

Dynamics of Trade Credit in China*

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Abstract

We use Chinese manufacturing data to show that upstream manufacturing industries received higher credit during the monetary expansion of 2005-2011. However, the higher credit received by upstream industries did not generate a similar increase in ‘trade lending’ to downstream industries, which limited the transmission of the credit expansion to the whole manufacturing sector. We develop a model that formalizes some of the key features of the Chinese economy and show why a credit expansion tilted toward the upstream sector may not fully cascade to the whole economy.

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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 stimulus that increases the liquidity of banks may generate an increase in the supply of credit towards firms that are more connected to banks. Firms that are less connected could still benefit, indirectly, from the supply of ‘trade credit’, that is, loans received from bank-connected firms. In this way, a financial expansion cascades to the whole economy with real macroeconomic effects. However, if the increase in bank lending to bank-connected firms is not followed by an increase in trade credit, the macroeconomic impact of the financial expansion would be limited. 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 its distinctive dual structure. On the one hand, there are large firms—often state-owned and operating in upstream industries—that have easier access to bank credit. On the other, there are smaller firms—often privately owned and operating in downstream industries—with limited access to bank credit. Even if these firms have lower access to banks, they can still fund some of their operations through trade credit, that is, by borrowing from suppliers that have easier access to banks.¹ Is the trade-credit channel effective in propagating the financial expansion to the whole economy?

We first address the question empirically using Chinese data for manu-

¹Several empirical studies show that state-owned firms in China have easier access to bank loans and they serve as intermediaries that borrow from banks and lend to other firms through trade credit. For example, Li et al. (2009) find that state ownership is positively associated with access to long-term debt. Cull et al. (2009) provide evidence that state-owned firms tend to receive more formal credit and provide more trade credit to their customers. Ge and Qiu (2007) show empirically that non-state-owned firms use trade credit more than state-owned firms. Financial policies in China have also a distinctive structure. Financial expansions arise predominantly through bank credit. As a result, firms with privileged access to banks benefit more from the expansion. For example, during the stimulus periods following the 2008 financial crisis, more bank loans were channeled to heavy sectors such as real estate, infrastructure and manufacturing (Chen et al. (2016) and Cong et al. (2019)). For a more detailed description of the financial policies in China we refer the reader to Chen and Zha (2020).

facturing industries over the period 2005-2016. This period is characterized by two distinct phases. In the first phase, spanning from 2005 to 2011, the Chinese economy experienced a liquidity/credit expansion, in part driven by monetary policy. Monetary policy was especially important in 2009-2010 in response to the global financial crisis. The second phase, spanning from 2012 to 2016, was characterized by much lower rates of credit growth.²

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 (Liu (2019)). In brief, an industry is more upstream than another industry if the former is more influential as a supplier of intermediate goods to other industries. It turns out that more upstream manufacturing industries in China have a stronger presence of large and state-owned enterprises.

We find that during the expansionary phase 2005-2011, upstream manufacturing industries experienced higher rates of credit growth than downstream manufacturing industries, which is consistent with the finding of Bai et al. (2018) and Cong et al. (2019). This may reflect the fact that firms operating in upstream industries are more connected to banks because of the stronger presence of large and state-owned enterprises. Another finding is that the higher rate of credit growth in these industries was not associated to a similar increase in trade lending from these industries. Effectively, the increase of funds received by more bank-connected industries were not re-channeled to other less connected industries. Instead, they were used for financial investments outside the manufacturing sector. Because of this, the credit expansion did not generate a full credit cascade. This suggests that the real impact of the credit boom—in particular, the one induced by the 2009-2010 monetary policy expansion—did not achieve its full potential.

To analyze more closely the role played by monetary policy for the credit dynamics of upstream and downstream industries, we also use the monetary policy shocks constructed by Chen et al. (2018). The estimation results confirm that upstream manufacturing industries experienced higher rates of credit growth during the expansionary phase of 2005-2011 and trade lending from upstream to downstream industries did not grow as much.

In the second part of the paper we propose a theoretical model with a special form of trade credit network. The model outlines a mechanism that

²The timing of these two phases is consistent with Chen et al. (2018) who find a structural break in the monetary policy rule after the 2009-2010 economic stimulus.

dampens the role of the ‘trade’ credit channel for the cascade of a credit expansion tilted toward bank-connected firms.

The model features two sectors, ‘upstream’ and ‘downstream’. In the upstream sector firms choose optimally the credit supplied to downstream firms. However, due to an externality, trade credit is under-supplied: when an upstream firm increases trade lending to downstream firms, it facilitates not only its own sales but also the sales of other upstream firms. Since an individual firm cares only about its own sales, in equilibrium trade credit is below the social optimum.

To understand this property, we should consider the trade-off faced by upstream firms when they choose trade lending. Firms equalize the ‘individual’ marginal benefit from trade lending to the opportunity cost (this is the return on other financial investments). Because the ‘individual’ marginal benefit is smaller than the social benefit, upstream firms use a smaller quantity of the extra credit received from banks to finance the purchases of downstream firms. The model also predicts that the ‘individual’ benefit of trade lending increases with the average size of upstream firms. As a result, a credit expansion that is tilted toward larger firms generates greater downstream credit cascade. We find empirical support for this theoretical property in the data.

A final finding is that the severity of the externality is counter-cyclical, that is, it becomes more severe during recessions. This has two implications. First, the externality acts as an amplification mechanism for the diffusion of macroeconomic shocks. Second, the effectiveness of a credit expansion policy is lower when the economy is in recession, exactly when the credit expansion might be needed the most.

The organization of the paper is as follows. After a brief discussion of the related literature, Section 2 provides some evidence of the dynamic features of trade credit in China as well as some features of the Chinese industrial and financial structure. Section 3 presents the model and characterizes its properties. By comparing the competitive equilibrium with a planner’s allocation, this section highlights the importance of the externality for the dynamics of trade credit and the macro-economy. Section 4 concludes.

Related literature Our paper contributes to several strands of literature, starting with studies that investigate the importance of trade credit for relaxing financial constraints. Using firm-level data for the United States, 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 an advantage over banks in lending to customers because the diversion of production inputs is more difficult than cash. Allen et al. (2005) find that informal financing channels such as trade credit have facilitated the growth of non-listed private firms in China while Cull et al. (2009) find that underperforming state-owned firms tend to re-channel credit to firms with less access to bank loans. We contribute to this literature by highlighting an externality that affects the dynamics of trade credit and, as a consequence, the effectiveness of a financial expansion.

Our study is also 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 productivity but greater access to credit. Chang et al. (2018) show that the adjustment of bank reserve requirement not only affects the supply of bank credit but also 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 studies investigate credit allocation across sectors and firms during the four trillion Yuan economic stimulus of 2009-2010. Chen et al. (2016) provide evidence that during this period a significant fraction of new loans were channeled to ‘heavy sectors’ such as real estate, infrastructure, and manufacturing. Cong et al. (2019) find that the effect of the increased credit supply on firms’ borrowing was stronger for state-owned firms than for private firms. Our work focuses on the reallocation of credit from bank-connected firms to firms with lower access to credit.

Another strand of related literature studies the propagation of shocks in trade credit network. This literature dates back to Kiyotaki and Moore (1997) who proposed a theory of default cascade in trade credit network during recessions. Following their work, Jacobson and Von Schedvin (2015) quantified the importance of trade credit chains in the propagation of corporate bankruptcy using data for failed trade borrowers. Costello (2020) studied the propagation of liquidity shocks through trade credit linkages using data on inter-firm sales and Kalemli-Ozcan et al. (2014) argue that trade credit are obligations that bind the interests of firms in a production chain.

More recently, few studies introduced trade credit in the input-output network structure of Acemoglu et al. (2012). For example, Bigio and La’O

(2020) investigate the macroeconomic implications of sectoral distortions in a model with production network. Luo (2020), Reischer (2020) and Altinoglu (2021) examine the propagation of shocks in a production network model with trade credit linkages. Our paper complements this literature by considering a two-sector model in which the upstream sector has better access to bank credit than the downstream sector, which is a key feature of the Chinese economy. We also show that bank credit expansions can cascade from the upstream sector to the downstream sector through the trade credit channel, but the pass-through can be weakened by the externality.

Finally, our work relates to the literature on trade credit and monetary policy, partly reviewed in Mateut (2005). Early work by Meltzer (1960) provides evidence that cash-rich firms extend more trade credit to cash-poor firms during monetary tightenings. Nilsen (2002) finds that credit constrained firms (small firms) get more trade credit during monetary contractions. Choi and Kim (2005) find that, during periods of tightening monetary policy, S&P 500 firms tend to expand their trade credit supply while Mateut et al. (2006) show that trade credit increases relative to bank lending. More recently, Altunok et al. (2020) find that monetary policy tightening induces a flow of trade credit from public firms to private firms. We contribute to this literature by highlighting that the transmission of monetary policy through trade credit depends on the significance of the externality.

2 Empirical analysis

In this section we document some empirical facts about the propagation of a credit expansion using industry level data for the manufacturing sector in China. We do this in three steps. Subsection 2.1 categorizes manufacturing industries according to their position in the input-output production network. Subsection 2.2 documents how a credit expansion impacts the financial flows of an industry based on its position in the input-output structure. Subsection 2.3 documents how trade credit flows correlate with broader measures of financial flows.

The empirical analysis provides a snapshot of a channel through which a credit expansion propagates in the Chinese economy. This is illustrated, schematically, in Figure 1.

Banks play a dominant role in the financial structure of China and a credit expansion takes place, primarily, through increased bank lending. Up-

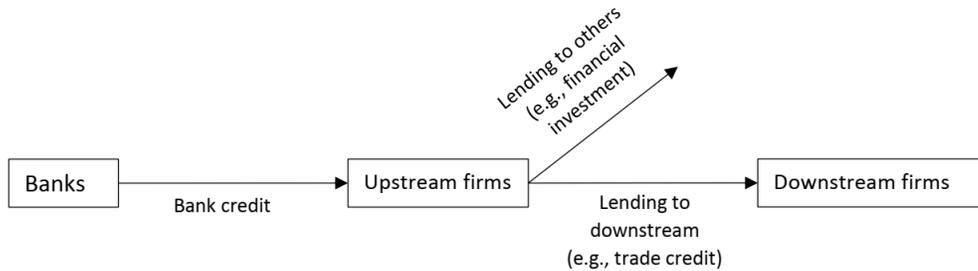


Figure 1: Channel of transmission of a credit expansion.

stream firms are the first to benefit from a credit expansion because they are larger and more directly connected to banks. Downstream firms are affected indirectly through trade credit received from upstream firms. This implies that, for a credit expansion to cascade to the whole manufacturing sector, it is necessary that the increased credit received by upstream firms is re-channeled to downstream firms through trade lending. Although shadow banking can be another form of inter-firm financing, its size was relatively small during the expansionary phase of 2005-2011.

The key empirical findings can be summarized as follows:

1. Subsection 2.1 shows that upstream industries have higher shares of large and state-owned enterprises. They also have higher trade lending in percentage of their sales.
2. Subsection 2.2 shows that borrowing and lending in upstream industries are more sensitive to credit policies. This can be related to the above finding that upstream industries have a higher share of large firms.
3. Subsection 2.3 shows that the expansion of credit in upstream industries does not generate an equivalent increase in trade lending, especially for smaller upstream firms.

In the second part of the paper we propose a model that formalizes the channel illustrated in Figure 1 and is consistent with the three empirical findings summarized here. The model shows that the limited cascade of the credit expansion to the whole economy could be caused, in part, by an externality for which upstream firms fail to fully recognize the benefits of

trade lending for the whole economy. The externality—and therefore, the limited cascade—is more severe for smaller upstream firms.

2.1 Upstream and downstream in manufacturing

We rank Chinese manufacturing industries according to the upstream measure used by Liu (2019). This measure is based on an upstream score constructed from a production network model in the spirit of Acemoglu et al. (2012) and Bigio and La’O (2020). The upstream score captures how an idiosyncratic productivity shock to a particular industry impacts aggregate net output via downstream propagation. An industry with a higher score tends to be more influential in the production network as a ‘supplier’ of intermediate inputs. The detailed derivation of the upstream score is described in the online appendix.

The upstream score is computed for each of the 26 two-digit Chinese manufacturing industries based on the 2007 input-output table. The 26 industries are listed in the online appendix. For some of the analysis we use a more aggregative approach by forming two groups of industries: the ‘upstream’ group containing the 13 manufacturing industries with the highest upstream score, and the ‘downstream’ group containing the other 13 industries.

To characterize the properties of the various industries, we use the 2007 firm-level data from the China Industrial Enterprise Database. An important industry-level variable is *net trade lending*. This is defined as “accounts receivable” minus “accounts payable”. For each industry we compute (i) the average ratio of net trade lending over sales, (ii) the sales share of ‘large-firms’, and (iii) the sales share of ‘state-owned’ firms.³

Figure 2 draws scatter plots that correlate some of the characteristics of the two-digit manufacturing industries with their upstream ranking. The shares of sales for ‘large’ and ‘state-owned’ firms tend to be higher in upstream industries. The online appendix shows that the relation is statistically significant. On average, the sales shares of large firms and state-owned

³Large firms correspond to ‘large/medium-sized firms’ as classified by the 2003 Statistical Definitions of Large, Medium and Small Enterprises of China. A firm is included in this category if it satisfies one of these criteria: (i) sales greater than 300 million Yuan; (ii) total assets greater than 400 million Yuan; (iii) number of employees greater than 2,000; (iv) sales greater than 30 million Yuan, total assets greater than 40 million Yuan, and number of employees greater than 300. State-owned firms include ‘state-owned enterprises’, ‘state-owned joint ventures’ and ‘state-owned holding companies’.

firms in the upstream group are, respectively, 14% and 17% higher than in the downstream group.

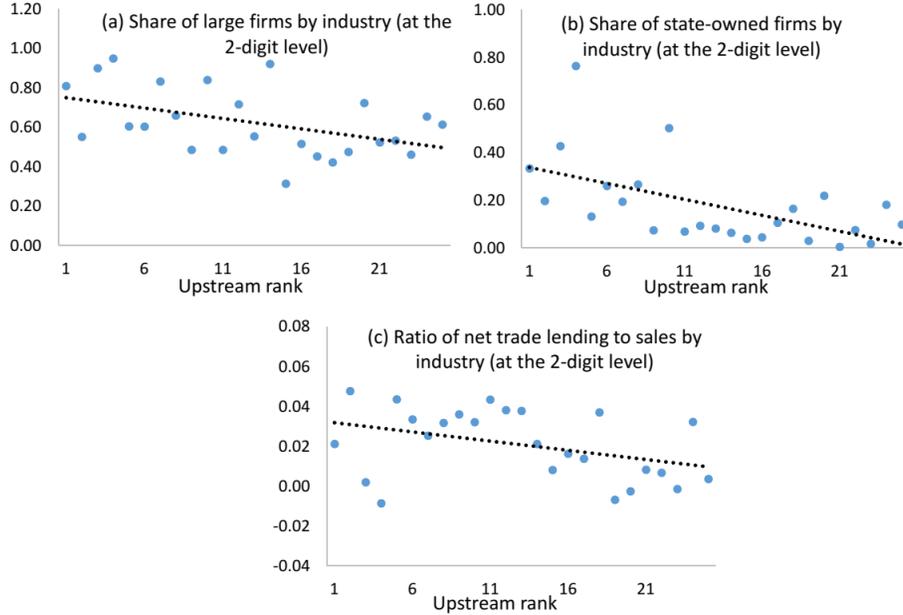


Figure 2: Characteristics of Chinese manufacturing industries.

Notes: Panel (a) plots the share of large firms (weighted by sales) in each of the two-digit manufacturing industries as a function of the upstream ranking. Panel (b) plots the share of state-owned firms (also weighted by sales). Panel (c) plots the average ratio of net trade lending to sales. Net trade lending is defined as accounts receivable minus accounts payable. The tobacco industry is excluded because it has only state-owned firms and highly regulated. The plotted statistics are computed using the 2007 firm-level data from the China Industrial Enterprise Database.

These findings suggest that upstream industries, having a higher presence of large and state-owned firms, may have easier access to bank credit. The figure also shows that the ratio of net trade lending (account receivable minus accounts payable) over sales tends to be higher in upstream industries. We interpret this as evidence that upstream firms are, on average, net lenders to downstream firms via trade credit.⁴

⁴The online supplement computes the above statistics at the 3-digit industry level and the shares of sales for large firms under alternative definitions of ‘large firms’. The results are consistent with those based on the 2-digit classification.

2.2 Financial cycle

After characterizing some of the features of manufacturing industries, we now investigate how the financial flows of the various industries correlate with the credit cycle. In particular, we would like to explore how financial flows in upstream and downstream industries respond to a credit expansion.

To address this question we use industry-level data from the National Bureau of Statistics of China. Industry-level aggregates for “all firms above designated size” (*all firms* henceforth) and the subset of “large/medium-sized firms” (*large firms* henceforth) are available annually for the period 2003-2016. The sales share of large firms is around 63% throughout the sample period.⁵

The main variables of interest, deflated by CPI and expressed in 2000 Chinese Yuan, are:

- *Short-term lending*: It corresponds to “non-inventory current assets”, and it is the sum of
 - *Trade lending*: Corresponding to “accounts receivable”.
 - *Non-trade lending*: Remaining part of short-term lending.
- *Short-term borrowing*: It corresponds to “current liabilities”, and it is the sum of
 - *Trade borrowing*: Corresponding to “accounts payable”.
 - *Non-trade borrowing*: Remaining part of short-term borrowing.

The monetary policy of the People’s Bank of China (PBOC)—the central bank of China—operates mainly through banks. This implies that the supply of bank credit is highly affected by PBOC’s monetary policy. Because of this, M2 growth is considered an indicator of credit conditions and represents an intermediate target for monetary policy.

After the 2009-2010 economic stimulus, the PBOC ended its expansionary policy and started tightening money supply in 2011. The policy change led to a persistent slowdown of M2 growth, which in turn led to a decline in bank

⁵According to the 2003 Statistical Definitions of Large, Medium and Small Enterprises of China, “all firms above designated size” correspond to industrial firms with annual sales no less than 5 million Yuan, which account for around 80% of the industrial sector’s total sales. “Large/medium-sized firms” are a subset of all firms as specified in footnote 3.

credit supply. Based on the conduct of monetary policy, we divide the sample period into two phases: the expansion phase, 2005-2010, and the contraction phase, 2011-2016. The distinction between these two phases is consistent with Chen et al. (2018) who estimated a Taylor-style policy rule for M2 and found a structural break right after the 2009-2010 economic stimulus.

Figure 3 shows that upstream industries experienced faster financial growth than downstream industries during the credit expansion phase. We show below that this is mainly due to the fact that upstream industries, with a higher presence of large firms, are more sensitive to changes in credit conditions.

