_f$ when $a_j > 0$.

The function $f(\phi_j, \mu_j)$ depends only on ϕ_j and μ_j , and represents the unitary revenue net of the financial costs. For example, if the firm's sales are $s_j = \int_{i \in \mathbf{I}_j} q_i x_i$, the opportunity cost of trade lending is $s_j(1 - \phi_j)\mu_j$, and the monitoring cost is $s_j g(\phi_j)$. Thus the revenues net of the financial costs are $s_j[1 - (1 - \phi_j)\mu_j - g(\phi_j)] = s_j f(\phi_j, \mu_j)$. Note that $f(\phi_j, \mu_j)$ is strictly increasing in ϕ_j , capturing the fact that higher down payments reduce the financial cost for the upstream firm. This is because the firm lends less funds to downstream firms, which lowers the monitoring cost for trade credit. We assume that the elasticity of $f(\phi_j, \mu_j)$ with respect to ϕ_j , that is, $\phi_j f'_1(\phi_j, \mu_j)/f(\phi_j, \mu_j)$, is decreasing in ϕ_j .

3.4 Equilibrium

An *equilibrium* of the economy consists of prices $\mathbf{Q} = \{\mathbf{Q}_1, \dots, \mathbf{Q}_N\}$, where $\mathbf{Q}_j = \{q_i\}_{i \in \mathbf{I}_j}$, down payment policies $\Phi = \{\phi_1, \dots, \phi_N\}$, and quantities $y, \mathbf{x} = \{x_1, \dots, x_N\}$, and $\mathbf{a} = \{a_1, \dots, a_N\}$ such that (i) the representative downstream firm maximizes its profits; (ii) each upstream firm maximizes its profits; (iii) markets clear.

4 Trade finance externality

When an upstream firm raises the down payment ratio, it reduces not only its own sales (internal effect) but also the sales of other firms (external effect). These two effects are characterized in the next subsection 4.1. In the following subsections 4.2 and 4.3, we show that the externality leads to under provision of trade credit and becomes more severe when the upstream sector is more decentralized.

4.1 Internal and external effects of trade finance

We first analyze how a change in the down payment ratio by upstream firm j affects the demands for its products, i.e., x_i , with $i \in \mathbf{I}_j$. This is the *internal effect* of trade credit. The internal effect can be derived by differentiating by ϕ_j the demand function (8), which for convenience we rewrite here

$$x_i = D_i(q_i, \phi_j, y, \lambda) \equiv \frac{y}{[1 + (r + \lambda)\phi_j]^\varepsilon q_i^\varepsilon}, \quad \text{for } i \in \mathbf{I}_j, \text{ and } j = 1, 2, \dots, N.$$

The derivative allows us to decompose the internal effect as follows:

$$\frac{\partial x_i}{\partial \phi_j} = \underbrace{\frac{\partial D_i}{\partial \phi_j}}_{\text{relative cost}} + \underbrace{\frac{\partial D_i}{\partial \lambda} \frac{\partial \lambda}{\partial \phi_j}}_{\text{liquidity}} + \underbrace{\frac{\partial D_i}{\partial y} \frac{\partial y}{\partial \phi_j}}_{\text{market size}}, \quad \text{for } i \in \mathbf{I}_j. \quad (17)$$

The internal effect is the sum of three separate effects:

1. *Relative cost.* This is the direct impact of the change in down payment on its own demand, keeping y and λ fixed. Note that the cost to purchase a unit of intermediate good i is augmented by the financing and shadow cost, i.e., $\phi_j(r + \lambda)q_i$. Thus, an increase in ϕ_j raises the financing and shadow cost of purchasing x_i , which reduces the demands for the intermediate goods produced by upstream firm j (that is, for goods $i \in \mathbf{I}_j$).
2. *Liquidity.* This is the indirect impact of changes in the down payment ratio required by an upstream firm on the demands for all intermediate goods via λ . Recall that downstream firms finance their down payments with bank credit but the amount borrowed from banks is bounded by \bar{b} . When the liquidity constraint binds, an increase in down payment ratios decreases the amounts of intermediate goods that downstream firms can buy with each dollar borrowed from banks. Therefore, the shadow value of liquidity decreases, i.e., $\partial \lambda / \partial \phi_j < 0$ (see equation (9)). As a result, the demand for all intermediate goods tend to rise.
3. *Market size.* This is the impact of changes in the down payment ratios on the demands for intermediate goods via y , i.e., $(\partial D_i / \partial y)(\partial y / \partial \phi_j)$, where $i \in [0, 1]$. An increase in down payment ratio ϕ_j decreases the production scale of downstream firms, i.e., $\partial y / \partial \phi_j < 0$, as shown in (10). Thus, the demands for all intermediate goods tend to drop as the production scale decreases, i.e., $\partial D_i / \partial y > 0$, for all $i \in [0, 1]$, as shown in (8).

We can now derive how the change in ϕ_j affects the demand of intermediate goods produced by other firms. This is the *external effect* of trade credit, which can be decomposed as follows:

$$\frac{\partial x_i}{\partial \phi_j} = \underbrace{\frac{\partial D_i}{\partial \lambda} \frac{\partial \lambda}{\partial \phi_j}}_{\text{liquidity}} + \underbrace{\frac{\partial D_i}{\partial y} \frac{\partial y}{\partial \phi_j}}_{\text{market size}}, \quad \text{for } i \notin \mathbf{I}_j. \quad (18)$$

The external effect is the sum of two different effects:

1. *Liquidity.* When the liquidity constraint binds, an increase in down payment ratios decreases the amounts of intermediate goods that downstream firms can buy with each dollar borrowed from banks. Therefore, the shadow value of liquidity decreases, i.e., $\partial\lambda/\partial\phi_j < 0$ (see equation (9)). As a result, the demand for all intermediate goods, including those produced by other firms, increases.
2. *Market size.* An increase in down payment ratio ϕ_j decreases the downstream firms' production scale, i.e., $\partial y/\partial\phi_j < 0$. As the production scale contracts, the demand for all intermediate goods decreases, including those produced by other firms.

4.2 Centrally-planned trade finance

When the down payment ratios are determined by upstream firms without coordination, the benefits of trade finance may not be fully internalized. To study the socially optimal level of trade finance, we consider an economy in which the down payment ratios and prices of intermediate goods are chosen by a planner for all the upstream firms.

The planner chooses the prices $q_i \in \mathbf{I}_j$ and down payment ratios ϕ_j for all upstream firms $j = 1, \dots, N$, to maximize total profits. In doing so, however, it takes as given the demand functions from downstream firms. The planner's objective can then be written as

$$\max_{\{q_i\}_{i \in \mathbf{I}_j}, \phi_j, a_j\}_{j=1}^N} \sum_{j=1}^N \left\{ \int_{i \in \mathbf{I}_j} q_i x_i - \int_{i \in \mathbf{I}_j} c(x_i) - g(\phi_j) \int_{i \in \mathbf{I}_j} q_i x_i \right\} \quad (19)$$

subject to (8) and (11).

The first order condition for q_i is the same as that in the benchmark economy and takes the form (14). The first order condition for ϕ_j is

$$\sum_{j=1}^N \left\{ \int_{i \in \mathbf{I}_j} [q_i f(\phi_j, \mu_j) - c'(x_i)] \frac{\partial x_i}{\partial \phi_j} \right\} + f'_1(\phi_j, \mu_j) \int_{i \in \mathbf{I}_j} q_i x_i = 0, \quad (20)$$

By comparing this equation with the first order condition for ϕ_j in the benchmark economy (15), we can see that the planner internalizes the externality

described above. This is because it takes into account the sum of the efficiency conditions for all firms (see summation operator in equation (20)), not just one firm.

