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Credit constraints and firm productivity: Microeconomic evidence from China☆

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ABSTRACT

We use a panel of over 600,000 Chinese firms (1998–2009) to investigate the effects of credit constraints on firm productivity. We find that both internal finance through a firms own cash flow and external credit supply significantly promote firm productivity and productivity growth rates. Specially, there is a substitution effect between internal finance and external credit supply: the marginal effect of internal finance on firm productivity is weaker when firms have sufficient external credit. Also, internal finance is more important for firms in those financially vulnerable industries. Finally, we observe that marginal effect of both external credit supply and internal finance on firm's productivity is weaker for SOEs than non-SOEs.

1. Introduction

The existing literature notes that inadequate financial development impedes firm investments in productivity-enhancing activities (Ayyagari et al., 2010). If firms face difficulties in obtaining external liquidity, e.g., bank loans, they might have to depend on internal financing, i.e., cash flows, to cover fixed investment costs. As a result, firms with sufficient cash flow have an advantage in technology improvement and, hence, in productivity, while firms with insufficient cash flow face binding financial constraints in productivity improvement (Brown and Petersen, 2009; Nickell and Nicolitsas, 1999; Fazzari et al., 1988).

The fact that either internal or external financing constraint plays a role in shaping firm's productivity is well documented by prior studies. However, few studies have combined internal and external financing together to explore their interactive effects and the impacts of them on firm productivity improvement. In fact, the degree of constraint caused by insufficient cash flow varies across firms with different demand for and access to external finance. Therefore, it is important to examine the interaction effect between internal and external financing in improving firm's productivity which has been largely overlooked by previous literature.

To address the interaction between internal and external financing, this paper includes both types of financing constraints and documents a substitution effect between the two in improving firms' productivity. Our findings suggest that when firms face an abundant supply of external credit or lower demand for external finance, internal financing constraints are less critical. The marginal effects of internal financing constraint varies, depending on different external factors, e.g., locations, ownerships and sector-level

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credit demand.

In China, due to underdeveloped financial institutions and immature credit markets, external credit allocations are distorted along several dimensions: within and across regions and ownership types. To be specific, companies located in municipal cities or coastal regions (or in special economic zones) are at a tremendous advantage in accessing to bank loans; the privileged group of state-owned enterprises (SOEs) can access credit more easily than those domestic private enterprises, especially for loans from the major state-owned banks. Moreover, different sectors demand various amounts of upfront investment cost for technology upgrading, and thus sectoral heterogeneity of external financing dependence exists. China offers an ideal laboratory to test those factors to study to what extent they determine the marginal effect of credit constraints on shaping the level and growth of firm productivity.

Our sample is an unbalanced panel of more than 600,000 firms from 1998 to 2009, drawn from the annual surveys of Chinese manufacturing firms conducted by the National Bureau of Statistics of China (NBSC). The survey reports firm-level production data and covers all SOEs and non-SOEs with annual sales of at least 5 million RMB (the Chinese currency). The approximate number of firms covered by the NBSC database ranged from 152,000 in 1998 to 317,000 in 2009. As we have rich information on both public and private firms with a wide range of firm characteristics, this dataset is ideal for studying the effects of structural financial distortions on enterprises in China.[1]

We obtain the following key findings. First, both internal financing (through a firm's own cash flow) and external financing significantly increase the productivity of the firm and the growth rate of firm productivity. Second, there is a substitution effect between internal financing and external credit: the marginal effect of internal financing on firm productivity is weaker when firms have a sufficient external credit supply. Thus, firms face different degrees of internal financing constraint conditional on their external credit supply. Third, firms in industries with higher external credit demand (i.e., those in more financially vulnerable industries) have lower productivity level and smaller growth rate of productivity, and internal finance is more important for firms in those financially vulnerable industries. In general, SOEs exhibit both lower productivity levels and slower productivity growth, and the internal financing constraint is less important for those SOEs. Moreover, the positive effect of the external credit supply on firm productivity is weakened for SOEs.

The results imply that internal financing (cash flow) is critical in determining productivity and growth rates. But when firms have access to external finance, their internal financing constraint is weaker, and they display greater potential to increase productivity. An external financing constraint greatly hinders firm productivity upgrading if cash flows are insufficient. Constrained firms are usually located in financially underdeveloped areas and, in general, are more likely to be private firms. These firms have to utilize their own profits or other resources to self-finance investments in productivity-enhancing projects. Thus, the financially disadvantaged firms, relative to those financially privileged ones, face more severe and challenging financial constraints which impede their productivity improvement within an underdeveloped financial system.