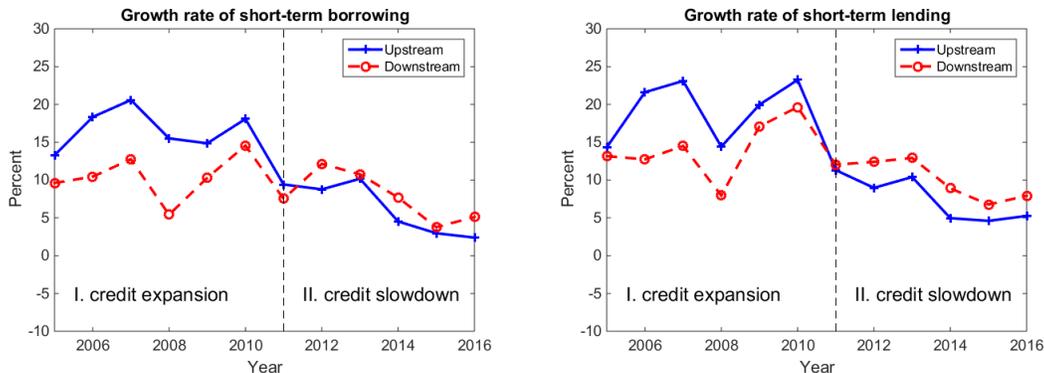


Figure 3: Growth rates of short-term borrowing and lending for upstream and downstream industries. The figure plots the average growth rates of short-term borrowing (non-inventory current assets) and lending (current liabilities).

To investigate how firms in upstream and downstream industries responded to changes in credit conditions during these two phases, we regress the growth rate of short-term borrowing and short-term lending on lagged M2 growth. More specifically, we consider the following regression equation:

$$y_{it} = \beta \cdot m2_{t-1} + \gamma \cdot m2_{t-1} \cdot D_{t-1}^{2009} + \theta_1 \cdot y_{i,t-1}^{sup} + \theta_2 \cdot y_{i,t-1}^{cus} + \theta_3 \cdot X_{i,t-1} + \theta_4 \cdot t + c_i + e_{it}. \quad (1)$$

The equation is estimated using four specifications of the dependent variable y_{it} : (i) growth rate of short-term borrowing, (ii) growth rate of non-trade borrowing, (iii) growth rate of short-term lending, (iv) growth rate of sales. The right-hand-side variables include the lagged growth rate of real M2, denoted by $m2_{t-1}$, and its interaction with a dummy variable for the 2009

economic stimulus (D_t^{2009} equals 1 if $t = 2009$). We include the 2009 dummy because M2 increased sharply by around 30% in 2009 as a result of the four trillion economic stimulus. However, the stimulus targeted sectors such as real estate and construction rather than manufacturing.

In order to control for interdependence across industries that derives from network effects, the regression equation includes the variables y_{it}^{sup} and y_{it}^{cus} . These variables are the weighted averages of the dependent variable for industry i 's suppliers and customers, respectively. They are computed as

$$y_{it}^{sup} = \sum_{j=1}^N \sigma_{ji}^{in} \cdot y_{jt} \quad \text{and} \quad y_{it}^{cus} = \sum_{j=1}^N \sigma_{ij}^{out} \cdot y_{jt}.$$

The term σ_{ji}^{in} is the share of intermediate goods used by industry i purchased from industry j , and σ_{ij}^{out} is the share of intermediate goods produced by industry i and sold to industry j .⁶ This approach has been used in the recent trade literature, for example, in Wang et al. (2018).

To control for industry i 's own financing demand, we add a vector of industry-level variables X_{it} , that includes the growth of sales and the growth of fixed assets. The last variables included in the regression are calendar time, t , industry fixed effect, c_i , and the error term, e_{it} .

We first estimate equation (1) separately for each industry i . The coefficient β_i captures the sensitivity of the dependent variable in industry i to monetary policy changes. Since the equation is estimated with four dependent variables, we have four estimated coefficients for each industry i .

Figure 4 plots the estimated β_i against the upstream ranking of the industry. It shows that the sensitivity of the four variables to monetary policy—captured by the estimated β_i —decreases with the upstream ranking of the industry (lower numbers for the ranking indicate more upstream industries). The statistical significance of the estimated coefficients is shown in the online appendix. Whether we look at the growth rate of short-term borrowing, non-trade borrowing, short-term lending or sales, upstream industries are more responsive to monetary policy than downstream industries.

We also estimate equation (1) for the two aggregative groups of industries: the upstream group (the 13 more upstream manufacturing industries) and the downstream group (the remaining 13 manufacturing industries). The results,

⁶ σ_{ji}^{in} and σ_{ij}^{out} are computed using the input-output table of China for the year 2007, which is the same input-output table used to compute the upstream scores.

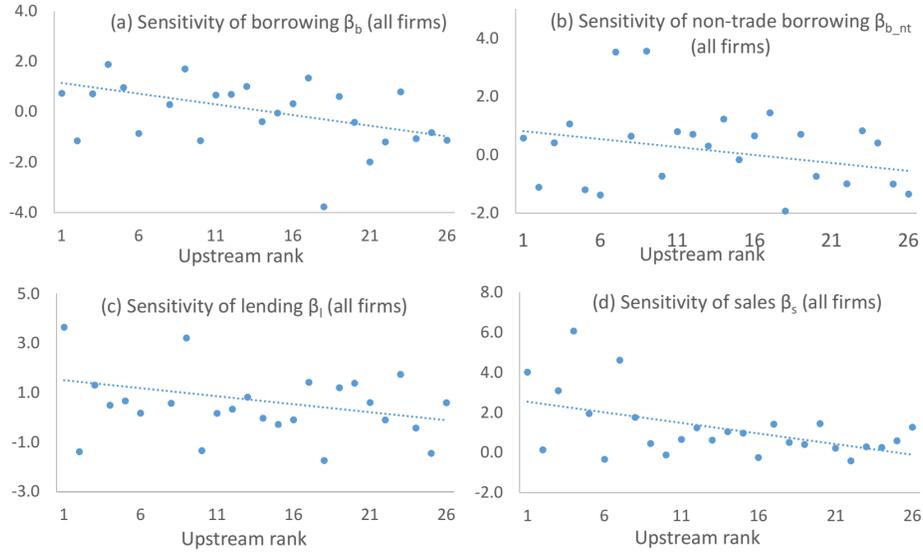


Figure 4: Industry sensitivities to monetary policy changes.

Notes: The figure plots the industry-level sensitivities to M2 growth of (a) growth rates of short-term borrowing, (b) non-trade borrowing, (c) short-term lending, and (d) sales. The sensitivity is the parameter β_i in equation (1) estimated separately for each industry i and for the four specifications of the dependent variables $y_{i,t}$. Lower numbers for the upstream ranking indicate more upstream industries.

reported in Table 1, show that the growth rates of short-term borrowing and lending are significantly correlated with lagged M2 growth only for upstream industries. For this group, a one percent increase in M2 growth is associated with a 0.68 percent rise in the growth rate of short-term borrowing (Column 1 in Panel I), and 0.98 percentage rise in the growth rate of short-term lending (Column 5 in Panel I). For downstream industries, instead, there is no significant correlation between the growth of short-term borrowing/lending and M2 growth (Columns 1 and 5 in Panel II). Column 3 also shows that the growth rate of non-trade borrowing is significantly correlated with M2 growth only for the upstream group.

As a robustness check, we estimate a modified version of equation (1) where M2 growth is replaced by the dummy variable ‘expansion phase’. The dummy takes the value of 1 in the expansion years 2004-2010 and zero in other years. Table 1 shows that, when we use short-term borrowing and lending

Table 1: Estimation of equation (1) for upstream and downstream industries.

I. Upstream manufacturing industries (all firms)								
	Short-term borrowing		Short-term non-trade borrowing		Short-term lending		Sales	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$m2_{t-1}$	0.677**		0.785***		0.982***		1.601***	
	(0.256)		(0.253)		(0.306)		(0.334)	
$m2_{t-1} \cdot D_{t-1}^{2009}$	-0.169		-0.268		-0.184		-0.437**	
	(0.138)		(0.179)		(0.192)		(0.165)	
$Expansion_{t-1}$		0.044***		0.042**		0.068**		0.076***
		(0.009)		(0.014)		(0.028)		(0.023)
Network E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Ctrl.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.548	0.501	0.491	0.451	0.516	0.442	0.707	0.599
II. Downstream manufacturing industries (all firms)								
	Short-term borrowing		Short-term non-trade borrowing		Short-term lending		Sales	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$m2_{t-1}$	-0.118		0.000		0.166		0.208	
	(0.293)		(0.304)		(0.303)		(0.206)	
$m2_{t-1} \cdot D_{t-1}^{2009}$	0.235		0.145		0.155		0.050	
	(0.147)		(0.162)		(0.153)		(0.095)	
$Expansion_{t-1}$		-0.051*		-0.051*		0.001		0.006
		(0.026)		(0.024)		(0.025)		(0.023)
Network E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Ctrl.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.211	0.208	0.245	0.250	0.334	0.271	0.693	0.667

Notes: The dependent variables are (a) growth rate of short-term borrowing (i.e., the sum of trade and non-trade borrowing), (b) growth rate of non-trade short-term borrowing, (c) growth rate of short-lending (i.e., the sum of trade and non-trade lending), and (d) growth rate of sales. The regression controls for network effects and industrial-level growth of sales and fixed assets. The estimation is conducted over 2004-2016. Standard errors are clustered at the industry level.

as dependent variable, the coefficient associated with the dummy ‘expansion phase’ is statistically significant and positive only for the upstream group (Columns 2 and 6). Also, the rise in the growth rate of sales is statistically significant only for upstream firms during the expansion phase (Column 8). This suggests that the credit expansion of 2004-2010 did not fully cascade to downstream industries.

These findings are consistent with our conjecture that upstream industries

are more directly connected to banks and, therefore, are more affected by a credit expansion.

Table 2: Estimation of equation (1) for large firms in the group of upstream and downstream industries.

I. Upstream manufacturing industries (large firms)								
	Short-term borrowing		Short-term non-trade borrowing		Short-term lending		Sales	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$m2_{t-1}$	1.090*** (0.312)		0.907** (0.353)		1.023** (0.380)		2.334*** (0.297)	
$m2_{t-1} \cdot D_{t-1}^{2009}$	-0.280 (0.201)		-0.161 (0.245)		-0.082 (0.265)		-0.635*** (0.169)	
$Expansion_{t-1}$		0.075*** (0.020)		0.075** (0.025)		0.103*** (0.033)		0.099*** (0.023)
Network E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Ctrl.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.585	0.500	0.559	0.478	0.509	0.427	0.691	0.508
II. Downstream manufacturing industries (large firms)								
	Short-term borrowing		Short-term non-trade borrowing		Short-term lending		Sales	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$m2_{t-1}$	0.751* (0.420)		0.706 (0.466)		0.955** (0.437)		1.671*** (0.462)	
$m2_{t-1} \cdot D_{t-1}^{2009}$	-0.200 (0.253)		-0.215 (0.270)		-0.243 (0.235)		-0.676 (0.274)	
$Expansion_{t-1}$		0.025 (0.026)		0.022 (0.030)		0.091*** (0.023)		0.073*** (0.021)
Network E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry Ctrl.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.301	0.238	0.355	0.312	0.380	0.340	0.563	0.467

Notes: The dependent variables are (a) growth rate of short-term borrowing (i.e., the sum of trade and non-trade borrowing), (b) growth rate of non-trade short-term borrowing, (c) growth rate of short-lending (i.e., the sum of trade and non-trade lending), and (d) growth rate of sales. All the regressions are conducted using the industry-level aggregate data for large firms controlling for network effects and industrial-level growth of sales and fixed assets. The estimation is conducted over 2004-2016. Standard errors are clustered at the industry level.

Next we investigate the role played by firms' size. We re-estimate equation (1) using industry-level aggregates for 'large firms' only. However, the variables that measure the network effects, $y_{i,t}^{cus}$ and $y_{i,t}^{sup}$, are based on industry-level aggregates for all firms. This is because the available data does not

allow us to compute these variables only for the sub-sample of large firms.

The bottom section of Table 2 shows that, once we restrict the sample to large firms, the responses of the growth rates of short-term financing and sales to M2 growth are statistically significant for both upstream and downstream industries. In the previous estimation with all firms, instead, the estimates were statistically significant only for the group of upstream firms. This suggests that the reason upstream industries benefited more from the credit expansion is because they have a higher share of ‘large firms’ than downstream industries.

Robustness check using monetary policy shocks. Changes in M2 may arise in response to economic conditions and, therefore, they are not exogenous measures of monetary policy. To address this issue, we reassess the sensitivity of upstream and downstream industries using the monetary policy shock series constructed by Chen et al. (2018).

To extract the exogenous component of M2 growth, Chen et al. (2018) considered a Taylor policy rule in which the growth rate of M2 responds endogenously to the inflation rate and to the deviation of GDP growth from their targets. They allow for an endogenous policy regime change to capture the PBOC’s asymmetric responsiveness to economic expansions and contractions. The residuals from the estimation of the policy rule (the exogenous component of M2 growth) are the monetary policy shocks.

We estimate an alternative version of equation (1) in which M2 growth is replaced by the monetary policy shock series. The results are reported in the online appendix. The responses of the growth rates of short-term financing and sales to monetary shocks are larger and more statistically significant for upstream industries than for the downstream industries. Once we restrict the sample to large firms, however, the estimates for the upstream and downstream groups are similar in magnitude and statistical significance. This is consistent with the results outlined above.

2.3 Trade lending of upstream industries

We have seen that downstream industries are less responsive to credit expansions. The different responsiveness can be linked to the fact that downstream industries have a higher share of small firms that, most likely, are less connected to banks. Thus, the extent to which credit expansion policies reach downstream industries could depend on the response of trade lending from

upstream industries. In this subsection we explore more explicitly the role of trade credit for the transmission of a credit expansion.

To compare trade and non-trade lending of upstream industries, we estimate the following regression

$$l_{it} = \beta \cdot m2_{t-1} + \gamma \cdot m2_{t-1} \cdot D_{t-1}^{2009} + \theta_1 \cdot s_{i,t-1}^{cus} + \theta_2 \cdot b_{i,t-1}^{cus} + \theta_3 \cdot X_{i,t-1} + \theta_4 \cdot t + c_i + e_{it}, \quad (2)$$

for the group of upstream industries, that is, $i \in I^{up}$.

The variable l_{it} is the growth rate of trade (non-trade) lending of upstream industry $i \in I^{up}$. The variables s_{it}^{cus} and b_{it}^{cus} are the growth rates of sales and short-term borrowing of industry i 's customers. These variables control for the demand of funds of upstream industry i 's customers, defined as

$$s_{it}^{cus} = \sum_{j=1}^N \sigma_{ij}^{out} \cdot s_{jt} \quad \text{and} \quad b_{it}^{cus} = \sum_{j=1}^N \sigma_{ij}^{out} \cdot b_{jt}.$$

The term σ_{ij}^{out} is the share of intermediate goods produced by industry i sold to industry j . The variable X_{it} is the growth of fixed assets, which controls industry i 's own financing needs for capital accumulation.

Columns 1 and 3 of Table 3 show that a one percentage point rise in the growth rate of M2 is associated with a 0.74 percent increase in the growth rate of non-trade lending. The growth rate of trade lending, instead, increases by the lower value of 0.6 percent. We also estimate equation (2) after replacing M2 growth with the dummy variable for the expansion phase. As shown in Columns 2 and 4 of Table 3, only the growth rate of non-trade lending increased significantly during the expansion phase 2004-2010. When the dependent variable is the growth rate of trade lending, the estimated coefficient for the dummy variable is not statistically different from zero. Therefore, non-trade lending, which consists mainly of financial investments, is more responsive to changes in credit conditions than trade lending.⁷ We interpret this finding as evidence that the increased credit received by firms in upstream industries did not generate a significant increase in trade lending. Instead, the extra funds were allocated to alternative uses, limiting the cascade of the credit expansion to downstream industries.

⁷Our data does not allow us to break down the components of non-trade lending. However, using balance sheet data of listed industrial firms from Wind over the 2000-2016 period, we find that cash & financial assets account for around 70% of non-trade lending.

Table 3: Estimation of equation (2) for upstream industries.

	I. Upstream industries (all firms)				II. Upstream industries (large firms)			
	Trade lending		Non-trade lending		Trade lending		Non-trade lending	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$m2_{t-1}$	0.595*		0.735**		1.327***		1.027***	
	(0.305)		(0.322)		(0.425)		(0.325)	
$m2_{t-1} \cdot D_{t-1}^{2009}$	-0.103		0.010		-0.347		0.007	
	(0.196)		(0.217)		(0.256)		(0.283)	
$Expansion_{t-1}$		-0.033		0.124***		0.029		0.147***
		(0.023)		(0.021)		(0.027)		(0.028)
Industry Ctrl.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.374	0.328	0.483	0.461	0.384	0.270	0.488	0.433

Notes: The dependent variables are the growth rate of trade lending and the growth rate of non-trade lending. The estimation controls for the demand of funds for customer industries, and upstream industry's own financing needs for capital accumulation. Estimates in Columns (1)-(4) use industry-level aggregate data for all firms, while estimates in Columns (5)-(8) use industry-level aggregate data for large firms. The estimation is conducted over 2004-2016. Standard errors are clustered at the industry level.

If we restrict the sample to large firms, we find that trade lending of upstream firms is actually more responsive to M2 growth than their non-trade lending. See the second part of Table 3. An indication that large firms have a higher propensity to supply trade credit.

To further investigate the importance of firm size in accounting for these findings, we regress trade lending growth of upstream industries on the growth rate of their own short-term borrowing, non-trade borrowing, short-term lending and sales, while allowing for time fixed effects and industry fixed effects. We perform the same regressions using industry-level aggregate data for all firms and industry-level aggregate data for large firms.

Table 4 shows that a one percent increase in the growth of non-trade borrowing (which consists mainly of short-term bank loans) is associated with a 0.63 percent increase in the growth rate of trade lending for large firms while the value for the whole industry is 0.57. In addition, a one percent increase in the growth rate of short-term borrowing is associated with a 0.84 percent increase in the growth rate of trade lending, while the value for the whole industry is 0.8. Thus, large firms tend to have higher propensity to provide trade credit to their customers. The cascade of a credit expansion, then, should increase with the average size of firms operating in

Table 4: Trade lending of upstream industries.

	I. Upstream industries (all firms)				II. Upstream industries (large firms)			
	Trade lending				Trade lending			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Short-term borrowing	0.803*** (0.034)				0.842*** (0.090)			
Non-trade borrowing		0.565*** (0.062)				0.631*** (0.096)		
Short-term lending			0.618*** (0.104)				0.649*** (0.145)	
Sales				0.638*** (0.071)				0.650*** (0.086)
Time F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.725	0.634	0.713	0.686	0.700	0.619	0.697	0.639

Notes: The dependent variable is the growth rate of trade lending. The independent variables are (a) growth rate of short-term borrowing, (b) growth rate of non-trade borrowing, (c) growth rate of short-term lending, and (d) growth rate of sales. Estimates in Columns (1)-(4) use industry-level aggregate data for all firms, while estimates in Columns (5)-(8) use industry-level aggregate data for large firms. The estimation is conducted over 2004-2016. Standard errors are clustered at the industry level.

the upstream sector.