Proposition 1 *Consider a symmetric version of the model economy in which $\gamma_j = j/N$ for $j = 1, 2, \dots, N$. Assume that c_j , for $j = 1, 2, \dots, N$, are large enough such that all upstream firms hold positive amounts of financial assets in equilibrium, i.e., $a_j > 0$ for $j = 1, 2, \dots, N$. In the symmetric equilibrium of this economy in which all upstream firms choose the same prices and down payment policies, if $\varepsilon(1 - q^*) < 1$, the equilibrium down payment ratio ϕ^* is higher than the ratio that a planner for all upstream firms would choose.*

Proof 1 *See Appendix.*

4.3 Degree of decentralization

We now characterize how the trade credit externality varies with the degree of decentralization represented by the number of firms, N . A higher value of N (larger number of upstream firms) captures a higher degree of decentralization while a lower value of N (smaller number of upstream firms) captures a lower degree of decentralization.

In addition, to derive sharper analytical results, we make the following assumption about the production cost function:

Assumption 1 *The cost of production takes the form*

$$c(x) = \left(\frac{z}{1 + \alpha} \right) x^{1+\alpha}, \quad (21)$$

where $z > 0$ and $\alpha > 1$.

Consider an increase in the number of firms N . When trade finance is decentralized, an increase in N implies that upstream firms are smaller and, therefore, each firm internalizes less the benefits of trade lending. As a result, the equilibrium down payment rises. We have also shown that, when trade finance is centrally planned, the down payment ratio does not depend on N .

Proposition 2 *Consider a symmetric version of the model economy in which $\gamma_j = j/N$ for $j = 1, 2, \dots, N$. Assume that c_j , for $j = 1, 2, \dots, N$, are large enough such that all upstream firms hold positive amounts of financial assets in equilibrium, i.e., $a_j > 0$ for $j = 1, 2, \dots, N$. The equilibrium down payment ratio ϕ^* decreases with N , while the socially efficient level of down payment ratio does not depend on N .*

Proof 2 *See Appendix.*

Figure 4.3 illustrates this property with a numerical example. As can be seen, in the decentralized economy a higher number of upstream firms results in higher down payment and lower aggregate output, while in the planned economy these variables are insensitive to N .

5 Liquidity expansions and cascade effects

Liquidity injection of the central bank increases the available funds for upstream firms that have greater accesses to banks. This could in turn encourage more trade lending to downstream firms. However, a concern often voiced in policy discussions is that extra credit received during liquidity expansions by firms more connected to banks would not necessarily generate an increase in trade lending. Instead, the extra funds could be used to make financial investments with minor spillovers to firms that are less connected with banks. In other words, liquidity expansion may not fully cascade down to the whole economy through the trade credit channel.

We now examine how the trade finance externality affects the degree of liquidity cascade. To this end, we consider a simple asymmetric version of the model in which $N = 2$ and $\gamma_1 > 0.5$. This indicates that upstream firm 1 is larger than firm 2 in the sense that it produces a larger mass of intermediate goods. A liquidity expansion is captured in the model by an increase in the total funds received by upstream firms in the form of higher endowments, that is, $e = e_1 + e_2$. We assume that the endowments of upstream firms are proportional to the variety of goods they produce, which is a proxy for size. Thus,

$$\begin{aligned} e_1 &= \gamma_1 c, \\ e_2 &= (1 - \gamma_1)c. \end{aligned}$$

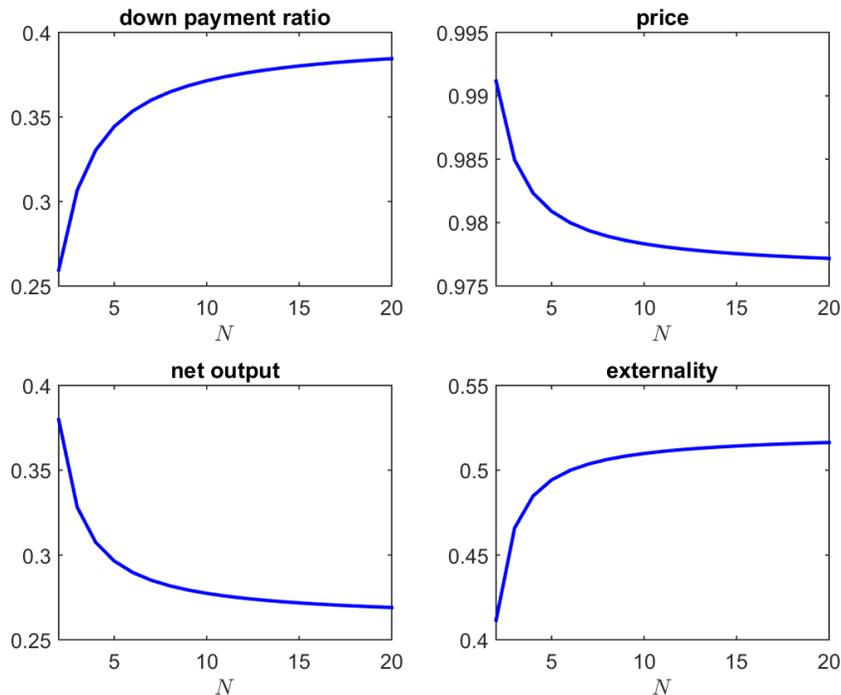


Figure 7: Number of firms

Notes: The figure shows how the equilibrium down payment ratio ϕ^* , net output y^* , price of intermediate goods q^* and the degree of externality change with N . Net output is the difference between the total production of the composite good, y , and the cost to produce intermediate goods in the upstream sector. The degree of externality is measured as the ratio of the external effects to the sum of the external and the internal effects of trade finance (see (17) and (18)). Parameter values are reported in Appendix B.

Figure 8 shows how the two upstream firms respond to the liquidity expansion. The upper panel reports the responses of the shadow values of the endowed funds, μ_j , to the liquidity expansion. Recall that the endowed funds is allocated between trade lending and financial investments as shown in (12). The middle and the bottom panels show the allocations of the endowed funds e_j between financial investment a_j and trade lending $(1 - \phi_j) \int_{i \in \mathbf{I}_j} x_i q_i$, for different levels of e .