To summarize, we have shown that the expansion of credit in upstream industries did not generate an equivalent increase in trade lending, limiting the cascade of the credit expansion. We have also shown that the size of firms could be important in affecting the response of trade credit and the cascade of the credit expansion to the whole economy. An important question is why we observe limited responsiveness of trade credit, especially from smaller firms. In the next section we propose a model of trade credit that formalizes some of the key characteristics of the Chinese economy and outlines a particular channel that contributes to lowering the cascade of a credit expansion.

3 A model of trade credit supply

In this section we develop a theoretical model that formalizes the key features of the Chinese economy outlined in the empirical analysis, and allows us to rationalize some of the empirical findings. In particular, we have shown that:

1. Upstream industries have higher shares of large and state-owned en-

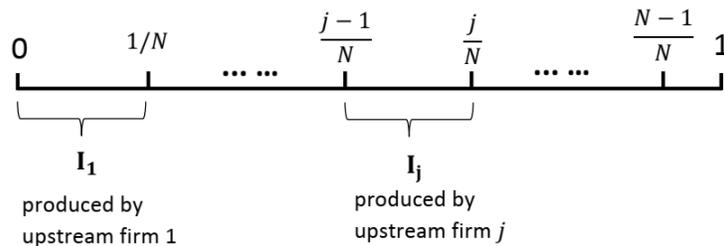
terprises, as well as higher trade lending in percentage of their sales (Subsection 2.1).

2. Borrowing and lending in upstream industries are more sensitive to credit policies. This can be related to the finding that upstream industries have a higher share of large firms (Subsection 2.2).
3. The expansion of credit in upstream industries does not generate an equivalent increase in trade lending, especially for smaller upstream firms (Subsection 2.3).

The first two facts inform us on how to construct the model. The third fact, instead, is generated endogenously by the model. In particular, the model shows that the limited cascade of a credit expansion could be related, at least in part, to an externality that prevents upstream firms from fully internalizing the benefits of trade lending for the whole economy. The externality is more severe for smaller upstream firms, which could explain why a credit expansion is associated with less trade lending growth in smaller firms.

3.1 Model setup

There are two sectors of production: the upstream sector and the downstream sector. In the upstream sector there are N firms indexed by $j = 1, \dots, N$. Each upstream firm produces a continuum of intermediate inputs, indexed by i , that are sold to downstream firms. Formally, upstream firm j produces intermediate goods of variety contained in the set \mathbf{I}_j . The sum of varieties produced by all firms gives the unitary set, that is, $\bigcup_{j=1}^N \mathbf{I}_j = [0, 1]$. We will focus on the symmetric case in which upstream firms produce the same number of (differentiated) varieties. Therefore, the production set of firm j is $\mathbf{I}_j = ((j - 1)/N, j/N]$ as illustrated in Figure 1.



In the downstream sector there is a continuum of competitive firms. They produce a final good by combining intermediate goods produced by upstream firms. There is only one period in the model.

3.1.1 Production technology

Upstream firms produce intermediate goods with labor. The production technology displays decreasing returns to scale, which results in an increasing marginal cost of production. Denoting by x_i the production of intermediate good i , the total production cost for firm j is

$$w \int_{i \in \mathcal{I}_j} l(x_i). \quad (3)$$

The function $l(\cdot)$ is the input of labor needed to produce x_i units of good i and w is the wage rate expressed in units of the final good. The function $l(\cdot)$ is strictly increasing and convex. For simplicity we also assume that the supply of labor is perfectly elastic in this economy and, therefore, the wage rate w is constant.⁸

Final goods are produced in the downstream sector by a unitary mass of competitive firms with the production function

$$y = \left(\int_{i \in [0,1]} x_i^{\frac{\varepsilon-1}{\varepsilon}} \right)^{\frac{\varepsilon}{\varepsilon-1}}, \quad (4)$$

where x_i is the quantity of intermediate good i used in production and $\varepsilon > 1$ is the elasticity of substitution between intermediate goods. Final goods are consumed.

3.1.2 Downstream firms

Downstream firms can borrow from banks at the interest rate r up to a maximum \bar{b} . Because of their limited access to bank financing, downstream firms may want to borrow from upstream firms with trade credit. However, trade credit is also limited due to enforcement problems.

⁸This can be formalized by assuming that there is a continuum of workers with utility $c - Al$. The optimality condition for the supply of labor is $w = A$, which implies that the wage rate is equal to the constant A . Having a supply of labor that is not perfectly elastic does not change the key properties of the model but the wage is affected by shocks.

Denote by ϕ_j the down payment per unit of intermediate purchases required by upstream firms. The fraction of purchases funded with trade credit is $1 - \phi_j$. The unitary down payment ϕ_j is endogenous in the model as it is chosen optimally by upstream firm j (as we will describe below).

For simplicity we assume that downstream firms do not have any capital. Therefore, the down payment made to upstream firms must be funded with bank loans. The borrowing constraint for bank credit can 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 in units of the final good and the quantity purchased of intermediate good i .

The left-hand-side of equation (5) is total borrowing from banks needed to cover the down payments to purchase intermediate inputs. Given the purchase of x_i units of intermediate good $i \in \mathbf{I}_j$ from upstream firm j , the down payment is $\phi_j \int_{i \in \mathbf{I}_j} q_i x_i$. Since there are N upstream firms, the total down payment is $\sum_{j=1}^N \phi_j \int_{i \in \mathbf{I}_j} q_i x_i$. Trade credit is the difference between the purchased value of intermediate goods and the total down payment.

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

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

subject to (4) and (5).

Profits are the difference between production, y , and the cost of intermediate inputs. The cost has two components. The first is the direct cost to purchase the intermediate inputs. The second is the cost of financing the down payment, that is, the interests charged by banks.

The first order condition with respect to x_i is

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

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. 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 and, therefore, $\lambda > 0$.

The first order condition gives us the demand for intermediate good $i \in \mathbf{I}_j$,

$$x_i = D_i(q_i, \phi_j, y, \lambda) \equiv \frac{y}{[1 + (r + \lambda)\phi_j]^\varepsilon q_i^\varepsilon}. \quad (8)$$

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 $(r + \lambda)\phi_j q_i$. In absence of down payment, that is, $\phi_j = 0$, the cost reduces to the price q_i and we revert to a standard Dixit-Stiglitz demand function.

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

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

The equation defines the shadow price λ as a function of intermediate prices $\mathbf{Q} \equiv \{q_1, \dots, q_N\}$ and down payment requirements $\mathbf{\Phi} = \{\phi_1, \dots, \phi_N\}$ chosen by the N upstream firms.⁹ Using (8) to replace x_i in the borrowing constraint (5) under the assumption that it binds, we 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 expression defines final output y as a function of intermediate prices $\mathbf{Q} \equiv \{q_1, \dots, q_N\}$, down payment 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.

3.1.3 Upstream firms

Upstream firms start with endowed funds e_j measured in units of final goods. Each upstream firm j chooses the fraction of sales that needs to be paid

⁹Upstream firm j chooses a continuum of prices for each $i \in \mathbf{I}_j$. Since the production cost and demand for all products are identical, it is optimal to choose the same price q_j .

upfront by downstream customers, ϕ_j . The remaining fraction, $1 - \phi_j$, is paid at the end of the period and represents trade credit. Although there is not an explicit interest rate on trade lending, the interest is implicitly reflected in the prices chosen by upstream firms.

Trade credit requires costly monitoring which is necessary to secure repayment. The monitoring cost incurred by the upstream firm increases with the fraction of sales funded with trade credit (or, equivalently, decreases with the down payment fraction). The total monitoring cost is $c(\phi_j) \int_{i \in \mathbf{I}_j} x_i q_i$, where $c'(\phi_j) < 0$ and $c''(\phi_j) > 0$. The cost decreases in ϕ_j but the rate of decline decreases with ϕ_j . This captures the idea that increasing the down payment rate is especially beneficial when ϕ_j is small.

We assume that an upstream firm does not differentiate ϕ_j across goods and costumers. Since there is a finite (non-atomistic) number of upstream firms, this implies that the optimal choice of ϕ_j takes into account the aggregate implications. Production and pricing policies, instead, are specific to each good produced by the firm. Therefore, the quantity and price chosen for a single intermediate good i have negligible aggregate consequences.¹⁰

Upstream production requires working capital to pay the wage bill, that is, $w \int_{i \in \mathbf{I}_j} l(x_i)$. Working capital can be financed with owned funds, e_j , and with down payments from downstream customers, $\phi_j \int_{i \in \mathbf{I}_j} x_i q_i$. Upstream firms can also invest in financial assets with return r_f .

The flow of funds constraint, before production, is

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

where $a_j \geq 0$ is the investment in financial assets.

The left-hand-side is the sum of owned funds and down payments received from downstream firms. The right-hand-side contains the payment of wages (working capital) and the financial investment. Lower down payments must be compensated with lower financial investments. Thus, r_f is the opportunity cost of trade lending, unless the non-negative constraint for financial investments binds ($a_j = 0$).

¹⁰These assumptions could be motivated by the fact that financial decisions in large organizations tend to be centralized while product decisions are more decentralized. This suggests that trade credit policies are centrally decided while pricing and production decisions for single products are chosen autonomously by individual units within the firm.

Upstream firms choose prices, production, down payment ratios and financial investments, taking as given the demand functions from downstream firms and the policies of other upstream firms (prices and down payments). The optimization problem of upstream firm j can be written as

$$\max_{\{q_i\}_{i \in \mathbf{I}_j}, \phi_j, a_j} \left\{ \int_{i \in \mathbf{I}_j} x_i q_i - w \int_{i \in \mathbf{I}_j} l(x_i) - c(\phi_j) \int_{i \in \mathbf{I}_j} x_i q_i + a_j r_f \right\} \quad (12)$$

subject to (8) and (11).

The first term in the objective function is the revenue from the sales of intermediate goods; the second term is the direct cost of production (for hiring labor); the third term is the monitoring cost associated with trade lending; the last term is the interest earned on the financial investment a_j . Given the down payment and price policies, a_j is determined by the flow of funds constraint (11). This constraint shows that, when upstream firm j chooses a higher down payment ϕ_j , a larger amount of owned funds are invested in financial assets that earn the interest rate r_f .

The optimization problem solved by the upstream firm is also subject to the demands for its products, equation (8). The demands depend not only on the firm's policies, q_i and ϕ_j , but also on the policies of other upstream firms through the shadow price λ and aggregate output y . According to equations (9) and (10), the shadow price λ and the aggregate output y are functions of $\mathbf{Q} = \{q_1, \dots, q_N\}$ and $\mathbf{\Phi} = \{\phi_1, \dots, \phi_N\}$.

The strategic interaction between upstream firms takes the form of a Nash game where each firm takes as given the policies chosen by other firms, that is, prices and down payments. To derive the optimal responses of firm j , we differentiate problem (12) with respect to q_i and ϕ_j to obtain

$$\left[f(\phi_j, \mu_j) q_i - (1 + \mu_j) w l'(x_i) \right] \frac{\partial x_i}{\partial q_i} + f(\phi_j, \mu_j) x_i = 0, \quad (13)$$

$$\int_{i \in \mathbf{I}_j} \left[f(\phi_j, \mu_j) q_i - (1 + \mu_j) w l'(x_i) \right] \frac{\partial x_i}{\partial \phi_j} + \left[\mu_j - c'(\phi_j) \right] \int_{i \in \mathbf{I}_j} x_i q_i = 0. \quad (14)$$

To simplify notations, we have defined the function

$$f(\phi_j, \mu_j) \equiv 1 - c(\phi_j) + \phi_j \mu_j,$$

where μ_j is the Lagrangian multiplier associated with constraint (11). This is the shadow value of endowed funds e_j . Since the endowed funds can also be used to purchase financial assets a_j , besides funding working capital, μ_j is bounded below by r_f .

The function $f(\phi_j, \mu_j)$ represents the unitary revenue from sales, net of the monitoring cost, $c(\phi_j)$, plus the financial benefit of the down payment, $\phi_j \mu_j$. It is strictly increasing in ϕ_j , capturing the fact that higher down payments reduce the monitoring cost and increases the funds allocated to financial investments. In the rest of the paper we assume that the elasticity of $f(\phi_j, \mu_j)$ with respect to ϕ_j is decreasing in ϕ_j .¹¹

An *equilibrium* consists of prices $\mathbf{Q} = \{q_1, \dots, q_N\}$, down payment policies $\Phi = \{\phi_1, \dots, \phi_N\}$, intermediate productions $\mathbf{x} = \{x_1, \dots, x_N\}$, final production y , financial investments $\mathbf{a} = \{a_1, \dots, a_N\}$, such that (i) upstream firms maximize profits given the policies chosen by other firms (upstream and downstream); (ii) downstream firms maximize profits; (iii) markets clear.

3.2 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). The internal and external effects are characterized in the next subsection 3.2.1. Then, in subsections 3.2.2 and 3.2.3 we show that the externality leads to under provision of trade credit. Furthermore, we show that the under provision becomes more severe when the upstream sector is less concentrated.

3.2.1 Internal and external effects of trade finance

We first characterize how a change in the down payment ratio chosen by an upstream firm j affects the demand for its own products, that is, x_i for $i \in \mathbf{I}_j$. This is the *internal effect* of trade credit, which we can derive by differentiating the demand function (8). The derivative has three components:

$$\frac{\partial x_i}{\partial \phi_j} = \underbrace{\frac{\partial D_i}{\partial \phi_j}}_{\text{Relative cost}} + \underbrace{\frac{\partial D_i}{\partial \lambda} \frac{\partial \lambda}{\partial \phi_j}}_{\text{Liquidity}} + \underbrace{\frac{\partial D_i}{\partial y} \frac{\partial y}{\partial \phi_j}}_{\text{Market size}}. \quad (15)$$

¹¹Since $f(\phi_j, \mu_j)$ is increasing in ϕ_j , a sufficient condition is that $\phi_j f'_\phi(\phi_j, \mu_j)$ is decreasing in ϕ_j . This would be the case, for example, when $c(\phi_j) = \kappa/\phi_j$ with $\kappa > \mu_j$.

1. *Relative cost.* This captures the impact of a change in down payment on the relative demand for intermediate good i , keeping y and λ fixed (in addition to keeping the prices fixed). An increase in ϕ_j raises the financing and shadow cost for downstream firms to purchase intermediate good $i \in \mathbf{I}_j$. This is the term $\phi_j(r + \lambda)q_i$. The higher cost then reduces the relative demand for the goods produced by upstream firm j . Essentially, downstream firms substitute intermediate goods produced by upstream firm j with goods produced by other upstream firms.
2. *Liquidity.* This captures the impact that a change in down payment has on the demand for intermediate good i via λ . Recall that downstream firms finance their down payments with bank credit, which is bounded by \bar{b} . When the borrowing constraint binds, an increase in down payment decreases the amounts of intermediate goods that downstream firms can buy with each unit they borrow from banks. This implies that the shadow value of liquidity decreases, i.e., $\partial\lambda/\partial\phi_j < 0$ (see equation (9)). Since $\partial D_i/\partial\lambda < 0$, the liquidity effect on x_i is positive.
3. *Market size.* This captures the impact of a change in down payment on the demand for intermediate good i via aggregate production y . As shown in (10), an increase in ϕ_j decreases the production scale of downstream firms, i.e., $\partial y/\partial\phi_j < 0$. Since $\partial D_i/\partial y > 0$ (see equation (8)), the demand for all intermediate goods declines.

Notice that the liquidity and market size effects (second and third terms on the right-hand-side of (15)) would be negligible if upstream firms were atomistic: when $N \rightarrow \infty$, we have $\partial\lambda/\partial\phi_j \approx 0$ and $\partial y/\partial\phi_j \approx 0$.

Next we derive how a change in ϕ_j affects the demand for intermediate goods produced by other upstream firms, that is, x_i for $i \notin \mathbf{I}_j$. This is the *external effect* of trade credit. Differentiating the demand function (8) with respect to ϕ_j , for $i \notin \mathbf{I}_j$, we obtain

$$\frac{\partial x_i}{\partial \phi_j} = \underbrace{\frac{\partial D_i}{\partial \lambda} \frac{\partial \lambda}{\partial \phi_j}}_{\text{Liquidity}} + \underbrace{\frac{\partial D_i}{\partial y} \frac{\partial y}{\partial \phi_j}}_{\text{Market size}}. \quad (16)$$

1. *Liquidity.* When the borrowing constraint binds for downstream firms, a higher down payment decreases the amount of intermediate goods that downstream firms can buy with bank loans. Therefore, the shadow

value of liquidity decreases, i.e., $\partial\lambda/\partial\phi_j < 0$. Since $\partial D_i/\partial\lambda < 0$, the liquidity effect is positive.

2. *Market size.* A higher down payment decreases the production scale of downstream firms, 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.

The ‘external’ effects (liquidity and market size) are similar to the ‘internal’ liquidity and market size effects. They would be negligible if the upstream sector were populated by atomistic firms. However, since in our model upstream firms are not atomistic, the external effects—both liquidity and market size—are not negligible and they play an important role.

3.2.2 Centrally-planned trade finance

When the down payment ratios are chosen by upstream firms without coordination, the benefits of trade finance are not fully internalized. To study the optimal level of trade finance that is socially optimal, we consider an economy in which the down payment ratios and prices of intermediate goods are chosen by a planner on behalf of the upstream firms. This can be interpreted as an equilibrium in which upstream firms coordinate their policies.

The planner chooses the prices q_i , with $i \in \mathbf{I}_j$ and down payment ratios ϕ_j , for all $j = 1, \dots, N$, to maximize total profits. In doing so it takes as given the demand functions from downstream firms and solves the problem

$$\max_{\{q_i\}_{i \in \mathbf{I}_j}, \phi_j, a_j\}_{j=1}^N} \sum_{j=1}^N \left\{ \int_{i \in \mathbf{I}_j} x_i q_i - w \int_{i \in \mathbf{I}_j} l(x_i) - c(\phi_j) \int_{i \in \mathbf{I}_j} x_i q_i + a_j r_f \right\} \quad (17)$$

subject to (8) and (11).

The first order condition for q_i is the same as in the decentralized economy (equation (13)). However, the first order condition for ϕ_j is different and equal to

$$\sum_{\kappa=1}^N \left\{ \int_{i \in \mathbf{I}_\kappa} \left[f(\phi_\kappa, \mu_\kappa) q_i - (1 + \mu_\kappa) w l'(x_i) \right] \frac{\partial x_i}{\partial \phi_j} \right\} + [\mu_j - c'(\phi_j)] \int_{i \in \mathbf{I}_j} q_i x_i = 0. \quad (18)$$

We can now compare the planner optimality condition (18) to the first order condition in the decentralized economy, equation (14). The planner internalizes the effect that the choice ϕ_j has on other firms. This is indicated by the fact that the first order condition (18) contains the sum of the efficiency conditions for all firms, not just firm j .

Proposition 1 *Assume that e_j is large enough so that $a_j > 0$ and condition $\varepsilon(1 - q) < 1$ holds. Then, the optimal ϕ_j chosen by the planner is lower than in the decentralized equilibrium.*

Proof 1 *See Appendix A.*

3.2.3 Degree of competition

We now characterize how the trade credit externality varies with the degree of competition captured by the number of upstream firms N . To derive sharper analytical results, we make the following assumption:

Assumption 1 *The labor input function takes the form $l(x) = \bar{l} + \frac{(zx)^{1+\alpha}}{1+\alpha}$ with $z > 0$ and $\alpha > 0$.*

Proposition 2 *Assume that e_j is large enough so that $a_j > 0$ and condition $\varepsilon(1 - q) < 1$ holds. Then, the equilibrium ϕ in the decentralized economy increases with N while ϕ chosen by the planner is independent of N .*

Proof 2 *See Appendix B.*

When trade finance is decentralized, a higher value of N implies that upstream firms are smaller. Each firm, then, internalizes less the benefits of trade lending. As a result, the equilibrium down payment rises. Instead, when the down payment ratio is chosen by the planner, the trade credit spillover is always internalized and the optimal ϕ is independent of N . These properties are illustrated with a numerical example in Figure 5. The parameter values are reported in Table 5.

Table 5: Parameter values.

Description	Parameter	Value
Fixed labor input	l	0.75
Scaling in labor input function (inverse of productivity)	z	0.7
Curvature of labor input function	α	0.6
Exogenous wage rate (normalized to 1)	w	1
Number of upstream firms	N	2
Return on financial investment	r_f	0.01
Maximum bank credit to downstream firms	b	1
Elasticity of substitution between intermediate goods	ε	10
Parameter in monitoring cost function $c(\phi) = \kappa/\phi$	κ	0.05

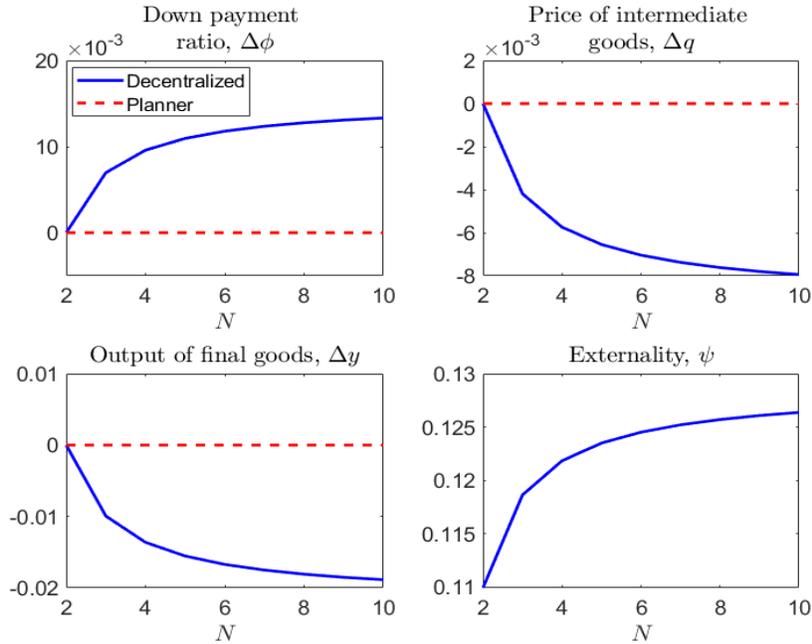


Figure 5: Sensitivity to number of upstream firms, N . The solid line is for the decentralized equilibrium. The dashed line is for the planner equilibrium.

Notes: The first three panels plot the deviations of the down payment ratio, ϕ , price of intermediate goods, q , and output, y , from their corresponding values in the planner equilibrium as functions of N . The fourth panel plots the degree of externality, ψ , computed as the ratio of the external effect of trade finance (equation (15)) to the sum of the external and internal effects (equations (15) and (16)). Parameter values are in Table 5.

3.2.4 Amplification of productivity shocks

We now examine the role of productivity. We continue to assume that the labor input function takes the form specified in Assumption 1. An increase in z corresponds to a negative productivity shock since it raises the quantity of labor needed to produce a given quantity of intermediate goods. A decrease in z corresponds to a positive productivity shock since it lowers the quantity of labor that is needed to produce a given quantity of intermediate goods.

A negative productivity shock raises the production cost and induces upstream firms to charge higher prices. This in turn reduces the demand for intermediate goods from downstream firms which ultimately leads to lower aggregate production.

This effect would emerge even in absence of financial frictions. With financial frictions, however, the macroeconomic impact depends on the response of the down payment ratio ϕ . In particular, if a negative productivity shock is associated with a higher ϕ , then the macroeconomic impact of the shock will be amplified. This is the case in the decentralized economy as stated in the next proposition.

Proposition 3 *Assume that e_j is large enough so that $a_j > 0$, and condition $\varepsilon(1 - q) < 1$ holds. Then, the down payment ϕ in the decentralized economy increases with z , while in the planner equilibrium ϕ is independent of z .*

Proof 3 *See Appendix B.*

Why do upstream firms change ϕ in the decentralized equilibrium when z changes? To gain some intuition, consider a negative productivity shock, that is, an increase in z . This rises the production cost and induces upstream firms to charge higher prices. Because all intermediate inputs become more expensive, it is less profitable for downstream firms to expand the production scale. An implication of this is that downstream firms are less willing to replace intermediate goods supplied by firms demanding higher ϕ with intermediate goods supplied by firms demanding lower ϕ . Because of this, an individual upstream firm can affect less the demand of its products by offering more trade lending (lower down payments). It becomes optimal then to choose a higher down payment ratio ϕ .

The response of trade credit amplifies the impact of the productivity shock: downstream firms cut their demand for intermediate inputs not only

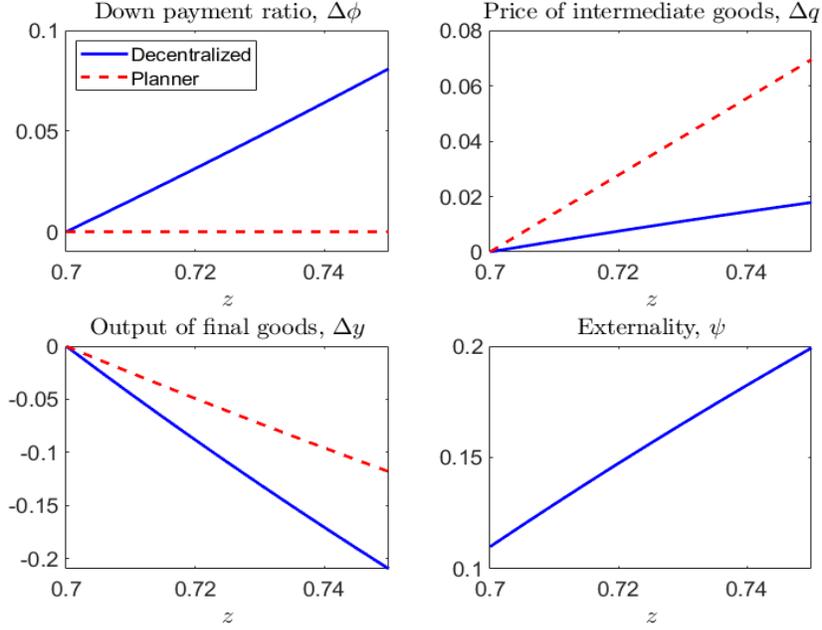


Figure 6: Sensitivity to production cost, z . The solid line is for the decentralized equilibrium. The dashed line is for the planner equilibrium.

Notes: The first three panels plot the deviations of the down payment ratio, ϕ , price of intermediate goods, q , and output, y , from their values in the planner equilibrium as functions of z . The last panel plots the degree of externality, ψ , computed as the ratio of the external effect of trade finance (equation (15)) over the sum of the external and internal effects (equations (15) and (16)). Parameter values are in Table 5.

because they are more costly to produce but also because of the lower ability to finance them. When trade finance is centrally planned, instead, the productivity shock has no impact on ϕ and there is not amplification.

Figure 6 illustrates these properties with a numerical example. The figure shows that the down payment ratio ϕ increases with z in the decentralized economy while it remains constant in the planned economy. The figure also plots a measure of externality (fourth panel). This is the ratio of the external effect of trade finance over the sum of external and internal effects. The internal effect is defined in (15) and the external effect in (16). The externality measure increases as the production cost increases, which is another way to see why the down payment ratio ϕ increases with z and, consequently, output drops more in the benchmark economy than in the planned economy.

3.2.5 The role of price markup

To explore the role played by market power in the sale of differentiated goods, we perform a sensitivity analysis with respect to the elasticity of substitution for intermediate goods. This is the parameter ε in the production function (4). As in Sections 3.2.3 and 3.2.4, we assume that upstream firms are homogeneous in size and the non-negative constraints for financial investments does not bind, that is, $a_j > 0$. The results are shown in Figure 7.

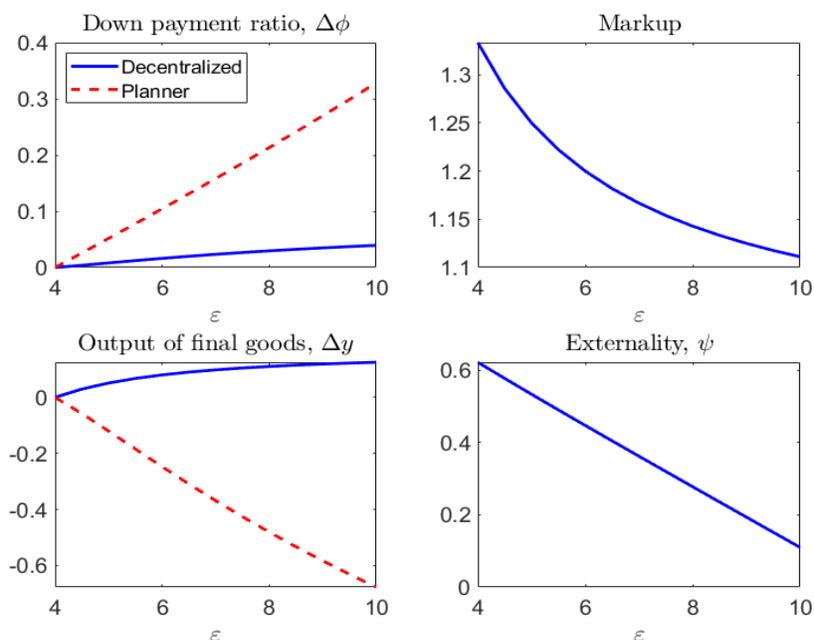


Figure 7: Sensitivity to elasticity of substitution ε . The solid line is for the decentralized equilibrium. The dashed line is for the centralized equilibrium.

Notes: The figure shows the down payment ratio, price markup, aggregate output, and externality as functions of the elasticity of substitution ε . The externality is measured as the ratio of the external effect of trade finance (equation (15)) over the sum of the external and internal effects (equations (15) and (16)). Parameter values are in Table 5.

As expected, a higher elasticity of substitution ε reduces the price markup charged on intermediate goods (second panel). As far as trade credit is concerned, the elasticity has two opposite effects. On the one hand, a higher elasticity reduces the profits of upstream firms due to the lower markup. This lowers the benefits of a higher demand which in turn reduces trade

lending. On the other, a higher elasticity reduces the complementarity of intermediate goods. This implies that the demand for the goods produced by an upstream firms is more responsive to a change in the down payment policy: By lowering the down payment ratio ϕ_j , the firm can lure more customers from its competitors. This increases trade lending.

The first effect dominates in the numerical example, which explains why ϕ increases with ε . The down payment ratio, however, increases less than in the centralized economy. This is because the second effect is zero when optimal policies are chosen by the planner. There is no value for the planner in luring demand from one firm in favor of another firm. The externality is zero in the planner economy while in the decentralized economy decreases with ε (fourth panel).

Final output in the decentralized economy increases slightly with ε . This is due mainly to the declining markup. In the planner's economy, instead, output declines with ε . Even if the markup decreases also in the planner economy (remember that the markup policy is the same), the stronger decline in trade credit leads to a decline in aggregate output.

To conclude, higher elasticity of substitution is associated with a lower markup and a lower externality. This suggests that the cascade of credit expansion policies tends to be smaller if upstream intermediate producers have more market power and charge higher price markups.

3.3 Upstream firm heterogeneity and liquidity

In this section we deviate from the assumption that upstream firms have the same size and show that in the decentralized equilibrium trade credit policy depend on the relative size of a firm. The relative size of an upstream firm is determined by the number of produced varieties (the size of the set \mathbf{I}_j).

Size heterogeneity is important for two reasons. First, it rationalizes the empirical finding that credit cascade increases with the size of firms. Second, firm heterogeneity helps us understanding the overall cascade of a credit expansion to the whole economy.

When firms have different sizes and the constraint $a \geq 0$ is binding, it is difficult to provide an analytical characterization of the decentralized equilibrium. Therefore, we characterize the equilibrium with a numerical example. Still, the analytical properties derived earlier for the symmetric economy help us understanding the numerical properties shown here.

For the numerical exercise we consider a version of the model with two

upstream firms ($N = 2$). The first firm produces varieties $\mathbf{I}_1 = [0, 0.65]$ and the second firm produces varieties $\mathbf{I}_2 = (0.65, 1]$. We further assume that the initial endowments e_1 and e_2 are proportional to the produced varieties, that is, $e_1 = 0.65e$ and $e_2 = 0.35e$, where e denotes the aggregate endowment. Parameters are the same as those reported in Table 5.

Figure 8 plots several variables as functions of the endowed funds e . A credit expansion is captured in the model by an increase in e . An alternative way to formalize a credit expansion is with loans given to upstream firms at rate r_f . As long as the interest rate paid by upstream firms on these loans is r_f , the economic impact is identical to that generated by an increase in e .¹²

The figure displays four lines. The first three lines are for the decentralized economy: Firm 1, Firm 2, and the sum of the two. The fourth line is for the centralized economy. We only plot the aggregate values because the planner chooses the same down payment ratios ϕ and the same prices q for both firms.¹³ The bottom panels are for a higher value of z (lower productivity).

We focus first on the decentralized economy where prices and down payment ratios are chosen independently by upstream firms. When the economy is in *Regime I*, characterized by low values of the endowment (low liquidity), both firms choose $a = 0$. The shadow value of funds μ_j is bigger than the interest rate earned on financial assets, $r_f = 0.01$. In this region both firms in the upstream sector would like to lend more to downstream firms. However, the limited availability of funds restricts their ability to do so. We also observe that in this region the shadow value for the larger firm is bigger than for the smaller firm. This is because the larger firm internalizes more the benefits from trade lending. In this case, an increase in liquidity e raises trade lending and both firms use the additional funds to lower the down payment ϕ . Therefore, in *Regime I*, a liquidity expansion fully cascades to downstream firms through trade lending.

When the economy is in *Regime II*, the shadow value of endowed funds for Firm 1 (the larger firm) is still above the return on financial assets.

¹²To show this, denote by b_j the loan received by firm j as a result of the credit expansion. This increases the funds available to the firm and, therefore, it should be added to the left-hand-side of the flow of funds constraint (11). This shows that, what matters is the sum of e_t and b_t , not their composition. Therefore, whether the extra funds come from an increase in endowment or extra borrowing does not affect the decisions of upstream firms.

¹³We can prove that it is optimal for the planner to choose the same prices and down payment ratios for all firms even if each firm produces different number of varieties.

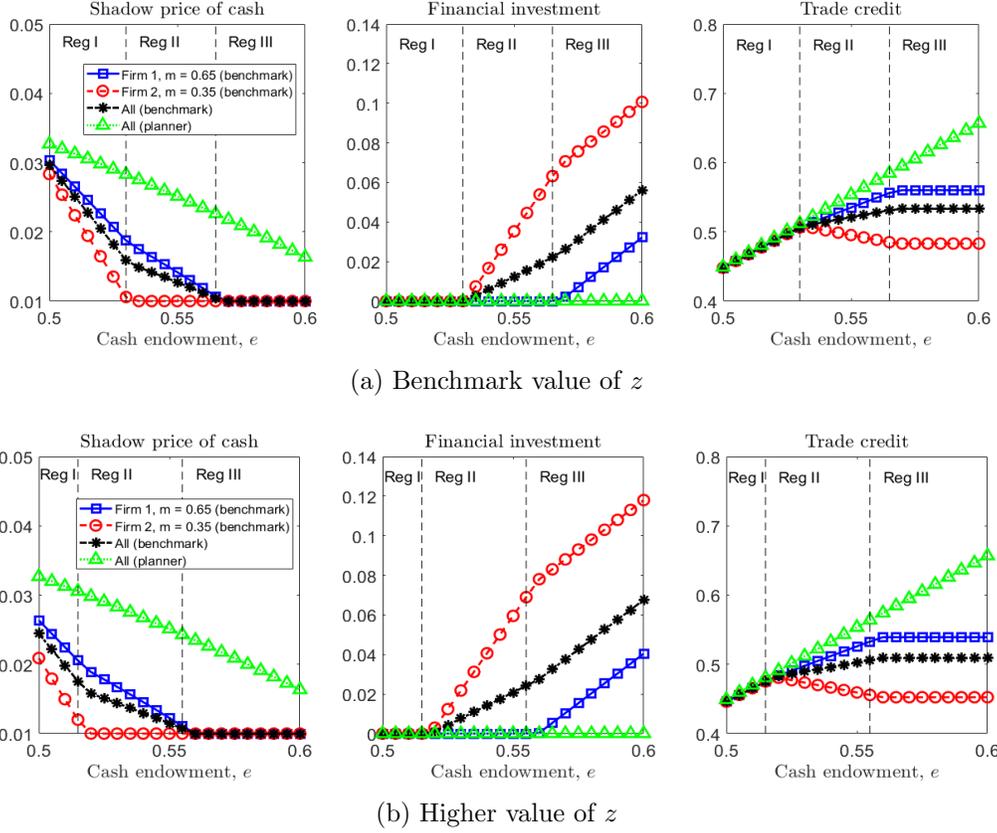


Figure 8: Financial policies when upstream firms are heterogeneous in size.

Notes: The figure shows how upstream firms of different sizes respond to a liquidity expansion in the decentralized and planned economies. In each row, the three panels plot the shadow price of endowed funds, μ_j , financial investment, a_j/m_j , and trade lending, $(1 - \phi_j) \int_{i \in \mathbf{I}_j} x_i q_i / m_j$, where m_j is the size of firm j (the size of \mathbf{I}_j). The top panels are for the benchmark value of z . The bottom panels are for a 1% higher value of z .

However, for Firm 2 (the smaller firm) the shadow value is equal to r_f .¹⁴ In this case, additional endowed funds received by Firm 1 are used for trade lending while additional funds received by Firm 2 are allocated to financial investments. In addition, Firm 2 reallocates some of the funds previously used in trade lending to financial investments (crowding out). This is because

¹⁴The shadow price μ_j cannot be below the return from financial assets, r_f , since the endowed funds can always be invested in financial assets.

the marginal gain from trade lending drops as the down payment requirement for downstream firms is relaxed (from the larger firm). Total trade lending increases only mildly. Therefore, in *Regime II*, a liquidity expansion cascades only partially to downstream firms through the trade credit channel.