When the economy is in *Regime I*, the shadow values of the endowed

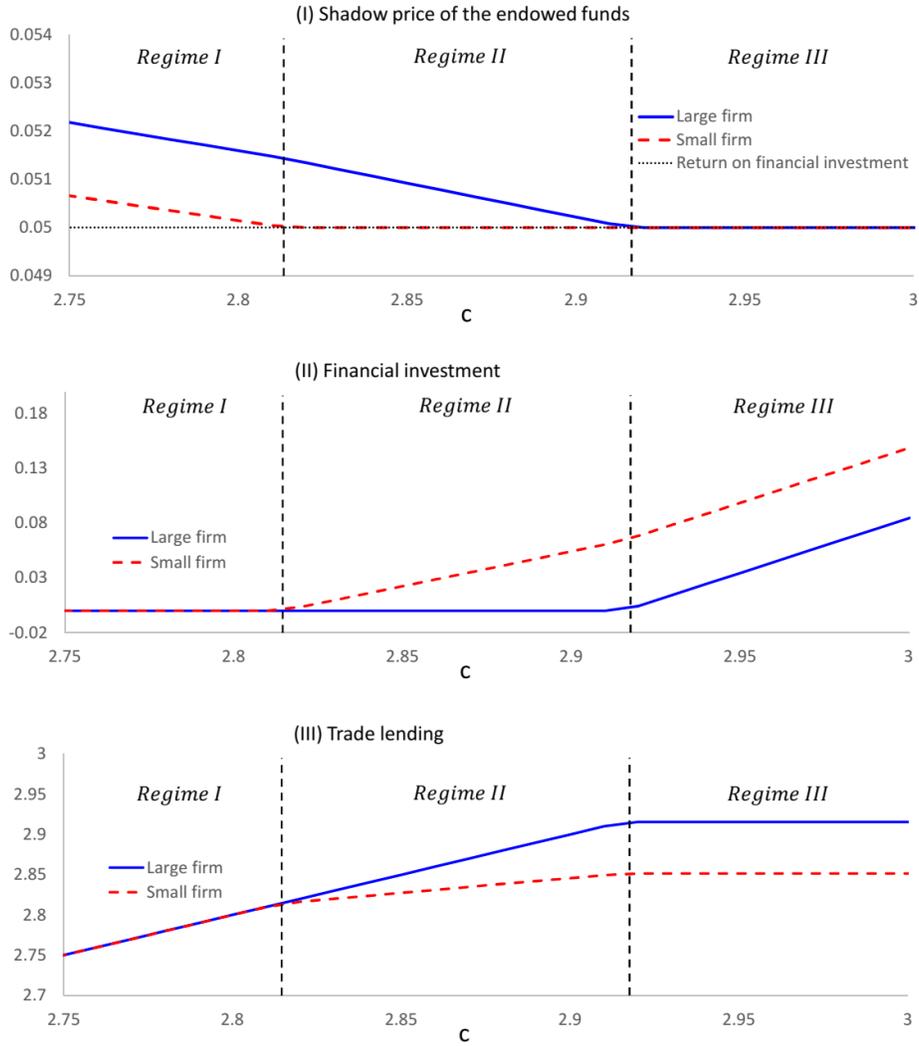


Figure 8: The impacts of liquidity expansion on the large and small upstream firm.

Notes: The above figure shows how the large and small upstream firms respond to the liquidity expansion. The upper panel shows the responses of the shadow values of the endowed funds, μ_j , for $j = 1, 2$, to liquidity expansion. The middle and the bottom panels show the allocations of the endowed funds c_j between financial investment a_j and trade lending $(1 - \phi_j) \int_{i \in \mathbf{I}_j} x_i q_i$ for $j = 1, 2$, and for different levels of c .

funds μ_j is above the return of financial assets r_f for both firms. In addition, the shadow value of the endowed funds is higher for the large upstream firm than for the small upstream firm. This is because the large upstream firm internalizes more the benefits from trade lending and, therefore, values liquidity more. In this case, an increase in e leads only to an increase in trade lending, without raising financial investments. In other words, the extra funds from liquidity expansions fully cascade to downstream firms through trade lending.

When the economy is in *Regime II*, the shadow value of endowed funds for the large firm is still above the return of financial assets. However, for the small firm it drops to r_f . Notice that the shadow value μ_j cannot be below r_f since the endowed funds can always be allocated to financial investments. In this case, all the extra funds from liquidity expansion allocated to the large upstream firm will be used to expand trade lending as in *Regime I*. Instead, the part allocated to the small upstream firm will only be partially used for trade lending to downstream firms. As shown in Figure 8, both financial investments and trade lending of the small upstream firm increase with e . In other words, the liquidity expansion only partially cascades to downstream firms through trade credit.

When the economy is in *Regime III*, the shadow values of the endowed funds e_j drop to r_f for both upstream firms. In this case, all the extra funds received by the large and small firms will be used to make financial investments, and thus liquidity expansion has no effect on trade lending. In other words, the effects of liquidity expansion does not cascade at all to downstream firms.

Region II is the most relevant to show the importance of the externality to limit the downstream cascade of a liquidity expansion. In this region a credit expansion may fail to fully reach downstream firms. This is because some of the upstream firms—those that are smaller and internalize less the value of trade lending for the whole economy—reallocate some of the funds to financial investments rather than passing them down through trade lending.

6 Conclusions

Chinese upstream firms have easier access to bank loans than downstream firms. However, downstream firms can borrow indirectly from banks through trade credit provided by upstream firms. This paper shows that the opti-

mal trade lending of upstream firms is not socially efficient because of an externality that is not fully internalized by individual firms.

When an upstream firm lends to downstream firms, the increased sales is shared with other upstream firms. But since each upstream firm cares only about its own sales, it ignores the benefits that the lending creates to other firms. This implies that in equilibrium the volume of trade credit is below its socially optimal level.

Liquidity injection increases the available funds for upstream firms that have greater accesses to banks. This could in turn encourage more trade lending to downstream firms. However, the effects of liquidity injection to upstream firms may not fully cascade to downstream firms due to trade finance externality. In addition, the severity of trade finance externality varies with firm's size. Large firms internalize more the benefits of trade lending and, therefore, have a stronger incentive to lend the extra funds to downstream firms.

A Mathematical derivations and proofs

A.1 Equilibrium conditions

To derive the equilibrium conditions, we first note that the equilibrium conditions include the following equations. *First*, the demand function for intermediate good i :

$$x_i = D_i(q_i, \phi_j, y, \lambda) \equiv \frac{y}{[1 + (r + \lambda)\phi_j]^\varepsilon q_i^\varepsilon}, \quad (22)$$

for $i \in I_j$ and $j = 1, 2, \dots, N$, and y and λ are functions of \mathbf{Q} and Φ defined by the following equations:

$$1 = \sum_{\kappa=1}^N [1 + (r + \lambda)\phi_\kappa]^{1-\varepsilon} \int_{i \in \mathbf{I}_\kappa} q_i^{1-\varepsilon}, \quad (23)$$

$$y = \frac{\bar{b}}{\sum_{\kappa=1}^N \phi_\kappa [1 + (r + \lambda)\phi_\kappa]^{-\varepsilon} \left(\int_{i \in \mathbf{I}_\kappa} q_i^{1-\varepsilon} \right)}, \quad (24)$$

Second, the first order conditions for q_i and ϕ_j :

$$[q_i f(\phi_j) - c'(x_i)] \frac{\partial x_i}{\partial q_i} + f(\phi_j) x_i = 0, \quad (25)$$

and

$$\int_{i \in \mathbf{I}_j} [q_i f(\phi_j) - c'(x_i)] \frac{\partial x_i}{\partial \phi_j} + f'(\phi_j) \int_{i \in \mathbf{I}_j} q_i x_i = 0, \quad (26)$$

where

$$f(\phi_j) \equiv 1 - (1 - \phi_j)\mu_j - g(\phi_j). \quad (27)$$

Finally, the flow of funds constraint for the upstream firms:

$$\phi_j \int_{i \in \mathbf{I}_j} x_i q_i + c_j = \int_{i \in \mathbf{I}_j} x_i q_i + a_j, \quad (28)$$

and one of the following two conditions should hold:

$$a_j > 0 \quad \text{and} \quad \mu_j = r_f, \quad (29)$$

$$a_j = 0 \quad \text{and} \quad \mu_j > r_f. \quad (30)$$

A.1.1 Derivatives of x_i w.r.t. q_i and ϕ_j

The derivatives $\partial x_i/\partial q_i$ and $\partial x_i/\partial \phi_j$ can be written as

$$\frac{\partial x_i}{\partial q_i} = \frac{\partial D_i}{\partial q_i} + \frac{\partial D_i}{\partial y} \frac{\partial y}{\partial q_i} + \frac{\partial D_i}{\partial \lambda} \frac{\partial \lambda}{\partial q_i}, \quad (31)$$

$$\frac{\partial x_i}{\partial \phi_j} = \frac{\partial D_i}{\partial \phi_j} + \frac{\partial D_i}{\partial y} \frac{\partial y}{\partial \phi_j} + \frac{\partial D_i}{\partial \lambda} \frac{\partial \lambda}{\partial \phi_j}. \quad (32)$$