In *Regime III* there is plenty of liquidity and the shadow value of endowed funds is equal to r_f for both firms. This is because both firms have funds that exceed those allocated to trade lending ($a > 0$ for both). In this regime, additional funds received by upstream firms are fully allocated to financial investments, not trade credit. Therefore, a liquidity expansion has no effect on trade lending and there is no cascade to downstream firms.

We now turn to the case in which decisions in the upstream sector are made by the planner. The planner sets the same price q for all intermediate goods and chooses the same down payment ratio ϕ for the two upstream firms. This implies that all intermediate goods are produced in the same quantity. All upstream firms share the same μ and their financial investments are proportional to the produced varieties. Therefore, an increase in endowed funds leads to the same responses from the two upstream firms even if they are of different sizes. For the range of e considered in the graph, trade credit in the centralized economy always increases with e . At some point, however, with a sufficiently high e , the shadow value for the planner would also drop to r_f . At that point, further liquidity expansions would not increase trade lending. However, that threshold is bigger than in the decentralized economy.

Changes in trade lending can be decomposed in two components: changes that derive from the down payment ratio ϕ and changes that derive from the demand of intermediate inputs $\int_{i \in \mathbf{I}_j} x_i q_i$. Figure 9 plots these two variables for both firms as functions of liquidity. Sales are plotted per-product.

In Regime I, per-product sales of the smaller upstream firm are slightly higher. This is because the shadow cost of working capital financing, and therefore, the marginal cost of production, is lower for the smaller firm (as shown in Figure 8). This implies that the price for an intermediate good produced by the smaller firm is lower while its sales are higher.

In Regime II, the down payment ratio chosen by the larger firm decreases, while that chosen by the smaller firm increases. Even if the smaller firm raises the down payment ratio, its sales still rises. This is mainly due to the fact that more trade lending from the larger firm increases also the demand for the intermediate goods produced by the smaller firm.

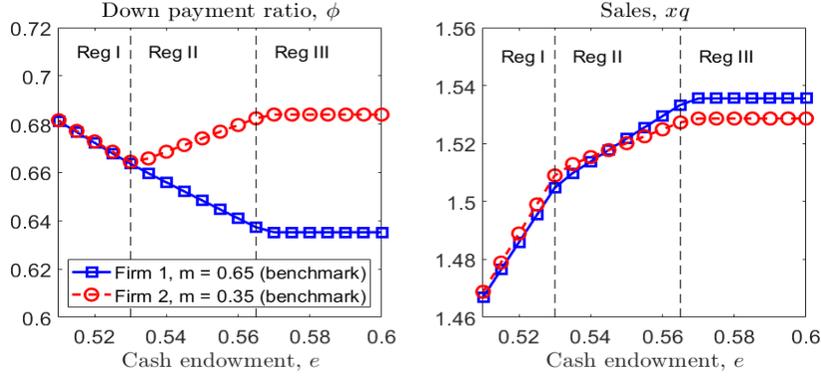


Figure 9: Down payment ratio and per-product sales with heterogeneous firms.

Notes: The figure shows how upstream firms of different sizes respond to a liquidity expansion in the benchmark economy. The first panel plots the down payment ratio, ϕ_j , for $j \in \{1, 2\}$. The second panel plots per-product sales, $\int_{i \in \mathbf{I}_j} x_i q_i / m_j$, where m_j is the number of intermediate goods produced by firm $j \in \{1, 2\}$.

3.3.1 Liquidity expansion and cascade

The empirical analysis suggests that liquidity injections increase the availability of funds for firms, especially in the upstream sector. This could encourage more trade lending to downstream firms. However, a concern often voiced in policy discussions is that the additional credit received by more connected firms does not necessarily lead to an increase in trade lending. Instead, the extra funds could be allocated to alternative financial investments, limiting the benefits of the credit expansion to firms that are less connected to banks. The theoretical analysis with heterogeneous firms shows how the model could generate the limited cascade and how this could be related to the externality in trade lending.

Consider the range of endowments e that defines *Regime II* in Figure 8. In this regime, the larger upstream firm have a higher propensity to supply trade credit than the smaller firm, consistently with the empirical findings of Section 2.3 (Tables 3 and 4). A credit expansion may fail to fully reach downstream firms because some of the upstream firms—those that are smaller—do not find optimal to use the additional funds to expand trade lending. Let's compare this to the centralized economy.

If financial decisions are made by the planner and we are still located in *Regime II*, additional funds would be fully allocated to trade lending. This

shows that the externality in trade lending could be important for generating the heterogeneous responses of small and large upstream firms. It could also be important in generating a limited cascade of the liquidity expansion to the whole economy. In fact, if we start from an initial value of e located in *Regime II* or *Regime III*, an increase in e in the centralized economy leads to the same increase in trade credit. In the decentralized economy, instead, the same increase in e leads to a smaller increase in trade lending.

To investigate how macroeconomic conditions affect the degree of liquidity cascade and, therefore, the effectiveness of expansionary credit policies, we repeat the exercise considered in Section 3.3 when productivity is lower (that is, the value of z is higher). We interpret the lower productivity state as capturing a recessionary scenario where credit policies are more likely to be implemented. The results are shown in the bottom panels of Figure 8.

By comparing the bottom panels to the top panels, we can see that lower productivity enhances the incidence of the externality. When productivity is lower, it becomes less profitable for downstream firms to expand production. This reduces their willingness to substitute intermediate goods requiring high down payment ratios with those requiring lower down payments. This reduces the ability of an upstream firm to stimulate its own demand through trade lending, which is reflected in a lower shadow value of endowed funds.

With a lower productivity, *Regime II* and *Regime III* shift to the left and become wider. Therefore, a liquidity expansion that partially cascades to downstream industries in normal times may not have any significant effect in recession. For example, in the benchmark scenario (top panels), a liquidity expansion that raises e from 0.56 to 0.57 induces a mild increase in total trade lending to downstream firms. However, in the recession scenario (bottom panels), the same liquidity expansion has no effect on trade lending. Instead, when financial decisions are centralized, the same liquidity expansion leads to the same and larger increase in trade credit.

3.4 Additional properties

In this subsection we explore additional features of the model. We consider first the case in which liquidity injections are tilted toward larger firms. We then explore the case in which credit expansions target downstream firms.

3.4.1 Targeting larger firms

The simulation shown in Figure 8 is based on the assumption that the credit expansion—captured by an increase in the endowment e —is proportional to the size of upstream firms. In reality, larger firms may be the primary beneficiary of a credit expansion. In this subsection we discuss the implications of a credit expansion that targets larger firms.

Consider again the environment with two upstream firms where Firm 1 is bigger than Firm 2. We repeat the exercise presented in the previous subsection (top panels of Figure 8) but under the assumption that the increase in the aggregate endowment e is fully allocated to the larger firm. Thus, the increase in cash endowments for Firm 1 is $\Delta e_1 = \Delta e/m_1$, where m_1 is the mass of Firm 1, while the change in cash endowment for Firm 2 is $\Delta e_2 = 0$.

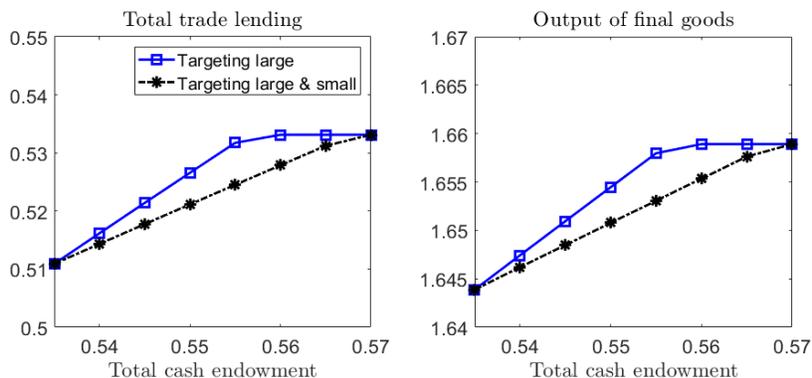


Figure 10: Aggregate trade lending and output in response to credit expansions.

Notes: The figure plots the response of total trade lending and final output to credit expansion policies when targeting both upstream firms or only the larger firm. The range of total endowment used to construct the figure corresponds to Regime II in Figure 8.

Figure 10 plots aggregate trade lending and aggregate output as functions of the aggregate endowment, when financial expansion policies have different targets. The range of the aggregate endowment plotted in the figure is for Regime II outlined in the top panels of Figure 8. Both aggregate trade lending and output increase faster when the financial expansion targets the larger upstream firm. This indicates that a credit expansion targeting the larger firm is more effective, at least when the state of the economy is in Regime II. This reflects the different behavior of the two upstream firms. While the

smaller firm hoards the extra funds received from the credit expansion, the larger firm uses the funds to expand trade lending to downstream firms.

3.4.2 Targeting downstream firms

A simple way to explore the role of credit expansions that target downstream firms is to increase the borrowing limit \bar{b} . An increase in \bar{b} could be very effective as a macroeconomic stimulus. Provided, of course, that this is technically possible. Borrowing limits are typically imposed for enforceability reasons, rather than being the result of regulatory restrictions. Nevertheless, it is interesting to explore the macroeconomic consequences of relaxing the borrowing limit \bar{b} .

Figure 11 shows the responses to two alternative credit expansions. The first targets the upstream sector (higher e) while the second targets the downstream sector (higher \bar{b}). For this exercise we assume that upstream firms have the same size, that is, $m_1 = m_2 = 0.5$.

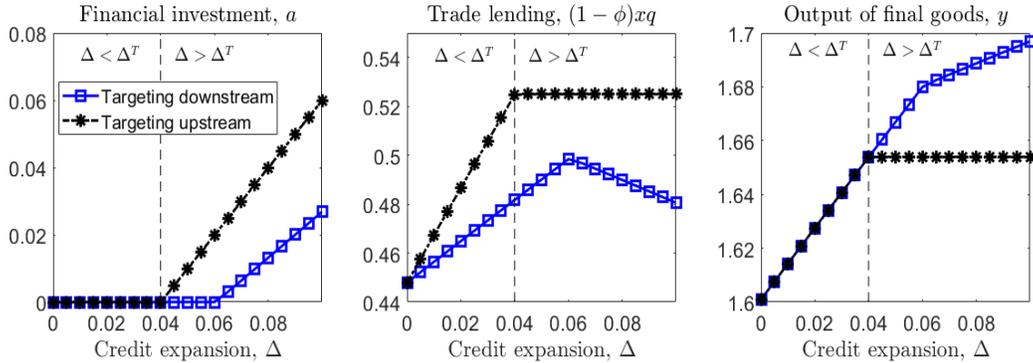


Figure 11: Responses of upstream and downstream firms to a credit expansion.

Notes: The above figure shows the responses of upstream and downstream firms to a credit expansion, when the expansion targets upstream firms and when it targets downstream firms. Upstream firms are of the same size.

With a credit expansion of size Δ targeted at the upstream sector, the endowment of upstream firms increases by Δ . With a credit expansion targeted at the downstream sector, the borrowing limit \bar{b} increases by Δ .

When the size of the credit expansion Δ is smaller than the threshold Δ^T , a credit expansion that targets the upstream sector is as effective as a credit

expansion that targets the downstream sector. This is because when $\Delta < \Delta^T$, the additional funds received by upstream firms are fully re-channeled to downstream firms through trade lending. Thus, a credit expansion that targets upstream firms fully cascades to the downstream sector. In this case a credit expansion that targets the upstream sector is equivalent to a credit expansion that targets the downstream sector.

When Δ is larger than Δ^T , a credit expansion targeted at the downstream sector could be more effective in stimulating output. This is because the extra funds received by upstream firms are used for financial investments rather than being re-channeled to downstream firms. In order to channel more credit to downstream firms, the borrowing limit \bar{b} needs to be relaxed. Thus, a credit expansion that targets the downstream sector is more effective.

4 Conclusions

Chinese upstream firms may have easier access to bank financing than downstream firms. Still, downstream firms can borrow indirectly from banks through trade lending provided by upstream firms. Thus, even if a credit expansion benefits more directly firms operating in the upstream sector, it can reach other sectors of the economy through the trade credit channel. The empirical analysis conducted in the first part of the paper, however, suggests that credit expansions do not fully cascade from more bank-connected firms (upstream) to less bank-connected firms (downstream).

We develop a theoretical model that can generate limited credit cascade. The model highlights an externality that impacts the trade lending decisions of firms. When an upstream firm lends to downstream firms, the increased sales allowed by trade credit are shared with other upstream firms. But since each firm cares only about its own sales, it ignores the benefits that trade lending creates for other firms. This implies that in equilibrium the volume of trade credit is below its social optimal level. Also, the cascade of a credit expansion to the whole economy may be reduced by the externality.

The severity of the trade credit externality varies with the size of upstream firms and with the state of the economy. Size matters because larger firms internalize more the benefits of trade lending. The state of the economy matters because the externality becomes more severe in recessions. This suggests that credit policy expansions in China may be less effective exactly when they might be needed the most, that is, in an economic slowdown.

A 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 (S.25) to (S.27), while all other equilibrium conditions do not change. As shown in Section S1.6, in the equilibrium of the market economy, q^* and ϕ^* , are jointly determined by (S.58) and (S.59), while in the planner's equilibrium, q^* and ϕ^* , are jointly determined by (S.58) and (S.61). By comparing (S.59) and (S.61), it is easy to see that if $\varepsilon(1 - q^*) < 1$ in the competitive equilibrium, the left-hand-side of (S.59) is smaller than the left-hand-side of (S.61). Since upstream firms invest positive amounts on financial assets, thus $\mu^* = r_f$. Thus, the right-hand-sides of (S.59) and (S.61) are the same and decreasing in ϕ , and it follows that the ϕ^* chosen by the planner is lower than in the competitive equilibrium. ■

B Proof of Propositions 2 and 3

Note that under Assumption 1, by using (S.45) in (S.58) to eliminate x^* , we have

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

In addition, since upstream firms hold positive amounts of financial assets in equilibrium, thus the shadow price of endowed funds, μ^* , is r_f . Thus, the above equation implies

$$q^* = z \left(\frac{\varepsilon(1 + r_f)w}{(\varepsilon - 1)f(\phi^*, r_f)} \right)^{\frac{1}{1+\alpha}} \left(\frac{\bar{b}}{\phi^*} \right)^{\frac{\alpha}{1+\alpha}}. \quad (19)$$

Using the above equation and $\mu^* = r_f$ in (S.59) to eliminate q^* and μ^* , we obtain

$$\frac{1}{\varepsilon} \left\{ \frac{1}{N} + \varepsilon \left(\frac{N-1}{N} \right) \left[1 - z \left(\frac{\varepsilon(1 + r_f)w}{(\varepsilon - 1)f(\phi^*, r_f)} \right)^{\frac{1}{1+\alpha}} \left(\frac{\bar{b}}{\phi^*} \right)^{\frac{\alpha}{1+\alpha}} \right] \right\} = \frac{\phi^* f'(\phi^*, r_f)}{f(\phi^*, r_f)}, \quad (20)$$

by which the equilibrium down payment policy ϕ^* is determined. Note that the only endogenous variable in the above equation is ϕ^* . Moreover, the left-hand-side of the above equation is increasing in ϕ^* since $f(\phi_j, \mu_j)$ is increasing in ϕ_j , and the right-hand-side is decreasing in ϕ^* by assumption.¹⁵ Thus, if there exists an equilibrium, ϕ^* is uniquely determined.

¹⁵Recall that the elasticity of $f(\phi_j, \mu_j)$ with respect to ϕ_j is assumed to be negative.

Consider a symmetric equilibrium in which $\varepsilon(1 - q^*) < 1$ holds. Note that q^* is given by (19). Thus, $\varepsilon(1 - q^*) < 1$ implies that the second term on the left-hand-side of (20) is less than the first term. First, suppose N increases. All else being equal, the left-hand-side of (20) decreases. Since the left-hand-side of (20) is increasing in ϕ^* and the right-hand-side is decreasing in ϕ^* , the down payment ratio should be higher with the increased value of N .

Second, suppose z increases. All else being equal, the left-hand-side of (20) decreases. Since the left-hand-side of (20) is increasing in ϕ^* and the right-hand-side is decreasing in ϕ^* , the down payment ratio should be higher with the increased value of z .

Finally, when trade finance is centrally planned, the equilibrium down payment ratio, ϕ_p^* , is determined by (S.61). Obviously, when $\mu^* = r_f$ holds, the equilibrium down payment ratio does not vary with N or z . ■

C Proof of Proposition 4

Proposition 4 *Consider a version of the model in which there are N upstream firms and the varieties of intermediate goods produced by upstream firms is given by $\mathbf{I}_1, \mathbf{I}_2, \dots, \mathbf{I}_N$. Suppose the endowed funds are proportional to the mass of varieties produced by each firm. If the planner makes decisions on behalf of all upstream firms, then there exists a symmetric equilibrium in which*

- *All upstream firms produce and sell the same quantity x^* of each intermediate good at the same price q^* and they have the same ϕ^* and μ^* . Financial investments are proportional to the mass of produced varieties.*
- *The values of q^* , x^* , ϕ^* and μ^* are independent of the distribution of production varieties $\mathbf{I}_1, \mathbf{I}_2, \dots, \mathbf{I}_N$.*

Proof. As shown in Section S1.4, the planner's equilibrium is defined by equations (S.21)-(S.24), (S.26) and (S.27). We now show that there exists an equilibrium in which the planner chooses the same down payment ratio ϕ^* for all the firms and the same price q^* for all the intermediate goods. To do so, we first note that by imposing $\phi_j = \phi^*$, for any j , and $q_i = q^*$, for any i , on (S.21)-(S.23), we have

$$x^* = \frac{y^*}{[1 + \phi^*(r + \lambda^*)]^\varepsilon (q^*)^\varepsilon}, \quad (21)$$

$$q^* = \frac{1}{1 + \phi^*(r + \lambda^*)}, \quad (22)$$

$$y^* = \frac{\bar{b}}{\phi^* [1 + \phi^*(r + \lambda^*)]^{-\varepsilon} (q^*)^{1-\varepsilon}}, \quad (23)$$

which imply

$$x^* = y^* = \frac{\bar{b}}{\phi^* q^*}. \quad (24)$$

Second, note that by evaluating $\partial x_i / \partial q_i$ and $\partial x_i / \partial \phi_j$ derived in Section S1.5 at the equilibrium point and using (21)-(23), we have

$$\left. \frac{\partial x_i}{\partial q_i} \right|_{\mathbf{Q}=\mathbf{Q}^*, \mathbf{\Phi}=\mathbf{\Phi}^*} = -\varepsilon \frac{y^*}{q^*} \quad (25)$$

$$\left. \frac{\partial x_i}{\partial \phi_j} \right|_{\mathbf{Q}=\mathbf{Q}^*, \mathbf{\Phi}=\mathbf{\Phi}^*} = -\frac{y^*}{\phi^*} [m_j + \varepsilon (1 - m_j) (1 - q^*)], \text{ for } i \in \mathbf{I}_j, \quad (26)$$

$$\left. \frac{\partial x_i}{\partial \phi_j} \right|_{\mathbf{Q}=\mathbf{Q}^*, \mathbf{\Phi}=\mathbf{\Phi}^*} = -\frac{y^*}{\phi^*} [m_j - \varepsilon m_j (1 - q^*)], \text{ for } i \notin \mathbf{I}_j, \quad (27)$$

where m_j is the mass of variety produced by firm j , with $m_j > 0$ and $\sum_{j=1}^N m_j = 1$. Third, by evaluating (S.24) and (S.27) at the equilibrium point and using (25)-(27) in the obtained equations, we have

$$q^* f(\phi^*, \mu^*) = \left(\frac{\varepsilon}{\varepsilon - 1} \right) (1 + \mu^*) w l'(y^*), \quad (28)$$

$$\frac{1}{\varepsilon} = \frac{\phi^* f'(\phi^*, \mu^*)}{f(\phi^*, \mu^*)}. \quad (29)$$