The derivatives of D_i with respect to q_i , ϕ_j , y and λ are given by

$$\frac{\partial D_i}{\partial q_i} = \frac{-\varepsilon y}{[1 + \phi_j(r + \lambda)]^\varepsilon q_i^{1+\varepsilon}} \quad (33)$$

$$\frac{\partial D_i}{\partial \phi_j} = \frac{-\varepsilon y(r + \lambda)}{[1 + \phi_j(r + \lambda)]^{1+\varepsilon} q_i^\varepsilon} \quad (34)$$

$$\frac{\partial D_i}{\partial y} = \frac{1}{[1 + \phi_j(r + \lambda)]^\varepsilon q_i^\varepsilon} \quad (35)$$

$$\frac{\partial D_i}{\partial \lambda} = \frac{-\varepsilon y \phi_j}{[1 + \phi_j(r + \lambda)]^{1+\varepsilon} q_i^\varepsilon} \quad (36)$$

To obtain $\partial \lambda/\partial q_i$ and $\partial \lambda/\partial \phi_j$ we use (23) which defines implicitly λ as a function of \mathbf{Q} and $\mathbf{\Phi}$. Using the implicit function theorem we obtain

$$\frac{\partial \lambda}{\partial q_i} = 0 \quad (37)$$

$$\frac{\partial \lambda}{\partial \phi_j} = -\frac{(r + \lambda) [1 + \phi_j(r + \lambda)]^{-\varepsilon} \int_{i \in \mathbf{I}_j} q_i^{1-\varepsilon}}{\sum_{\kappa=1}^N \phi_\kappa [1 + \phi_\kappa(r + \lambda)]^{-\varepsilon} \int_{i \in \mathbf{I}_\kappa} q_i^{1-\varepsilon}}. \quad (38)$$

To obtain $\partial y/\partial q_i$ and $\partial y/\partial \phi_j$, we first define

$$z(\mathbf{Q}, \mathbf{\Phi}, \lambda) = \sum_{\kappa=1}^N \phi_\kappa [1 + \phi_\kappa(r + \lambda)]^{-\varepsilon} \left(\int_{i \in \mathbf{I}_\kappa} q_i^{1-\varepsilon} \right), \quad (39)$$

so that we can write (24) as:

$$y = \frac{\bar{b}}{z(\mathbf{Q}, \mathbf{\Phi}, \lambda)}. \quad (40)$$

The derivatives of y with respect to q_i and ϕ_j are given by

$$\frac{\partial y}{\partial q_i} = 0, \quad (41)$$

$$\frac{\partial y}{\partial \phi_j} = -\frac{\bar{b}}{z^2} \left(\frac{\partial z(\mathbf{Q}, \Phi, \lambda)}{\partial \phi_j} + \frac{\partial z(\mathbf{Q}, \Phi, \lambda)}{\partial \lambda} \frac{\partial \lambda}{\partial \phi_j} \right), \quad (42)$$

where

$$\frac{\partial z(\mathbf{Q}, \Phi, \lambda)}{\partial \phi_j} = \left[1 - \varepsilon \frac{\phi_j(r + \lambda)}{1 + \phi_j(r + \lambda)} \right] [1 + \phi_j(r + \lambda)]^{-\varepsilon} \int_{i \in \mathbf{I}_j} q_i^{1-\varepsilon}, \quad (43)$$

$$\frac{\partial z(\mathbf{Q}, \Phi, \lambda)}{\partial \lambda} = -\sum_{\kappa=1}^N \frac{\varepsilon \phi_\kappa^2}{[1 + \phi_\kappa(r + \lambda)]^{1+\varepsilon}} \int_{i \in \mathbf{I}_\kappa} q_i^{1-\varepsilon}, \quad (44)$$

and $\partial \lambda / \partial \phi_j$ is given by (38).

A.1.2 Symmetric equilibrium

Denote by q^* , ϕ^* , x^* , y^* and λ^* the variables in the symmetric equilibrium. By imposing symmetric equilibrium on (22), (23), (24) and (39), we have

$$x^* = \frac{y^*}{[1 + \phi^*(r + \lambda^*)]^\varepsilon (q^*)^\varepsilon}, \quad (45)$$

$$q^* = \frac{1}{1 + \phi^*(r + \lambda^*)}, \quad (46)$$

$$y^* = \frac{\bar{b}}{\phi^* [1 + \phi^*(r + \lambda^*)]^{-\varepsilon} (q^*)^{1-\varepsilon}}, \quad (47)$$

$$z^* = \phi^* [1 + \phi^*(r + \lambda^*)]^{-\varepsilon} (q^*)^{1-\varepsilon}. \quad (48)$$

By using (46) in the other three equations, we have

$$x^* = y^* = \frac{\bar{b}}{\phi^* q^*}, \quad (49)$$

$$z^* = \phi^* q^*. \quad (50)$$

By evaluating (33), (34), (35), (36), (37), (38), (41), (42), (43) and (44), and using (46), (49) and (50) in the obtained equations, we have

$$\left. \frac{\partial D_i}{\partial q_i} \right|_{\mathbf{Q}=\mathbf{Q}^*, \Phi=\Phi^*} = -\varepsilon \frac{y^*}{q^*} \quad (51)$$

$$\left. \frac{\partial D_i}{\partial \phi_j} \right|_{\mathbf{Q}=\mathbf{Q}^*, \Phi=\Phi^*} = -\varepsilon \frac{y^*}{\phi^*} (1 - q^*) \quad (52)$$

$$\left. \frac{\partial D_i}{\partial y} \right|_{\mathbf{Q}=\mathbf{Q}^*, \Phi=\Phi^*} = 1 \quad (53)$$

$$\left. \frac{\partial D_i}{\partial \lambda} \right|_{\mathbf{Q}=\mathbf{Q}^*, \Phi=\Phi^*} = -\varepsilon y^* \phi^* q^* \quad (54)$$

$$\left. \frac{\partial \lambda}{\partial q_i} \right|_{\mathbf{Q}=\mathbf{Q}^*, \Phi=\Phi^*} = 0 \quad (55)$$

$$\left. \frac{\partial \lambda}{\partial \phi_j} \right|_{\mathbf{Q}=\mathbf{Q}^*, \Phi=\Phi^*} = -\frac{r + \lambda^*}{N \phi^*} \quad (56)$$

$$\left. \frac{\partial y}{\partial q_i} \right|_{\mathbf{Q}=\mathbf{Q}^*, \Phi=\Phi^*} = 0 \quad (57)$$

$$\left. \frac{\partial y}{\partial \phi_j} \right|_{\mathbf{Q}=\mathbf{Q}^*, \Phi=\Phi^*} = -\frac{y^*}{N \phi^*} \quad (58)$$

$$\left. \frac{\partial z}{\partial \phi_j} \right|_{\mathbf{Q}=\mathbf{Q}^*, \Phi=\Phi^*} = \frac{q^* [1 - \varepsilon(1 - q^*)]}{N} \quad (59)$$

$$\left. \frac{\partial z}{\partial \lambda} \right|_{\mathbf{Q}=\mathbf{Q}^*, \Phi=\Phi^*} = -\varepsilon (\phi^* q^*)^2 \quad (60)$$

By using the above equations in (31) and (32), we have

$$\left. \frac{\partial x_i}{\partial q_i} \right|_{\mathbf{Q}=\mathbf{Q}^*, \Phi=\Phi^*} = -\varepsilon \frac{y^*}{q^*} \quad (61)$$

$$\left. \frac{\partial x_i}{\partial \phi_j} \right|_{\mathbf{Q}=\mathbf{Q}^*, \Phi=\Phi^*} = -\frac{y^*}{\phi^*} \left[\frac{1}{N} + \varepsilon \left(\frac{N-1}{N} \right) (1 - q^*) \right] \quad (62)$$

By evaluating (25) at the equilibrium point and using (61) in the obtained equation, we have

$$-\varepsilon [q^* f(\phi^*) - c'(y^*)] \frac{y^*}{q^*} + f(\phi^*) y^* = 0, \quad (63)$$

which implies

$$q^* f(\phi^*) = \left(\frac{\varepsilon}{\varepsilon - 1} \right) c'(y^*). \quad (64)$$

By evaluating (26) at the equilibrium point and using (62) we obtain

$$\frac{1}{\varepsilon} \left[\frac{1}{N} + \varepsilon \left(\frac{N-1}{N} \right) (1 - q^*) \right] = \frac{\phi^* f'(\phi^*)}{f(\phi^*)} \quad (65)$$

Thus, the equilibrium prices and down payment policies, q^* and ϕ^* , are jointly determined by (64) and (65).

A.2 Proofs of propositions

A.2.1 Proof of Proposition 1

Note that the only difference between the planner's equilibrium and the competitive equilibrium is that the first order condition for ϕ_j is changed from (15) to (20), while all other equilibrium conditions do not change. To solve for the equilibrium level of down payment ratio in the planner's economy, we first note that by imposing symmetry, (20) can be written as

$$\frac{1}{\varepsilon} = \frac{\phi_p^* f'(\phi_p^*)}{f(\phi_p^*)}. \quad (66)$$

Recall also that in the equilibrium of the market economy, q^* and ϕ^* , are jointly determined by (64) and (65). By comparing the two first order conditions, it is easy to see that if $\varepsilon(1 - q^*) < 1$ in the competitive equilibrium, the left-hand-side of (65) is smaller than the left-hand-side of (66). Since the right-hand-sides of (65) and (66) are the same and decreasing in ϕ_j , it follows that $\phi^* > \phi_p^*$. ■

A.2.2 Proof of Proposition 2

Note that under Assumption 1, by using (49) in (64) to eliminate x^* , we have

$$q^* f(\phi^*) = \left(\frac{\varepsilon}{\varepsilon - 1} \right) z^{1+\alpha} \left(\frac{\bar{b}}{\phi^* q^*} \right)^\alpha, \quad (67)$$

which implies

$$q^* = z \left(\frac{\varepsilon}{(\varepsilon - 1) f(\phi^*)} \right)^{\frac{1}{1+\alpha}} \left(\frac{\bar{b}}{\phi^*} \right)^{\frac{\alpha}{1+\alpha}}.$$

By using the above equation in (65) to eliminate q^* , we obtain

$$\varepsilon^{-1} \left\{ \frac{1}{N} + \varepsilon \left(\frac{N-1}{N} \right) \left[1 - z \left(\frac{\varepsilon}{(\varepsilon-1)f(\phi^*)} \right)^{\frac{1}{1+\alpha}} \left(\frac{\bar{b}}{\phi^*} \right)^{\frac{\alpha}{1+\alpha}} \right] \right\} = \frac{\phi^* f'(\phi^*)}{f(\phi^*)},$$

by which the equilibrium down payment policy ϕ^* is determined. Note that the left hand side of the above equation is increasing in ϕ^* and the right hand side is decreasing in ϕ^* . Thus, if there exists an equilibrium, ϕ^* is uniquely determined. In addition, an increase in N shifts the left hand side downward and leads to increases ϕ^* . ■

B Parameter values

Parameter	Value	Description
z	0.9	scalar in cost function
α	0.01	elasticity of cost w.r.t. production scale, $1+\alpha$
r	0.05	interest rate
\bar{b}	1.0	maximum bank credit of downstream firms
ε	20	elasticity of substitution between intermediate goods
N	20	number of upstream firms in the sector i
Functions		
$c(\cdot)$	$c(x) = (z/1 + \alpha) x^{1+\alpha}$, for $x > 0$.	
$g(\cdot)$	$g(\phi) = 0.35 \log(\phi - 0.3) + 1$, for $\phi \in (0.3, 1]$.	

Table 5: Parameter values and function forms.

C Supplementary empirical results

C.1 Industrial upstreamness

To measure the industries' upstreamness, we consider a variant of Acemoglu et al. (2012). In the economy, households inelastically supply one unit of labor. There are N industries, indexed by $i = 1, 2, \dots, N$, which produce N distinct intermediate goods using Cobb-Douglas technologies. The production function of the representative firm of industry i is given by

$$x_i = \tau_i z_i l_i^{\alpha_i} \prod_{j=1}^N x_{ij}^{(1-\alpha_i)\omega_{ij}}, \quad (68)$$

where l_i is the amount of labor employed in industry i , $\alpha_i \in [0, 1]$ is the share of labor in total expenditures on inputs, x_{ij} are the amounts of intermediate goods j used by industry i , $\omega_{ij} \in [0, 1]$ are the shares of goods j in the non-labor inputs of industry i , with $\sum_{j=1}^N \omega_{ij} = 1$, z_i is the idiosyncratic productivity, and τ_i is an industry-specific constant given by

$$\tau_i = \left[\alpha_i^{\alpha_i} (1 - \alpha_i)^{(1-\alpha_i)} \prod_{j=1}^N \omega_{ij}^{\omega_{ij}} \right]^{-1}.$$

The representative consumption goods producer, indexed by 0, has a Cobb-Douglas technology over n intermediate goods:

$$y = \tau_0 \prod_{j=1}^N x_{0j}^{\theta_j}, \quad (69)$$

where $\theta_j > 0$, with $\sum_{i=1}^N \theta_i = 1$, are the shares of intermediate good i in the input expenditures of the consumption goods producers, and τ_0 is a constant given as

$$\tau_0 \equiv \left[\prod_{j=1}^N \theta_j^{\theta_j} \right]^{-1}.$$

We assume that market imperfections lead to exogenous transaction costs. Let p_j be the price of intermediate good j in terms of consumption goods, and w be the price of labor in terms of consumption goods. The costs to

purchase intermediate good j is assumed to be $(1 + \lambda)p_j$, with $\lambda > 0$, for $j = 1, 2, \dots, N$, and the costs for industry i to purchase labor inputs is assumed to be $(1 + \mu_i)w$, where $\mu_i > 0$ and $i = 1, 2, \dots, N$.

We start by solving the optimization problem of the representative firm i . By plugging the first order conditions for x_{ij} , with $j = 1, 2, \dots, N$, into the production function of the representative firm of industry i , (68), we obtain

$$\ln p_i = \alpha_i(\ln w + \ln \mu_i) + (1 - \alpha_i) \sum_{j=1}^N \omega_{ij}(\ln p_j + \ln \lambda) - \ln z_i, \quad (70)$$

which can be written compactly as

$$\ln \mathbf{p} = \mathbf{diag}(\boldsymbol{\alpha})(\mathbf{1} \ln w + \ln \boldsymbol{\mu}) + \mathbf{diag}(\mathbf{1} - \boldsymbol{\alpha})\boldsymbol{\Omega}(\ln \mathbf{p} + \mathbf{1} \ln \lambda) - \ln \mathbf{z},$$

where $\mathbf{1} \equiv (1, 1, \dots, 1)'$ is a $N \times 1$ vector of ones, the bold letters represent the vectors of the corresponding variables for all the industries, e.g., $\mathbf{p} \equiv (p_1, p_2, \dots, p_N)'$, and $\boldsymbol{\Omega} \equiv [\omega_{ij}]$ is the $N \times N$ matrix of ω_{ij} . Thus, the price vector, \mathbf{q} , can be solved for using the above system of equations as

$$\ln \mathbf{p} = \mathbf{1} \ln w + \ln \boldsymbol{\mu} - \boldsymbol{\Psi} \ln \mathbf{z} + (\boldsymbol{\Psi} - \mathbf{I}) \mathbf{1} \ln \lambda, \quad (71)$$

where $\boldsymbol{\Psi} \equiv [\mathbf{I} - \mathbf{diag}(\mathbf{1} - \boldsymbol{\alpha})\boldsymbol{\Omega}]^{-1}$ is a Leontief inverse matrix.¹