Finally, since the endowed funds are proportional to the mass of varieties produced by each firm, we have $e_j = m_j e$. By imposing symmetry on (S.26), we obtain

$$m_j e + m_j \phi^* x^* q^* = m_j w l(x^*) + a^*. \quad (30)$$

Thus, when the endowed funds, e , is large enough such that its shadow value drops to the return on the financial assets, i.e., $\mu^* = r_f$, then the financial investment of upstream firms is positive, i.e., $a^* > 0$, and the values of x^* , y^* , q^* , ϕ^* and a^* are jointly determined by (24), (28), (29) and (30). Otherwise, $a^* = 0$, and the values of x^* , y^* , q^* , ϕ^* and μ^* are jointly determined by the same set of equations. Obviously, the equilibrium quantities and prices are independent of the distribution of production varieties $\mathbf{I}_1, \mathbf{I}_2, \dots, \mathbf{I}_N$. ■

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Online Supplement to

”Dynamics of Trade Credit in China”

by

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S1 Industry upstreamness

We derive the measure of industry upstreamness used in the empirical analysis from a production network model based on Acemoglu et al. (2012). The model can be viewed as a simplified version of Bigio and La’O (2020) and Liu (2019). An industry that is more influential in the production network as supplier (relative to its scale) will have a higher degree of upstreamness. Let ξ_i^{in} denote the upstream score of industry i , and $\boldsymbol{\xi}^{in} = (\xi_1^{in}, \xi_2^{in}, \dots, \xi_N^{in})'$ the vector of all scores defined as

$$(\boldsymbol{\xi}^{in})' = \kappa^{in} \cdot \boldsymbol{\mu}' [\mathbf{I} - (1 + \lambda) \cdot \boldsymbol{\Theta}]^{-1}. \quad (\text{S.1})$$

$\boldsymbol{\Theta} \equiv [\theta_{ij}]$ is the matrix of θ_{ij} , with θ_{ij} the share of good j used by industry i as input; $\boldsymbol{\mu} = (\mu_1, \mu_2, \dots, \mu_N)'$ is the vector of μ_j , where μ_j is the share of good j used by consumption good producers; \mathbf{I} is the identity matrix of size N ; λ is the cost to purchase a dollar’s worth of intermediate goods; and κ^{in} is a scalar that normalizes the mean of ξ_i^{in} to one. We compute the upstream scores using the input-output table of China for the year 2007. For further details are provided below.

Table S1 lists the two-digit manufacturing industries ranked by upstreamness. The two-digit upstream scores are computed by averaging the three-digit scores weighted by sales.

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Table S1: Two-digit manufacturing industries in China ranked by upstreamness.

Upstream group	Score	Ranking
Non-ferrous metal smelting and rolling processing industry	1.26	1
General equipment manufacturing	1.23	2
Ferrous metal smelting and rolling processing industry	1.20	3
Petroleum processing, coking and nuclear fuel processing	1.16	4
Instrumentation manufacturing	1.16	5
Special equipment manufacturing	1.15	6
Chemical fiber manufacturing	1.14	7
Chemical raw materials and chemical manufacturing	1.14	8
Metal products industry	1.14	9
Transportation equipment manufacturing	1.13	10
Rubber and plastic products industry	1.12	11
Electrical machinery and equipment manufacturing	1.09	12
Paper and paper products industry	1.07	13
Downstream group	Score	Ranking
Computer, communications and other electronic equipment	1.07	14
Wood processing and wood, bamboo, rattan, palm, grass products	1.04	15
Textile industry	1.01	16
Non-metallic mineral products industry	0.98	17
Printing and recording media reproduction	0.97	18
Furniture manufacturing	0.89	19
Wine, beverage and refined tea manufacturing	0.87	20
Leather, fur, feathers and their products and footwear	0.87	21
Tobacco industry	0.85	22
Agricultural and sideline food processing industry	0.81	23
Textile and apparel, clothing industry	0.81	24
Pharmaceutical manufacturing	0.77	25
Food manufacturing	0.70	26

Table S2 reports the upstreamness scores for the top-ten and bottom-ten three-digit industries. The first section of the table is for all Chinese industries while the bottom section is for the manufacturing industries.

S1.1 Detailed derivation of the industry score

Households inelastically supply one unit of labor and consume. There are N industries, indexed by i , where $i = 1, 2, \dots, N$. Each of the N industries produces an intermediate good using a Cobb-Douglas technology. The production function of industry i is given by

$$x_i = \tau_i z_i l_i^{\alpha_i} \prod_{j=1}^N x_{ij}^{(1-\alpha_i)\omega_{ij}}, \quad \text{for } i = 1, 2, \dots, N. \quad (\text{S.2})$$

In the above expression, l_i is the amount of labor employed in industry i ; $\alpha_i \in (0, 1)$ is the share of labor in the total inputs of industry i ; x_{ij} , for

Table S2: Top-ten and bottom-ten three-digit industries by upstreamness.

(a) All industries		
Top-ten	Score	Ranking
Non-ferrous metal mining and dressing	1.42	1
Ferrous metal mining and dressing	1.34	2
Coking industry	1.32	3
Waste and scrap	1.32	4
Ferroalloy smelting industry	1.31	5
Iron industry	1.30	6
Non-ferrous metal smelting and alloy manufacturing	1.30	7
Metal processing machinery manufacturing	1.28	8
Steel industry	1.28	9
Transmission and distribution and control equipment manufacturing	1.28	10
Bottom-ten	Score	Ranking
Liquid milk and dairy products manufacturing	0.70	126
Other food manufacturing	0.69	127
Resident service industry	0.68	128
Health	0.68	129
Convenience food manufacturing	0.67	130
Education	0.66	131
Public facilities management industry	0.65	132
Physical education	0.64	133
Public administration and social organization	0.64	134
Social welfare industry	0.64	135
(b) Manufacturing industries		
Top-ten	Score	Ranking
Coking industry	1.32	1
Ferroalloy smelting industry	1.31	2
Iron industry	1.30	3
Non-ferrous metal smelting and alloy manufacturing	1.30	4
Metal processing machinery manufacturing	1.28	5
Steel industry	1.28	6
Transmission and distribution and control equipment manufacturing	1.28	7
Chemical, wood, non-metal processing equipment manufacturing	1.26	8
Mining, metallurgy, construction equipment manufacturing	1.26	9
Railway transportation equipment manufacturing	1.25	10
Bottom-ten	Score	Ranking
Aquatic product processing industry	0.81	71
Textile and garment, shoes and hat manufacturing	0.81	72
Corn milling	0.81	73
Pharmaceutical manufacturing	0.77	74
Slaughter and meat processing industry	0.77	75
Other food processing industry	0.75	76
Condiment, fermented product manufacturing	0.73	77
Liquid milk and dairy products manufacturing	0.70	78
Other food manufacturing	0.69	79
Convenience food manufacturing	0.67	80

$j = 1, 2, \dots, N$, are the quantities of goods produced by industry j used by industry i as inputs; ω_{ij} , for $j = 1, 2, \dots, N$, are the shares of goods j in

the non-labor inputs of industry i , with $\omega_{ij} \in (0, 1)$ and $\sum_{j=1}^N \omega_{ij} = 1$; z_i is the industry-specific productivity; $\tau_i = [\alpha_i^{\alpha_i} (1 - \alpha_i)^{1 - \alpha_i} \prod_{j=1}^N \omega_{ij}^{(1 - \alpha_i)\omega_{ij}}]^{-1}$ is a scalar.

Consumption good producing sector, indexed by 0, consists of a continuum of homogeneous and competitive firms. The representative firm produces consumption good using a Cobb-Douglas technology

$$x_0 = \tau_0 \prod_{j=1}^N x_{0j}^{v_j}, \quad (\text{S.3})$$

where v_j , with $v_j > 0$ and $\sum_{j=1}^N v_j = 1$, are the shares of intermediate goods j in the total inputs of the consumption goods producer, and $\tau_0 = (\prod_{j=1}^N v_j^{v_j})^{-1}$ is a scalar. Consumption good is used as the numeraire.

We deviate from Acemoglu et al. (2012) by assuming that market imperfections lead to exogenous transaction costs. Let p_j be the price of intermediate good j in terms of consumption goods. Define $\lambda > 0$ the cost to purchase a dollar's worth of intermediate goods. Thus, the costs for firms in industry i to purchase per unit of goods j are λp_j , for $j = 1, 2, \dots, N$. In addition, let w be the price of labor in terms of consumption goods. There is no transaction cost to purchase labor.

The optimization of the representative firm of industry i implies the following demand functions for labor and intermediate goods:

$$l_i = \frac{\alpha_i p_i x_i}{w}, \quad \text{for } i = 1, 2, \dots, N. \quad (\text{S.4})$$

$$x_{ij} = \frac{(1 - \alpha_i)\omega_{ij} p_i x_i}{(1 + \lambda)p_j}, \quad \text{for } i, j = 1, 2, \dots, N. \quad (\text{S.5})$$

In addition, the optimization of consumption goods producers imply

$$x_{0j} = \frac{v_j x_0}{p_j}, \quad \text{for } j = 1, 2, \dots, N. \quad (\text{S.6})$$

Market clearing for labor, intermediate goods, and consumption implies

$$1 = \sum_{i=1}^N l_i, \quad (\text{S.7})$$

$$x_j = \sum_{i=0}^N x_{ij}, \text{ for } j = 1, 2, \dots, N, \quad (\text{S.8})$$

$$x_0 = w + \lambda \sum_{j=0}^N p_j x_j. \quad (\text{S.9})$$

Since the aggregate labor supply is normalized to one, condition (S.9) says that the total income of firms, x_0 , is the sum of the labor cost, w , and transaction costs, $\lambda \sum_{j=0}^N p_j x_j$. Therefore, net aggregate output, denoted by y , is

$$y = x_0 - \lambda \sum_{j=0}^N p_j x_j = w. \quad (\text{S.10})$$

Solution. Plugging the demand functions (S.4) and (S.5) into the production function (S.2) and taking the natural log we obtain

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

which can be written compactly as

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

where $\mathbf{1} \equiv (1, 1, \dots, 1)'$ is a $N \times 1$ vector of ones, $\boldsymbol{\alpha} \equiv (\alpha_1, \alpha_2, \dots, \alpha_N)'$, $\mathbf{p} \equiv (p_1, p_2, \dots, p_N)'$, and $\boldsymbol{\Omega} \equiv [\omega_{ij}]$ is the $N \times N$ matrix of ω_{ij} . Using the above system of equations, we can solve for the vector of equilibrium prices \mathbf{p} ,

$$\ln \mathbf{p} = \mathbf{1} \cdot \ln w + (\boldsymbol{\Psi} - \mathbf{I}) \mathbf{1} \cdot \ln(1 + \lambda) - \boldsymbol{\Psi} \ln \mathbf{z}, \quad (\text{S.11})$$

where $\boldsymbol{\Psi} \equiv [\mathbf{I} - \mathbf{diag}(\mathbf{1} - \boldsymbol{\alpha}) \boldsymbol{\Omega}]^{-1}$ is a Leontief inverse matrix.^{S1}

^{S1}Note that $\mathbf{diag}(\mathbf{1} - \boldsymbol{\alpha}) \boldsymbol{\Omega} \mathbf{1} + \boldsymbol{\alpha} = \mathbf{1}$, which implies $\boldsymbol{\alpha} = [\mathbf{I} - \mathbf{diag}(\mathbf{1} - \boldsymbol{\alpha}) \boldsymbol{\Omega}] \mathbf{1}$. Thus, $\boldsymbol{\Psi} \boldsymbol{\alpha} = \mathbf{1}$.

By plugging demand functions (S.6) into production function (S.3) and taking the natural log of the both sides of the resulting equation, we obtain:

$$0 = \sum_{j=1}^N v_j \ln p_j,$$

which can be written compactly as

$$\mathbf{v}' \ln \mathbf{p} = 0. \tag{S.12}$$

Therefore, by left multiplying the both sides of (S.11) by \mathbf{v}' and using (S.12) and (S.10) in the resulting equation, we obtain

$$\ln y = \boldsymbol{\beta}' \ln \mathbf{z} - \mathbf{v}' (\boldsymbol{\Psi} - \mathbf{I}) \mathbf{1} \cdot \ln(1 + \lambda), \tag{S.13}$$

where $\boldsymbol{\beta} \equiv (\mathbf{v}' \boldsymbol{\Psi})'$ is referred to as the influence vector.

Upstreamness measure. The j th element of $\boldsymbol{\beta}$ corresponds to the percentage change in aggregate net output, y , in responding to a one percent change in industry j 's productivity, z_j . Thus, vector $\boldsymbol{\beta}'$ in (S.13) is interpreted as the “influence vector”, capturing the influences of industries on aggregate output.

To see how an industry specific shock propagates through the production network, we note first that $\boldsymbol{\beta}$ can be re-written as

$$\begin{aligned} \boldsymbol{\beta}' &= \mathbf{v}' \boldsymbol{\Psi} \\ &= \mathbf{v}' [\mathbf{I} - \mathbf{diag}(\mathbf{1} - \boldsymbol{\alpha}) \boldsymbol{\Omega}]^{-1} \\ &= \mathbf{v}' [\mathbf{I} + \mathbf{diag}(\mathbf{1} - \boldsymbol{\alpha}) \boldsymbol{\Omega} + (\mathbf{diag}(\mathbf{1} - \boldsymbol{\alpha}) \boldsymbol{\Omega})^2 + \dots]. \end{aligned}$$

The $(i$ th, j th) element of $\mathbf{diag}(\mathbf{1} - \boldsymbol{\alpha}) \boldsymbol{\Omega}$, i.e., $(1 - \alpha_i) \omega_{ij}$, is the elasticity of industry i 's output with respect to intermediate good j . Thus, it captures the direct impact of a shock to industry j (the supplier) on industry i (the buyer) through downstream propagation. Since all industries are interconnected, the impact also propagates to other industries. The Leontief inverse, $[\mathbf{I} - \mathbf{diag}(\mathbf{1} - \boldsymbol{\alpha}) \boldsymbol{\Omega}]^{-1}$, captures the sum of these direct and indirect impacts during the infinite rounds of propagation. Its $(i$ th, j th) element captures the total impacts of an industry j 's idiosyncratic shock on industry i through downstream propagation.

We consider an influence-based measure for industry upstreamness. The idea is that an industry that is more influential in the production network as

supplier (relative to its scale) should have a higher degree of upstreamness. Let $\gamma_i \equiv (x_i p_i)/x_0$ be the ratio of industry i 's sales to the gross output of consumption goods. This measures industry i 's size. Let ξ_i^{in} denote the upstream score of industry i , and $\boldsymbol{\xi}^{in} = (\xi_1^{in}, \xi_2^{in}, \dots, \xi_N^{in})'$ the vector of scores. This is defined as

$$(\boldsymbol{\xi}^{in})' = \kappa^{in} \cdot \boldsymbol{\beta}' \mathbf{diag}(\gamma_1^{-1}, \gamma_2^{-1}, \dots, \gamma_N^{-1}), \quad (\text{S.14})$$

where κ^{in} is a scalar that normalizes the mean of ξ_i^{in} to one. Thus, $\xi_i^{in} = \beta_i/\gamma_i$ measures the influence of industry i to the whole production sector through downstream propagation (relative to its size).^{S2} In other words, industry with a higher ξ_i^{in} is more influential in the production network as supplier.

When firms in each industry purchase intermediate goods from their upstream suppliers, they pay a transaction cost. These transaction costs “accumulate” when going from downstream to upstream. Thus, ξ_i^{in} is also referred to as “distortion centrality” in Liu (2019).

Upstream scores. To compute the upstream scores of Chinese industries, we first note that $\boldsymbol{\xi}^{in}$, given by (S.14), can be re-written as

$$(\boldsymbol{\xi}^{in})' = \kappa^{in} \cdot \boldsymbol{\mu}' [\mathbf{I} - (1 + \lambda) \cdot \boldsymbol{\Theta}]^{-1}. \quad (\text{S.15})$$

In the above expression, $\boldsymbol{\Theta} \equiv [\theta_{ij}]$ is the matrix of θ_{ij} , where $\theta_{ij} \equiv x_{ij}/x_j$ is the share of good j used by industry i as input; $\boldsymbol{\mu} = (\mu_1, \mu_2, \dots, \mu_N)'$ is the vector of μ_j , where $\mu_j \equiv x_{0j}/x_j$ is the share of good j used by consumption good producers. Thus, θ_{ij} and μ_j are referred to as demand shares. It is easy to see that clearing of the market for good j implies $\mu_j + \sum_{i=1}^N \theta_{ij} = 1$.^{S3}

Since China engages in international trade, we adjust the upstreamness measure to an open economy following Antràs et al. (2012). We consider a two-country economy in which both the domestic and foreign economies have a complete industrial system with production sectors 0 to N . We assume that there is no cost for production factors to move between the two countries.

^{S2}Note that in the presence of transaction cost, β_i is no longer equal to γ_i as in Acemoglu et al. (2012). In fact, it is easy to see that market clearing conditions S.5 imply $\boldsymbol{\gamma}' = \boldsymbol{v}' [\mathbf{I} - (1 + \lambda)^{-1} \cdot \mathbf{diag}(\mathbf{1} - \boldsymbol{\alpha})\boldsymbol{\Omega}]^{-1}$.

^{S3}Note that $(1 - \alpha_i)\omega_{ij} = (1 + \lambda)\theta_{ij}(x_j p_j)/(x_i p_i)$. Thus, $\mathbf{diag}(\mathbf{1} - \boldsymbol{\alpha})\boldsymbol{\Omega} = (1 + \lambda) \cdot \mathbf{diag}(\frac{1}{x_1 p_1}, \frac{1}{x_2 p_2}, \dots, \frac{1}{x_N p_N}) \boldsymbol{\Theta} \mathbf{diag}(x_1 p_1, x_2 p_2, \dots, x_N p_N)$. Thus, $[\mathbf{I} - \mathbf{diag}(\mathbf{1} - \boldsymbol{\alpha})\boldsymbol{\Omega}]^{-1} = \mathbf{diag}(\frac{1}{x_1 p_1}, \frac{1}{x_2 p_2}, \dots, \frac{1}{x_N p_N}) [\mathbf{I} - (1 + \lambda) \cdot \boldsymbol{\Theta}]^{-1} \mathbf{diag}(x_1 p_1, x_2 p_2, \dots, x_N p_N)$. Therefore, it is obvious that $\boldsymbol{\xi}^{in}$, defined by (S.14), can be re-written as (S.15).