Then, we solve the optimization problem of the competitive consumption goods producers. By plugging the first order conditions for x_{0j} , with $j = 1, 2, \dots, N$, into the production function of the representative consumption goods producer, (69), we obtain:

$$0 = \sum_{j=1}^N \theta_j \ln p_j. \quad (72)$$

Note that the net output equals the wage income in this economy, i.e., $y = w$. By using the above equation in (71), the net-output of the economy, y , can be solved for as:

$$\ln y = \boldsymbol{\beta}' \ln \mathbf{z} - \boldsymbol{\theta}' (\boldsymbol{\Psi} - \mathbf{I}) \mathbf{1} \ln \lambda - \ln \boldsymbol{\mu}, \quad (73)$$

¹It is shown that $\boldsymbol{\Psi} \mathbf{diag}(\boldsymbol{\alpha}) = \mathbf{1}$, and that $\boldsymbol{\Psi} \mathbf{diag}(\mathbf{1} - \boldsymbol{\alpha})\boldsymbol{\Omega} = \boldsymbol{\Psi} - \mathbf{I}$. See details in Liu (2017).

where $\beta \equiv (\theta' \Psi)'$ is the influence vector, and the i th element, β_i , corresponds to the percentage change in the net output of the economy, y , in responding to one percent change in industry i 's productivity, z_i .

Following Liu (2017), we define the upstream score of industry i as its influence on the aggregate net output (via downstream propagation) relative to sales, which is given as

$$\xi_i = \frac{\beta_i}{\gamma_i}, \quad (74)$$

where $\gamma_i = (x_i p_i)/y$ is the ratio of industry i 's sales to the aggregate net output.

We estimate ω_{ij} , θ_i , μ_i , for $i, j = 1, 2, \dots, N$, and λ using the 2007 input-output table of China. The transaction cost, λ , is set to 0.1, as estimated by Liu (2017). Parameters θ_i , for $i = 1, 2, \dots, N$, are estimated as the actual share of good i in the aggregate consumption. The share of expenditure on input j in industry i 's total expenditures on intermediate goods, ω_{ij} , for $i, j = 1, 2, \dots, N$, are set equal to its data counterparts. Parameters α_i , with $i = 1, 2, \dots, N$, are calibrated such that the total expenditure shares on intermediate goods, $1 - \alpha_i$, are equal to the actual ratios of total values of intermediate good inputs multiplied by $1 + \lambda$ to sales. The values of μ_i , with $i = 1, 2, \dots, N$, are chosen such that γ_i , i.e., the ratio of industry i 's sales to the aggregate wage, match their data counterparts.

Figure 9 shows the demand share matrix of all industries. The size of the dot on the i th row and j th column represents the share of intermediate goods i used by industry j , and the industries are ordered according to their upstream rank from top to bottom and from left to right. Figures 10, 11, and 12 show only the significant supply-demand relationships, in which demand shares below 5%, 10%, and 15% are removed. Figure 13 shows the demand share matrix for only manufacturing industries, in which demand shares of non-manufacturing industries and those below 10% are removed. As shown in these figures, the important supply-demand relationships are in the upper-right triangles of the figures, which indicates that upstream firms are important suppliers to the downstream firms, and not the opposite.

Industry	Upstream Rank	Upstream Score
Top 10:		
Non-ferrous metal mining and dressing	1	1.57
Ferrous metal mining and dressing	2	1.50
Coking industry	3	1.48
Waste and scrap	4	1.46
Iron industry	5	1.46
Ferroalloy smelting industry	6	1.46
Non-ferrous metal smelting and alloy manufacturing	7	1.44
Oil and gas extraction	8	1.44
Steel industry	9	1.44
Coal mining and washing industry	10	1.42
Bottom 10:		
Liquid milk and dairy products manufacturing	126	0.89
Other food manufacturing	127	0.89
Resident service industry	128	0.88
Health	129	0.88
Convenience food manufacturing	130	0.87
Education	131	0.86
Public facilities management industry	132	0.84
Public administration and social organization	133	0.84
Social welfare industry	134	0.84
Physical education	135	0.84

Table 6: The top and bottom ten industries

Manufacturing Industry	Upstream Rank	Upstream Score
Top 10:		
Coking industry	3	1.48
Waste and scrap	4	1.46
Iron industry	5	1.46
Ferrous alloy smelting industry	6	1.46
Non-ferrous metal smelting and alloy manufacturing	7	1.44
Steel industry	9	1.44
Metal processing machinery manufacturing	11	1.42
Mining, metallurgy, construction equipment manufacturing	12	1.41
Chemical, wood, non-metal processing equipment manufacturing	13	1.40
Transmission and distribution and control equipment manufacturing	14	1.39
Bottom 10:		
Leather, fur, feather (velvet) and their products	112	1.00
Textile and garment, shoes and hat manufacturing	113	1.00
Home audio-visual equipment manufacturing	114	1.00
Pharmaceutical manufacturing	118	0.96
Slaughter and meat processing industry	121	0.96
Other food processing industry	122	0.95
Condiment, fermented product manufacturing	123	0.93
Liquid milk and dairy products manufacturing	126	0.89
Other food manufacturing	127	0.89
Convenience food manufacturing	130	0.87

Table 7: The top and bottom ten manufacturing industries

Two-digit Manufacturing Industry	Upstream Rank
Upstream:	
Ferrous metal smelting and rolling processing industry	1
Non-ferrous metal smelting and rolling processing industry	2
Petroleum processing, coking and nuclear fuel processing	3
General equipment manufacturing	4
Instrumentation manufacturing	5
Special equipment manufacturing	6
Metal products industry	7
Chemical fiber manufacturing	8
Rubber and plastic products industry	9
Electrical machinery and equipment manufacturing	10
Chemical raw materials and chemical manufacturing	11
Transportation equipment manufacturing	12
Paper and paper products industry	13
Downstream:	
Non-metallic mineral products industry	14
Wood processing and wood, bamboo, rattan, palm, grass products industry	15
Textile industry	16
Computer, communications and other electronic equipment manufacturing	17
Printing and recording media reproduction industry	18
Textile and apparel, apparel industry	19
Furniture manufacturing	20
Wine, beverage and refined tea manufacturing	21
Tobacco industry	22
Agricultural and sideline food processing industry	23
Leather, fur, feathers and their products and footwear	24
Pharmaceutical manufacturing	25
Food manufacturing	26

Table 8: Two-digit manufacturing industries ranked by upstreamness

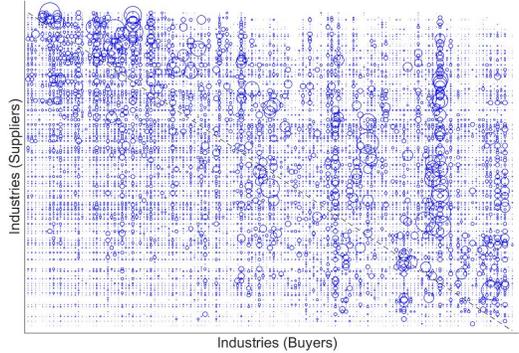


Figure 9: Demand share matrix of industries (no truncation)

Notes: The above figure shows the demand share matrix of all industries, in which the size of the dot on the i th row and j th column represents the share of intermediate goods i used by industry j , and the industries are ordered according to their upstream rank from top to bottom and from left to right. Within-section transactions are excluded.



Figure 10: Demand share matrix of industries (truncated below at 5%)

Notes: The above figure shows the demand share matrix of all industries truncated below at 5%, in which the size of the dot on the i th row and j th column represents the share of intermediate goods i used by industry j , and the industries are ordered according to their upstream rank from top to bottom and from left to right. Within-section transactions are excluded.

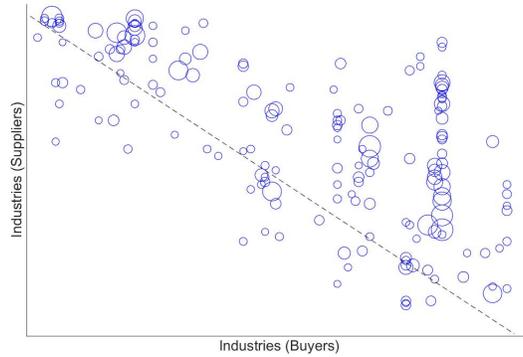


Figure 11: Demand share matrix of industries (truncated below at 10%)

Notes: The above figure shows the demand share matrix of all industries truncated below at 10%, in which the size of the dot on the i th row and j th column represents the share of intermediate goods i used by industry j , and the industries are ordered according to their upstream rank from top to bottom and from left to right. Within-section transactions are excluded.

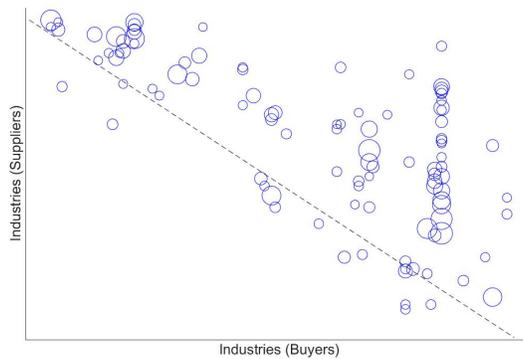


Figure 12: Demand share matrix of industries (truncated below at 15%)

Notes: The above figure shows the demand share matrix of all industries truncated below at 15%, in which the size of the dot on the i th row and j th column represents the share of intermediate goods i used by industry j , and the industries are ordered according to their upstream rank from top to bottom and from left to right. Within-section transactions are excluded.

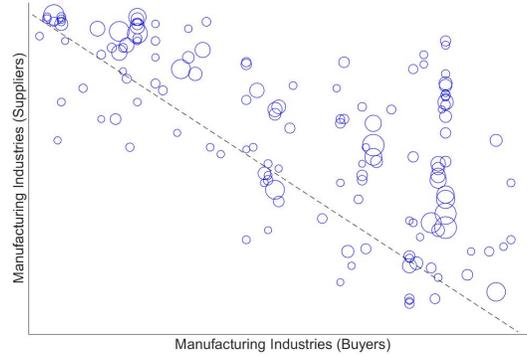


Figure 13: Demand share matrix of manufacturing industries (truncated below at 10%)

Notes: The above figure shows the demand share matrix of manufacturing industries truncated below at 10%, in which the size of the dot on the i th row and j th column represents the share of intermediate goods i used by industry j , and the industries are ordered according to their upstream rank from top to bottom and from left to right. Within-section transactions are excluded.

C.2 Characteristics of the upstream and downstream industries

We document several characteristics of upstream and downstream firms using firm-level data from the 2007 survey of manufacturing enterprises conducted by the National Bureau of Statistics of China. It covers all enterprises with annual sales of at least 5 million RMB, approximately 750,000 US dollars in 2007.

The share of large firms weighted by sales tends to be larger in upstream industries as shown in Figure 14, where large firms are defined as firms with sales higher than 400 million Yuan according to the National Bureau of Statistics of China. The share of large firms is 7% higher in upstream industries than in downstream industries as shown in the second column of Table 1.

The share of state-owned firms weighted by sales also tends to be larger in upstream industries as shown in Figure 15. As shown by the third column of Table 1, the share of state-owned firms is 11% higher in upstream industries than in downstream industries.

As observed before, upstream firms tend to be state-owned and larger, which indicates that upstream firms could be less financially constrained for working capital financing than downstream firms. As shown in Figure 16, the ratio of net trade lending to sales tend to be higher in upstream industries. As shown by the first column of Table 1, the ratio of net trade lending to sales is significantly higher in upstream industries than in downstream industries.

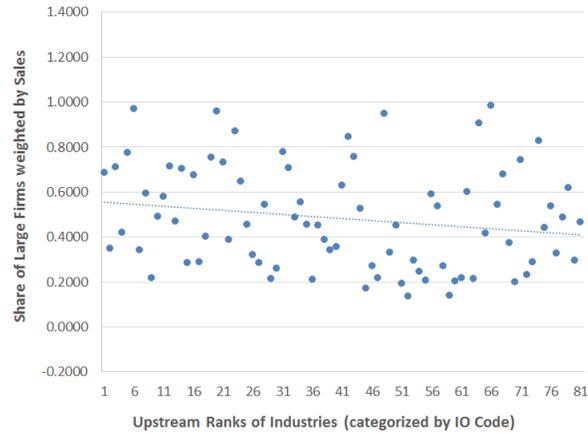


Figure 14: Share of large firms by industry

Notes: The above figure shows the shares of large firms weighted by sales of manufacturing industries, where industries are ordered by their upstream ranks from left to right, and large firms are defined as firms with sales higher than 400 million Yuan according to the National Bureau of Statistics of China.

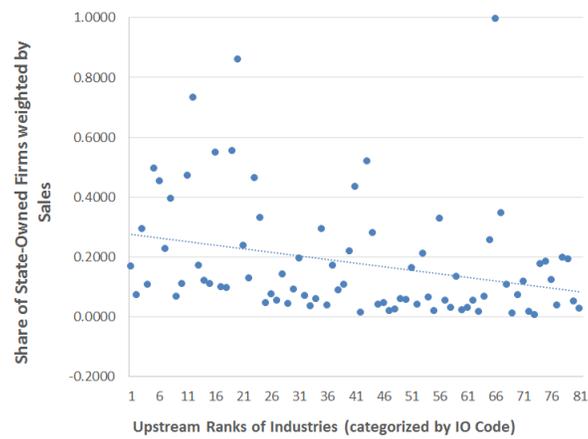


Figure 15: Share of state-owned firms by industry

Notes: The above figure shows the shares of state-owned firms weighted by sales of manufacturing industries, where industries are ordered by their upstream ranks from left to right, and state-owned firms are defined according to the National Bureau of Statistics of China.

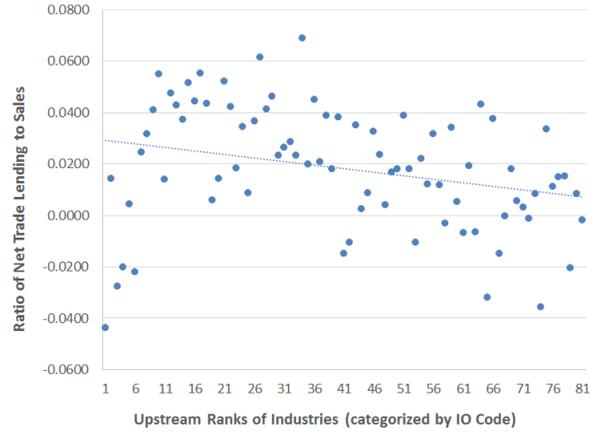


Figure 16: Ratio of net trade lending to sales by industry

Notes: The above figure shows the average ratio of net trade lending to sales of manufacturing industries, where industries are ordered by their upstream ranks from left to right.