Thus, domestic demands for good j and the sales of industry j are changed from (S.5) and (S.8) to

$$x_{ij} + im_{ij} = \frac{(1 - \alpha_i)\omega_{ij}p_i x_i}{(1 + \lambda)p_j}, \text{ for } i, j = 1, 2, \dots, N. \quad (\text{S.16})$$

$$x_j = \sum_{i=0}^N x_{ij} + \sum_{i=0}^N ex_{ij}, \text{ for } j = 1, 2, \dots, N. \quad (\text{S.17})$$

In the above equations, im_{ij} is the amount of good j industry i in the domestic economy purchases from industry j in the foreign economy; ex_{ij} is the amount of good j industry j in the domestic economy sells to industry i in the foreign economy. Thus, in the two-country economy the demand shares, θ_{ij} and μ_j , are changed from x_{ij}/x_j and x_{0j}/x_j to

$$\theta_{ij} = \frac{x_{ij} + ex_{ij}}{x_j}, \text{ for } i = 1, 2, \dots, N, \text{ and } \mu_j = \frac{x_{0j} + ex_{0j}}{x_j}. \quad (\text{S.18})$$

However, we observe only domestic inter-industry flows x_{ij} and total exports $\sum_{i=0}^N ex_{ij}$ but do not have information on international inter-industry flows ex_{ij} . Thus, we follow Antràs et al. (2012) and assume that the allocation of foreign sales between industries are the same as the allocation of domestic sales. This implies

$$\frac{ex_{ij}}{\sum_{i=0}^N ex_{ij}} = \frac{x_{ij}}{\sum_{i=0}^N x_{ij}}, \text{ for } i = 0, 1, \dots, N. \quad (\text{S.19})$$

We can show that the above conditions hold in a symmetric equilibrium with two countries. By using (S.19) and (S.17), θ_{ij} and μ_j can be re-written as

$$\theta_{ij} = \frac{x_{ij}}{\sum_{i=0}^N x_{ij}}, \text{ for } i = 1, 2, \dots, N, \text{ and } \mu_j = \frac{x_{0j}}{\sum_{i=0}^N x_{ij}}. \quad (\text{S.20})$$

We estimate θ_{ij} and μ_i , for $i, j = 1, 2, \dots, N$, using the 2007 input-output table for China. The transaction cost parameter, λ , is set to 0.1, as suggested by Liu (2019). The value of κ^{in} is such that the mean of the upstream scores is one.

Figure S1 shows the estimated demand share matrix of industries, i.e., Θ . The size of the dot on the i th row and j th column represents the share of intermediate good j used by industry i as input, i.e., θ_{ij} . The industries are ordered by upstreamness (most upstream to most downstream),

from top to bottom and from left to right. Demand shares below 10% and within-industry demands are excluded. As shown in the figure, the important supply-demand relationships are in the lower-left triangle of the box, which indicates that upstream firms are important suppliers to downstream firms, not the opposite.

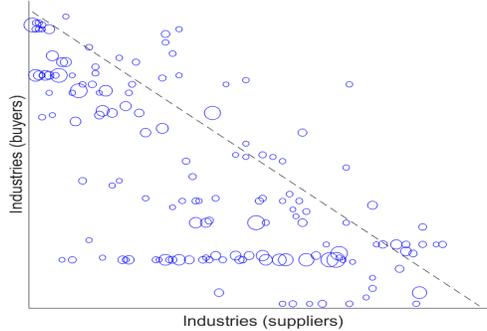


Figure S1: Inter-industry flows of intermediate goods.

Notes: The figure shows the demand share matrix of all industries, Θ , truncated below at 10%. The size of the circle on the i th row and j th column corresponds to the share of intermediate good j used by industry i as input, i.e., θ_{ij} . Circles that are smaller than 10% are removed. Industries are ordered by upstreamness (most upstream to most downstream), from top to bottom and from left to right. Circles that correspond to within-industry transactions (on the diagonal) are excluded.

We now compare the influence-based upstreamness measure, ξ^{in} , with the measure constructed by Fally (2011) and Antràs et al. (2012). This measure is based on the notion that industries that sell a disproportionate share of their output to relatively upstream industries should be relatively upstream themselves. It is given by $(\xi^f)' = \kappa^f \cdot \mathbf{1}'(\mathbf{I} - \Theta)^{-1}$, where $\kappa^f > 0$ is a scalar that normalizes the mean of ξ_i^f to one. As shown in Figure S2, the two measures are significantly correlated. The correlation coefficient between the two measures is 0.99.

S1.2 Characteristics of manufacturing industries

Table S3 reports the estimated correlations of industry characteristics with their upstream ranking at the two- and three-digit industry classifications.

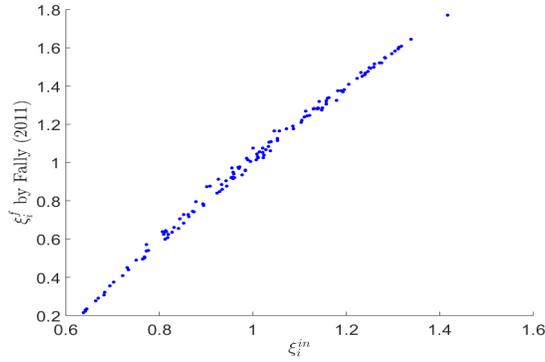


Figure S2: The influence-based measure, ξ_i^{in} , v.s. the upstreamness measure by Fally (2011), ξ_i^f .

Notes: The above figure scatters the industry upstream scores computed according to Fally (2011) and Antràs et al. (2012), i.e., ξ_i^f , against the influence-based upstream scores computed according to (S.1), i.e., ξ_i^{in} . Each dot represents a pair of (ξ_i^{in}, ξ_i^f) . The correlation coefficient between ξ_i^f and ξ_i^{in} is 0.99.

The statistics reported here provide a significance test to the pattern displayed in Figure 2.

Figure S3 shows that more upstream manufacturing industries (based on 3-digit classification) have higher shares of large firms, state-owned firms, and average ratio of trade lending.

S1.3 Short-term financial flows

Table S3: Characteristics of Chinese 2-digit and 3-digit manufacturing industries.

2-digit industry classification									
	Share of large firms			Share of state-owned firms			Ratio of net lending to sales		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Upstream score	0.413** (0.214)			0.522** (0.210)			0.053** (0.021)		
Upstream rank		-0.262** (0.110)			-0.333*** (0.105)			-0.023* (0.011)	
Upstream dummy			0.141** (0.064)			0.174*** (0.062)			0.018*** (0.006)
R^2	0.139	0.198	0.174	0.212	0.306	0.254	0.222	0.153	0.282
Averages for upstream and downstream industries:									
Upstream		0.692			0.261			0.029	
Downstream		0.551			0.087			0.011	
3-digit industry classification									
	Share of large firms			Share of state-owned firms			Ratio of net lending to sales		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Upstream score	0.215* (0.116)			0.361*** (0.105)			0.043*** (0.014)		
Upstream rank		-0.145** (0.070)			-0.227*** (0.063)			-0.024*** (0.009)	
Upstream dummy			0.095** (0.040)			0.120*** (0.037)			0.018*** (0.005)
R^2	0.042	0.052	0.066	0.131	0.141	0.118	0.102	0.090	0.156
Averages for the upstream and downstream industries:									
Upstream		0.683			0.229			0.027	
Downstream		0.588			0.110			0.008	

Notes: The dependent variables are the industry-level share of large firms (weighted by sales), share of state-owned firms (weighted by sales), and average ratio of net trade lending to sales across firms. Net trade lending refers to accounts receivable minus accounts payable. “Upstream score” is the measure for upstreamness constructed in Section S1. “Upstream rank” is the rank for industries in terms of upstreamness divided by the number of industries. “Upstream” is the dummy for the upstream group. The tobacco manufacturing industry, which only state-owned firms are allowed to enter by law, is excluded. The table also reports the average share of large firms, the average share of state-owned firms, and the average ratio of net trade lending to sales for the upstream and downstream industries.

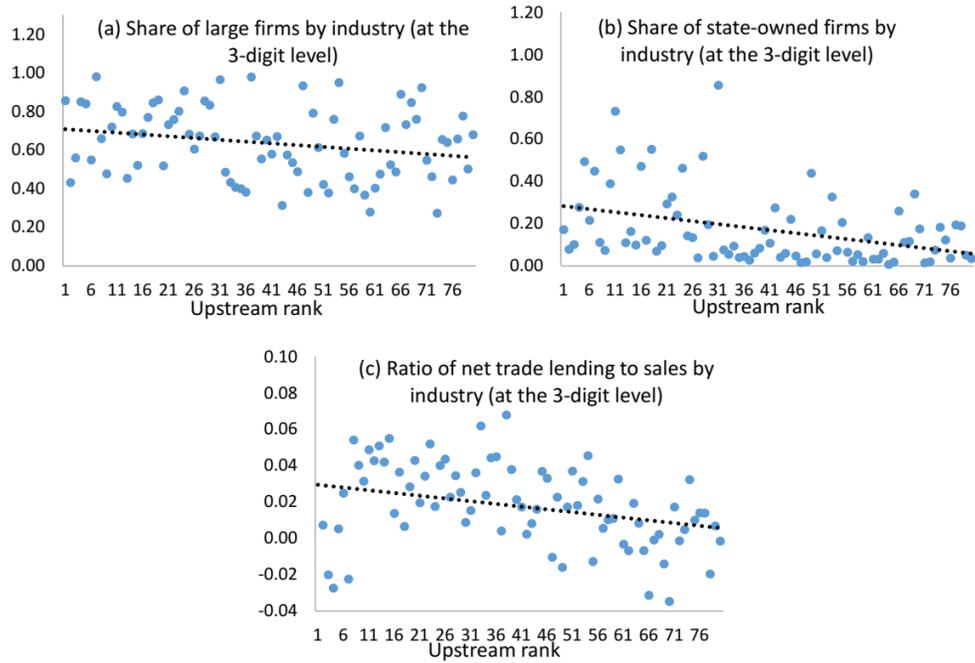


Figure S3: Characteristics of Chinese manufacturing industries at 3-digit level.

Notes: The first panel plots the share of large firms (weighted by sales) in each manufacturing industry. The second panel plots the share of state-owned firms (weighted by sales) in each manufacturing industry. The third panel shows the average ratio of net trade lending to sales across firms for each manufacturing industry. Net trade lending refers to accounts receivable minus accounts payable. The tobacco manufacturing industry, where only state-owned enterprises can operate, is excluded. Industries are ordered by upstreamness (more upstream to more downstream), from left to right. Reported statistics are computed using the 2007 firm-level data from the China Industrial Enterprise Database.

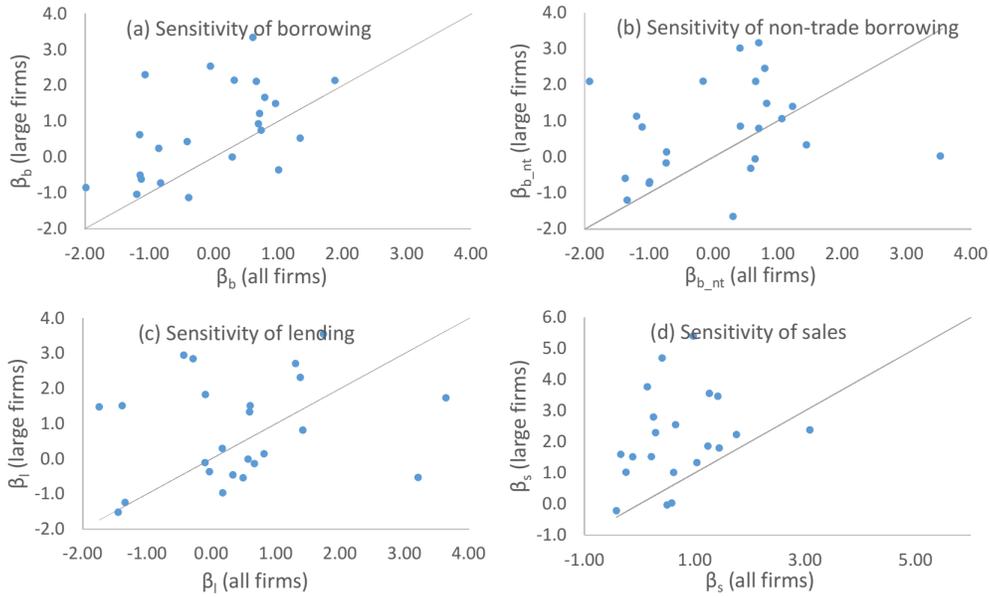


Figure S4: Sensitivity of large firms to monetary policy changes v.s. industry average.

Notes: The above figure compares the industry-level sensitivities of large firms' growth rate of short-term borrowing, growth rate of non-trade borrowing, growth rate of short-term lending and growth rate of sales to M2 growth (i.e., $\beta_{b,i}^{large}$, $\beta_{b_{nt},i}^{large}$, $\beta_{l,i}^{large}$ and $\beta_{s,i}^{large}$) with the corresponding industry averages (i.e., $\beta_{b,i}$, $\beta_{b_{nt},i}$, $\beta_{l,i}$ and $\beta_{s,i}$). The sensitivities for large firms are obtained by estimating equation (1) for each industry using industry-level aggregate data for large firms. The average sensitivities are obtained by estimating equation (1) for each industry using industry-level aggregate data for all firms. Each dot represents a pair of $(\beta_{b,i}^{large}, \beta_{b,i})$. The gray lines are the 45 degree lines.

Table S4: Upstreamness and sensitivities of firms to monetary policy.

Manufacturing industries (all firms)								
	Sensitivity of borrowing to M2		Sensitivity of non-trade borrowing to M2		Sensitivity of lending to M2		Sensitivity of sales to M2	
	$\beta_{b,i}$		$\beta_{b_n,i}$		$\beta_{l,i}$		$\beta_{s,i}$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Upstream score	3.989** (1.851)		3.086 (1.816)		2.642 (2.243)		4.230** (1.886)	
Upstream rank		-2.205** (0.972)		-1.416 (0.980)		-1.681 (1.177)		-2.749*** (0.949)
R^2	0.156	0.177	0.107	0.080	0.056	0.078	0.173	0.259

Notes: The dependent variables are the industry-level sensitivities of growth rate of short-term borrowing, growth rate of non-trade borrowing, growth rate of short-term lending and growth rate of sales to M2 growth (i.e., $\beta_{b,i}$, $\beta_{b_n,i}$, $\beta_{l,i}$ and $\beta_{s,i}$), which are obtained by estimating equation (1) using industry-level aggregate data for all firms. “Upstream score” is the measure for upstreamness constructed in Appendix ???. “Upstream rank” is the rank for industries in terms of upstreamness divided by the number of industries (lower numbers identifies more upstream industries).

Table S5: Upstreamness and sensitivities of large firms to monetary policy.

Manufacturing industries (large firms)								
	Sensitivity of borrowing to M2		Sensitivity of non-trade borrowing to M2		Sensitivity of lending to M2		Sensitivity of sales to M2	
	$\beta_{b,i}^{large}$		$\beta_{b_n,i}^{large}$		$\beta_{l,i}^{large}$		$\beta_{s,i}^{large}$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Upstream score	0.639 (1.957)		0.092 (2.022)		-1.800 (2.496)		2.770 (3.203)	
Upstream rank		-0.388 (1.040)		0.166 (1.075)		0.719 (1.333)		-1.888 (1.686)
R^2	0.004	0.006	0.000	0.001	0.021	0.012	0.030	0.050

Notes: The dependent variables are the industry-level sensitivities of growth rate of short-term borrowing, growth rate of non-trade borrowing, growth rate of short-term lending and growth rate sales to M2 growth (i.e., $\beta_{b,i}^{large}$, $\beta_{b_n,i}^{large}$, $\beta_{l,i}^{large}$ and $\beta_{s,i}^{large}$), which are obtained by estimating equation (1) using industry-level aggregate data for large firms. “Upstream score” is the measure for upstreamness constructed in Appendix ???. “Upstream rank” is the rank for industries in terms of upstreamness divided by the number of industries (lower numbers identifies more upstream industries).

Table S6: Short-term financing and sales of upstream and downstream industries.

I. Upstream manufacturing industries (all firms)								
	Short-term borrowing		Short-term non-trade borrowing		Short-term lending		Sales	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$mshock_{t-1}$	0.953*** (0.220)	1.108** (0.260)	0.954*** (0.291)	1.067*** (0.327)	1.363*** (0.231)	1.320*** (0.302)	1.710*** (0.307)	1.707*** (0.382)
Network E.	No	Yes	No	Yes	No	Yes	No	Yes
Industry Ctrl.	No	Yes	No	Yes	No	Yes	No	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.496	0.514	0.450	0.461	0.423	0.444	0.588	0.610
II. Downstream manufacturing industries (all firms)								
	Short-term borrowing		Short-term non-trade borrowing		Short-term lending		Sales	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$mshock_{t-1}$	0.539 (0.343)	0.538 (0.347)	0.642* (0.350)	0.604* (0.312)	1.079** (0.381)	1.139*** (0.322)	0.765*** (0.224)	0.812*** (0.242)
Network E.	No	Yes	No	Yes	No	Yes	No	Yes
Industry Ctrl.	No	Yes	No	Yes	No	Yes	No	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.164	0.186	0.218	0.231	0.284	0.301	0.665	0.682

Notes: For the regressions reported in the above table, the dependent variables are growth rate of short-term borrowing (i.e., the sum of trade and non-trade borrowing), growth rate of non-trade short-term borrowing, growth rate of short-lending (i.e., the sum of trade and non-trade lending), and growth rate of sales. $mshock_t$ is the exogenous M2 growth (i.e., monetary policy shock) estimated by Chen et al. (2018). The regression controls for network effects and industrial-level growth of sales and fixed assets. All the regressions are conducted using the industry-level aggregate data for all firms over 2004-2016. Regressions reported in Panel I include only upstream industries. Regressions reported in Panel II include only downstream industries.

Table S7: Short-term financing and sales of large firms in upstream and downstream industries.

I. Upstream manufacturing industries (large firms)								
	Short-term borrowing		Short-term non-trade borrowing		Short-term lending		Sales	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$mshock_{t-1}$	1.562*** (0.342)	1.658*** (0.389)	1.568*** (0.445)	1.675*** (0.503)	1.978*** (0.256)	1.751*** (0.408)	2.591*** (0.289)	2.595*** (0.424)
Network E.	No	Yes	No	Yes	No	Yes	No	Yes
Industry Ctrl.	No	Yes	No	Yes	No	Yes	No	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.506	0.514	0.463	0.493	0.402	0.422	0.529	0.537
II. Downstream manufacturing industries (large firms)								
	Short-term borrowing		Short-term non-trade borrowing		Short-term lending		Sales	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$mshock_{t-1}$	1.341** (0.467)	1.161*** (0.375)	1.408** (0.512)	1.060** (0.397)	2.042*** (0.509)	1.860*** (0.439)	2.300*** (0.316)	2.244*** (0.286)
Network E.	No	Yes	No	Yes	No	Yes	No	Yes
Industry Ctrl.	No	Yes	No	Yes	No	Yes	No	Yes
Time trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.231	0.261	0.265	0.329	0.337	0.342	0.497	0.516

Notes: For the regressions reported in the above table, the dependent variables are growth rate of short-term borrowing (i.e., the sum of trade and non-trade borrowing), growth rate of non-trade short-term borrowing, growth rate of short-lending (i.e., the sum of trade and non-trade lending), and growth rate of sales. $mshock_t$ is the exogenous M2 growth (i.e., monetary policy shock) estimated by Chen et al. (2018). The regression controls for network effects and industrial-level growth of sales and fixed assets. All the regressions are conducted using the industry-level aggregate data for large firms over 2004-2016. Regressions reported in Panel I include only upstream industries. Regressions reported in Panel II include only downstream industries.

S1.4 Equilibrium conditions

To derive the equilibrium conditions for the competitive equilibrium, we first note that the equilibrium conditions include the following equations. First, the demand functions for intermediate goods:

$$x_i = D_i(q_i, \phi_j, y, \lambda) \equiv \frac{y}{[1 + (r + \lambda)\phi_j]^\varepsilon q_i^\varepsilon}, \quad (\text{S.21})$$

for $i \in \mathbf{I}_j$ and $j = 1, 2, \dots, N$,

and y and λ are functions of \mathbf{Q} and Φ defined by the following equations:

$$1 = \sum_{j=1}^N [1 + (r + \lambda)\phi_j]^{1-\varepsilon} \int_{i \in \mathbf{I}_j} q_i^{1-\varepsilon}, \quad (\text{S.22})$$

$$y = \frac{\bar{b}}{\sum_{j=1}^N \phi_j [1 + (r + \lambda)\phi_j]^{-\varepsilon} \int_{i \in \mathbf{I}_j} q_i^{1-\varepsilon}}, \quad (\text{S.23})$$

Second, the first order conditions for q_i and ϕ_j are

$$\left[f(\phi_j, \mu_j) q_i - (1 + \mu_j) w'(x_i) \right] \frac{\partial x_i}{\partial q_i} + f(\phi_j, \mu_j) x_i = 0, \text{ for } i \in \mathbf{I}_j \text{ and } j = 1, 2, \dots, N, \quad (\text{S.24})$$

and

$$\int_{i \in \mathbf{I}_j} \left[f(\phi_j, \mu_j) q_i - (1 + \mu_j) w'(x_i) \right] \frac{\partial x_i}{\partial \phi_j} + f'_\phi(\phi_j, \mu_j) \int_{i \in \mathbf{I}_j} x_i q_i = 0, \text{ for } j = 1, 2, \dots, N, \quad (\text{S.25})$$

where

$$f(\phi_j, \mu_j) \equiv 1 - c(\phi_j) + \phi_j \mu_j.$$

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

$$e_j + \phi_j \int_{i \in \mathbf{I}_j} x_i q_i = w \int_{i \in \mathbf{I}_j} l(x_i) + a_j, \text{ for } j = 1, 2, \dots, N, \quad (\text{S.26})$$

and one of the following two conditions should hold,

$$\begin{aligned} a_j > 0 & \quad \text{and} \quad \mu_j = r_f, \\ a_j = 0 & \quad \text{and} \quad \mu_j > r_f. \end{aligned}$$

For the economy in which the down payment ratios and prices of intermediate goods are chosen by the planner, all the equilibrium conditions are the same as in the benchmark economy except that the first order condition for ϕ_j is changed from (S.25) to the following

$$\sum_{\kappa=1}^N \left\{ \int_{i \in \mathbf{I}_\kappa} [f(\phi_\kappa, \mu_\kappa) q_i - (1 + \mu_\kappa) w l'(x_i)] \frac{\partial x_i}{\partial \phi_j} \right\} + f'_\phi(\phi_j, \mu_j) \int_{i \in \mathbf{I}_j} q_i x_i = 0, \quad (\text{S.27})$$

for $j = 1, 2, \dots, N$.

S1.5 Derivatives of x_i w.r.t. q_i and ϕ_j

As shown in (S.21), x_i , with $i \in \mathbf{I}_j$, is function of q_i , ϕ_j , λ and y , where λ and y are, in turn, functions of \mathbf{Q} and Φ defined by (S.22) and (S.23). Thus, the derivatives $\partial x_i / \partial q_i$ and $\partial x_i / \partial \phi_j$ can be written as

$$\frac{\partial x_i}{\partial q_i} = \frac{\partial D_i}{\partial q_i}, \quad (\text{S.28})$$

$$\frac{\partial x_i}{\partial \phi_j} = \frac{\partial D_i}{\partial \phi_j} + \frac{\partial D_i}{\partial y} \frac{\partial y}{\partial \phi_j} + \frac{\partial D_i}{\partial \lambda} \frac{\partial \lambda}{\partial \phi_j}, \quad \text{for } i \in \mathbf{I}_j \quad (\text{S.29})$$

$$\frac{\partial x_i}{\partial \phi_j} = \frac{\partial D_i}{\partial y} \frac{\partial y}{\partial \phi_j} + \frac{\partial D_i}{\partial \lambda} \frac{\partial \lambda}{\partial \phi_j}, \quad \text{for } i \notin \mathbf{I}_j. \quad (\text{S.30})$$

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

$$\frac{\partial D_i}{\partial q_i} = \frac{-\varepsilon y}{[1 + \phi_j(r + \lambda)]^\varepsilon q_i^{1+\varepsilon}} \quad (\text{S.31})$$

$$\frac{\partial D_i}{\partial \phi_j} = \frac{-\varepsilon y(r + \lambda)}{[1 + \phi_j(r + \lambda)]^{1+\varepsilon} q_i^\varepsilon} \quad (\text{S.32})$$

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

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

To obtain $\partial \lambda / \partial \phi_j$, we use (S.22) which defines implicitly λ as a function of \mathbf{Q} and Φ . Using the implicit function theorem we obtain

$$\frac{\partial \lambda}{\partial \phi_j} = - \frac{(r + \lambda) [1 + \phi_j(r + \lambda)]^{-\varepsilon} \int_{i \in \mathbf{I}_j} q_i^{1-\varepsilon}}{\sum_{\kappa=1}^N \phi_\kappa [1 + \phi_\kappa(r + \lambda)]^{-\varepsilon} \int_{i \in \mathbf{I}_\kappa} q_i^{1-\varepsilon}}. \quad (\text{S.35})$$

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

$$h(\mathbf{Q}, \Phi, \lambda) = \sum_{\kappa=1}^N \phi_{\kappa} [1 + \phi_{\kappa}(r + \lambda)]^{-\varepsilon} \left(\int_{i \in \mathbf{I}_{\kappa}} q_i^{1-\varepsilon} \right), \quad (\text{S.36})$$

so that we can write (S.23) as:

$$y = \frac{\bar{b}}{h(\mathbf{Q}, \Phi, \lambda)}. \quad (\text{S.37})$$

The derivative of y with respect to ϕ_j is given by

$$\frac{\partial y}{\partial\phi_j} = -\frac{\bar{b}}{h^2} \left(\frac{\partial h(\mathbf{Q}, \Phi, \lambda)}{\partial\phi_j} + \frac{\partial h(\mathbf{Q}, \Phi, \lambda)}{\partial\lambda} \frac{\partial\lambda}{\partial\phi_j} \right), \quad (\text{S.38})$$

where

$$\frac{\partial h(\mathbf{Q}, \Phi, \lambda)}{\partial\phi_j} = \left[1 - \varepsilon \frac{\phi_j(r + \lambda)}{1 + \phi_j(r + \lambda)} \right] [1 + \phi_j(r + \lambda)]^{-\varepsilon} \int_{i \in \mathbf{I}_j} q_i^{1-\varepsilon} \quad (\text{S.39})$$

$$\frac{\partial h(\mathbf{Q}, \Phi, \lambda)}{\partial\lambda} = -\sum_{\kappa=1}^N \frac{\varepsilon\phi_{\kappa}^2}{[1 + \phi_{\kappa}(r + \lambda)]^{1+\varepsilon}} \int_{i \in \mathbf{I}_{\kappa}} q_i^{1-\varepsilon}, \quad (\text{S.40})$$

and $\partial\lambda/\partial\phi_j$ is given by (S.35).

S1.6 Symmetric equilibrium

Denote by q^* , ϕ^* , x^* , y^* and λ^* the variables in the symmetric competitive equilibrium. By imposing symmetry on (S.21), (S.22), (S.23) and (S.36), we have

$$x^* = \frac{y^*}{[1 + \phi^*(r + \lambda^*)]^{\varepsilon} (q^*)^{\varepsilon}}, \quad (\text{S.41})$$

$$q^* = \frac{1}{1 + \phi^*(r + \lambda^*)}, \quad (\text{S.42})$$

$$y^* = \frac{\bar{b}}{\phi^* [1 + \phi^*(r + \lambda^*)]^{-\varepsilon} (q^*)^{1-\varepsilon}}, \quad (\text{S.43})$$

$$h^* = \phi^* [1 + \phi^*(r + \lambda^*)]^{-\varepsilon} (q^*)^{1-\varepsilon}. \quad (\text{S.44})$$

By using (S.42) in the other three equations, we have

$$x^* = y^* = \frac{\bar{b}}{\phi^* q^*}, \quad (\text{S.45})$$

$$h^* = \phi^* q^*. \quad (\text{S.46})$$

By evaluating (S.31), (S.32), (S.33), (S.34), (S.35), (S.38), (S.39) and (S.40), and using (S.42), (S.45) and (S.46) in the obtained equations, we have

$$\left. \frac{\partial D_i}{\partial q_i} \right|_{\mathbf{Q}=\mathbf{Q}^*, \Phi=\Phi^*} = -\varepsilon \frac{y^*}{q^*} \quad (\text{S.47})$$

$$\left. \frac{\partial D_i}{\partial \phi_j} \right|_{\mathbf{Q}=\mathbf{Q}^*, \Phi=\Phi^*} = -\varepsilon \frac{y^*}{\phi^*} (1 - q^*) \quad (\text{S.48})$$

$$\left. \frac{\partial D_i}{\partial y} \right|_{\mathbf{Q}=\mathbf{Q}^*, \Phi=\Phi^*} = 1 \quad (\text{S.49})$$

$$\left. \frac{\partial D_i}{\partial \lambda} \right|_{\mathbf{Q}=\mathbf{Q}^*, \Phi=\Phi^*} = -\varepsilon y^* \phi^* q^* \quad (\text{S.50})$$

$$\left. \frac{\partial \lambda}{\partial \phi_j} \right|_{\mathbf{Q}=\mathbf{Q}^*, \Phi=\Phi^*} = -\frac{r + \lambda^*}{N \phi^*} \quad (\text{S.51})$$

$$\left. \frac{\partial y}{\partial \phi_j} \right|_{\mathbf{Q}=\mathbf{Q}^*, \Phi=\Phi^*} = -\frac{y^*}{N \phi^*} \quad (\text{S.52})$$

$$\left. \frac{\partial h}{\partial \phi_j} \right|_{\mathbf{Q}=\mathbf{Q}^*, \Phi=\Phi^*} = \frac{q^* [1 - \varepsilon(1 - q^*)]}{N} \quad (\text{S.53})$$

$$\left. \frac{\partial h}{\partial \lambda} \right|_{\mathbf{Q}=\mathbf{Q}^*, \Phi=\Phi^*} = -\varepsilon (\phi^* q^*)^2 \quad (\text{S.54})$$

Using the above equations in (S.28), (S.29), and (S.30), we have

$$\left. \frac{\partial x_i}{\partial q_i} \right|_{\mathbf{Q}=\mathbf{Q}^*, \Phi=\Phi^*} = -\varepsilon \frac{y^*}{q^*} \quad (\text{S.55})$$

$$\left. \frac{\partial x_i}{\partial \phi_j} \right|_{\mathbf{Q}=\mathbf{Q}^*, \Phi=\Phi^*} = -\frac{y^*}{\phi^*} \left[\frac{1}{N} + \varepsilon \left(\frac{N-1}{N} \right) (1 - q^*) \right], \text{ for } i \in \mathbf{I}_j \quad (\text{S.56})$$

$$\left. \frac{\partial x_i}{\partial \phi_j} \right|_{\mathbf{Q}=\mathbf{Q}^*, \Phi=\Phi^*} = -\frac{y^*}{\phi^*} \left[\frac{1}{N} - \varepsilon \left(\frac{1}{N} \right) (1 - q^*) \right], \text{ for } i \notin \mathbf{I}_j, \quad (\text{S.57})$$

By evaluating (S.24) at the equilibrium point and using (S.55) in the obtained equation, we have

$$-\varepsilon [q^* f(\phi^*, \mu^*) - (1 + \mu^*) w l'(y^*)] \frac{y^*}{q^*} + f(\phi^*, \mu^*) y^* = 0,$$

which implies

$$q^* f(\phi^*, \mu^*) = \left(\frac{\varepsilon}{\varepsilon - 1} \right) (1 + \mu^*) w l'(y^*). \quad (\text{S.58})$$

By evaluating (S.25) at the equilibrium point and using (S.56) and (S.58) we obtain

$$\frac{1}{\varepsilon} \left[\frac{1}{N} + \varepsilon \left(\frac{N-1}{N} \right) (1 - q^*) \right] = \frac{\phi^* f'_\phi(\phi^*, \mu^*)}{f(\phi^*, \mu^*)} \quad (\text{S.59})$$

Finally, by imposing symmetric equilibrium on (S.26)), we have

$$e + \left(\frac{1}{N} \right) \phi^* y^* q^* = \left(\frac{1}{N} \right) w l(y^*) + a^*. \quad (\text{S.60})$$

Thus, when the endowed funds, e , is large enough such that its shadow value drops to the return on the financial assets, i.e., $\mu^* = r_f$, then the financial investment of upstream firms is positive, i.e., $a^* > 0$, and the values of x^* , y^* , q^* , ϕ^* and a^* are jointly determined by (S.45), (S.58), (S.59) and (S.60). Otherwise, $a^* = 0$, and the values of x^* , y^* , q^* , ϕ^* and μ^* are jointly determined by the same set of equations.

Concavity of the optimization problem. Note that the second-order derivative of the Lagrangian function with respect to q_i is given by

$$\begin{aligned} \frac{\partial^2 \mathcal{L}}{\partial q_i^2} &= \left[f(\phi_j, \mu_j) - (1 + \mu_j) w l''(x_i) \frac{\partial x_i}{\partial q_i} \right] \frac{\partial x_i}{\partial q_i} \\ &\quad + \left[f(\phi_j, \mu_j) q_i - (1 + \mu_j) w l'(x_i) \right] \frac{\partial^2 x_i}{\partial q_i^2} + f(\phi_j, \mu_j) \frac{\partial x_i}{\partial q_i}, \end{aligned}$$

which can be derived by differentiating the left-hand-side of (S.24) with respect to q_i . Note that $\partial^2 x_i / \partial q_i^2 = -[(\varepsilon + 1)/q_i](\partial x_i / \partial q_i)$, and also that in equilibrium $(1 + \mu^*) w l'(x^*) = [(\varepsilon - 1)/\varepsilon] q^* f(\phi^*, \mu^*)$, as implied by (S.58). Thus, by evaluating the above expression at the equilibrium point, we have

$$\left(\frac{\partial^2 \mathcal{L}}{\partial q_i^2} \right)^* = \left[\left(\frac{\varepsilon - 1}{\varepsilon} \right) f(\phi^*, \mu^*) - (1 + \mu^*) w l''(x^*) \left(\frac{\partial x_i}{\partial q_i} \right)^* \right] \left(\frac{\partial x_i}{\partial q_i} \right)^*.$$

Recall that $\varepsilon > 1$, $l''(x_i) > 0$ and $\partial x_i / \partial q_i < 0$. Thus, $\partial^2 \mathcal{L} / \partial q_i^2$ is negative at the equilibrium point, which indicates that the optimization problem is locally concave in q_i . In addition, note that the second-order derivative of the Lagrangian function with respect to ϕ_i is given by

$$\begin{aligned} \frac{\partial^2 \mathcal{L}}{\partial \phi_i^2} &= \int_{i \in \mathbf{I}_j} \left\{ \left[(\mu_j - c'(\phi_j)) q_i - (1 + \mu_j) w l''(x_i) \frac{\partial x_i}{\partial \phi_j} \right] \frac{\partial x_i}{\partial \phi_j} \right. \\ &+ \left. \left[f(\phi_j, \mu_j) q_i - (1 + \mu_j) w l'(x_i) \right] \frac{\partial^2 x_i}{\partial \phi_j^2} \right\} \\ &- c''(\phi_j) \int_{i \in \mathbf{I}_j} x_i q_i + (\mu_j - c'(\phi_j)) \int_{i \in \mathbf{I}_j} q_i \frac{\partial x_i}{\partial \phi_j}, \end{aligned}$$

which can be derived by differentiating the left-hand-side of (S.25) with respect to ϕ_i . Note that in equilibrium $(1 + \mu^*) w l'(x^*) = [(\varepsilon - 1) / \varepsilon] q^* f(\phi^*, \mu^*)$, as implied by (S.58). Thus, by evaluating the above expression at the equilibrium point, we have

$$\begin{aligned} \left(\frac{\partial^2 \mathcal{L}}{\partial \phi_i^2} \right)^* &= m_j \left\{ \left[2(\mu^* - c'(\phi^*)) q^* - (1 + \mu^*) w l''(x^*) \left(\frac{\partial x_i}{\partial \phi_j} \right)^* \right] \left(\frac{\partial x_i}{\partial \phi_j} \right)^* \right. \\ &+ \left. \varepsilon^{-1} f(\phi^*, \mu^*) q^* \left(\frac{\partial^2 x_i}{\partial \phi_j^2} \right)^* - c''(\phi^*) x^* q^* \right\}. \end{aligned}$$

Note that $\partial x_i / \partial \phi_j < 0$, and also that by assumption $l''(x_i) > 0$, $c'(\phi_j) < 0$ and $c''(\phi_j) > 0$. Thus, the first and the third terms in the above equation are negative, but the second term can be positive. However, the whole expression is still negative if $c''(\phi^*)$ is large enough.

The planner's economy. Recall that in this economy the equilibrium conditions are the same as in the competitive economy except that the first order condition for ϕ_j is changed from (S.25) to (S.27). Thus, by evaluating (S.27) at the equilibrium point and using (S.56), (S.57) and (S.58) we obtain

$$\frac{1}{\varepsilon} = \frac{\phi^* f'(\phi^*, \mu^*)}{f(\phi^*, \mu^*)}. \quad (\text{S.61})$$

Thus, when the endowed funds, e , is large enough such that its shadow value drops to the return on the financial assets, i.e., $\mu^* = r_f$, then the financial investment of upstream firms is positive, i.e., $a^* > 0$, and the values of x^* , y^* , q^* , ϕ^* and a^* are jointly determined by (S.45), (S.58), (S.60) and (S.61). Otherwise, $a^* = 0$, and the values of x^* , y^* , q^* , ϕ^* and μ^* are jointly determined by the same set of equations.

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