C.3 Short-term financing of manufacturing industries



Figure 17: Growth rate of nominal M2

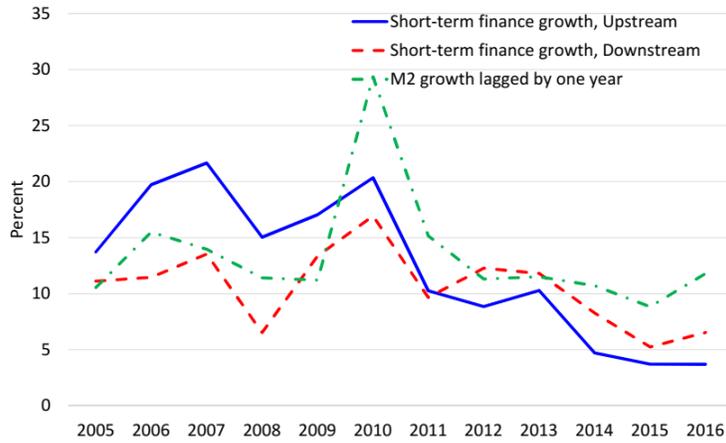


Figure 18: M2 growth v.s. Short-term financing growth of the upstream and downstream industries

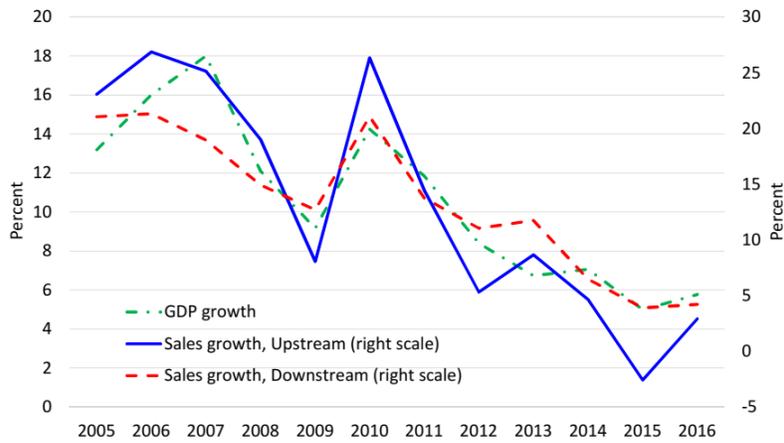


Figure 19: GDP growth v.s. Sales growth of the upstream and downstream industries

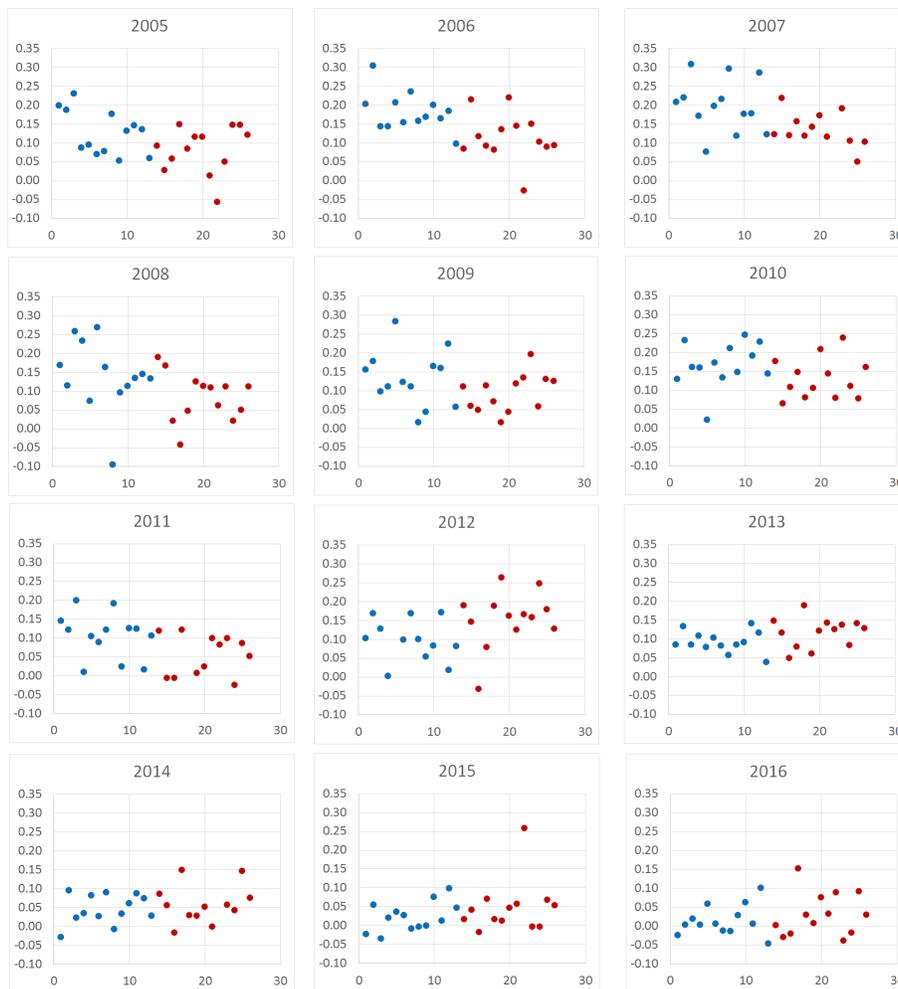


Figure 20: Snapshots of growth rates of short-term borrowing by industry

Notes: Each panel shows the growth rates of short-term borrowing of firms by industry for the year noted at the top. Each dot represents a manufacturing industry. Industries are ordered by their upstream ranks from left to right. Blue (red) dots correspond to the upstream (downstream) industries. The horizontal axis corresponds to the upstream rank.

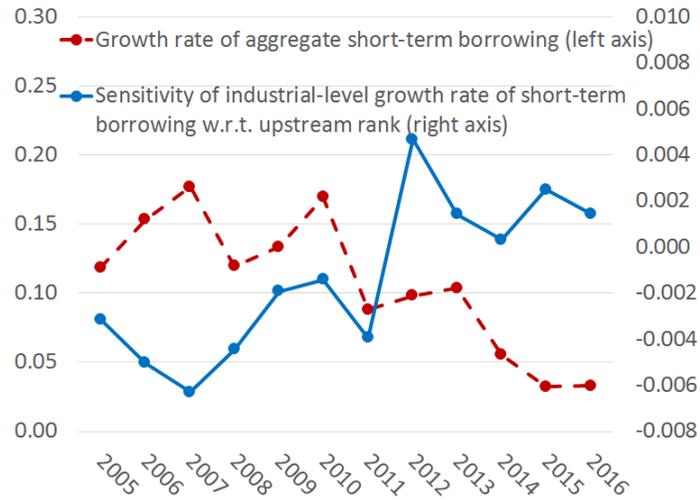


Figure 21: Sensitivity of short-term borrowing growth w.r.t. upstreamness

Notes: The solid (blue) line shows the sensitivity of industrial-level growth rate of short-term borrowing with respect to upstream rank, which corresponds to the slopes of the trend lines in the panels of Figure 20. The dashed (red) line shows the growth rate of aggregate short-term borrowing of all manufacturing firms.

Short-term finance growth				
	I. 2005-2016		II. 2005-2016 excluding 2010	
	Upstream	Downstream	Upstream	Downstream
	(1)	(2)	(3)	(4)
Time	-0.014*** (0.001)	-0.005*** (0.002)	-0.013*** (0.002)	-0.006*** (0.002)
M2 growth (lagged)	0.476*** (0.095)	0.304*** (0.102)	0.894*** (0.283)	0.089 (0.317)
Constant	0.144*** (0.018)	0.095*** (0.019)	0.088** (0.040)	0.124*** (0.044)
Industry F.E.	YES	YES	YES	YES
R-squared	0.540	0.258	0.532	0.209

Table 9: Short-term financing: upstream v.s. downstream industries

Notes: For the regressions reported in Panels I and II, the dependent variable is the growth rate of short-term financing (i.e., the sum of non-inventory current assets and current liabilities). “Time” is the time index, and equals $1, \dots, T$. “M2” is the growth rate of real M2 balance lagged by one year. The regressions reported in Columns (1) and (3) use the subsample that contains only the upstream industries over respectively the period of 2005-2016 and the same period excluding 2010, and the regressions reported in Columns (2) and (4) use the subsample that contains only the downstream industries over respectively the period of 2005-2016 and the same period excluding 2010.

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