The remainder of this paper is organized as follows: Section 2 discusses related literature. Section 3 provides background information on credit supply in China. Section 4 introduces the data and measurements. Section 5 presents baseline specifications and estimation methodology, as well as the main empirical findings and robustness tests. Section 6 discusses policy implications and then concludes.

2. Related literature

This paper is related to several branches of the literature. First, previous studies aim to find the link between financial development and economic growth. At the macro-level, Cheng and Degryse (2010) finds a positive link between the two, while others find no link, e.g., Boyreau-Debray (2003). At the micro-level, some works utilize firm-level data to explore this issue in detail. For example, Ayyagari et al. (2010), Cull et al. (2013) and Chen et al. (2016) show that poorly developed financial systems indeed hinder the fast growth rates of Chinese firms, especially non-state-owned firms.

However, even in the fragile Chinese financial system, firms without access to external financing have still grown quickly over the past two decades. To better understand this puzzling phenomenon, studies have turned to firms' internal financing for answers, and they argue that firms can use cash flow to increase productivity. Those studies include Chen and Guariglia (2013), Allen et al. (2005) and Guariglia et al. (2011). Allen et al. (2005) notes that although loans to private firms are easily refused by typical banks in China, these firms successfully utilize their own profits or other resources to self-finance investments in productivity-enhancing projects. Thanks to their high ability to generate cash flow, Chinese firms, especially private firms, have been able to upgrade quickly, leading to tremendous economic growth over the past two decades.

Our study is also related to previous research on variation in external credit dependence across industries, e.g., Kletzer and Bardhan (1987), Beck (2003) and Rajan and Zingales (1998). The classic study is Rajan and Zingales (1998), which shows that industries that require more external financing are also more constrained in countries with unhealthy financial systems. We employ an external finance dependence indicator[2] and find that the constraint effects are heterogeneous across sectors.

Finally, our study is related to others that explore financial frictions in the Chinese context.[3] For example, Guariglia and Yang (2016), Bai et al. (2006) and Chen et al. (2016) study unbalanced financing access among state-owned and non-state-owned firms and

[1] Although it is easier to collect data on listed firms' financing situation, there are only approximately three thousand listed firms in China, which is a small fraction of all firms in China. Thus, we choose to use the annual survey of manufacturing firms rather than listed firms to conduct our study.

[2] This index is widely used in the existing literature, e.g., Manova (2013).

[3] Other studies explore financial constraints using data from other emerging countries, such as de Sant'Anna et al. (n.d.) for Brazil, Sasidharan et al. (2015) for India, Molinari (2013) for Italy, and O'Toole and Newman (2012) for Vietnam.

its impact on Chinese economic growth. Some argue that non-financial institutions are equally important contributors to economic growth in China, e.g., Cheng and Degryse (2010), Ayyagari et al. (2010), and Cheng and Degryse (2010). However, multiple external factors lead to financial frictions in China, including ownership and regional development. Our paper examines factors produced by unhealthy financial systems from the perspective of ownership, regional development and sectoral financing demand, which all affect firms' ability to raise capital for efficiency improvement.

3. Credit allocation inefficiency in China

So far, bank loans are the major source of external financing for firms in China, accounting for approximately 75.2% of the total credit supply. The majority of loans are made by the so-called "Big Four" state-owned banks in China (representing over 75% of the total liquidity supply). Credit shortages are major threats to firms without access to normal bank loans. Financially constrained and unconstrained firms face substantially different costs: if firms without sufficient cash flow cannot obtain bank loans through normal channels, they usually turn to private, more expensive lenders. The interest expense of a private loan is usually more than four times that of a regular bank loan obtained from one of the "big four" state-owned banks (Brandt and Li, 2003).[4] Due to its underdeveloped financial markets, the credit supply in China displays an obviously unbalanced pattern across regions and ownership types. Thus, Chinese manufacturing firms represent an ideal laboratory in which to test wedges between supply and demand and their effects on firm productivity improvement.

Due to geographically unbalanced financial development in China, the credit supply varies across provinces and cities. The literature on financial development and growth often uses the bank loans to GDP ratio in a country to represent the degree of financial development or the external credit supply. The most recent studies of Chinas credit constraints extend this measure to sub-national regions, for example, to a province or a city in China (e.g., Fan et al., 2015; Li et al., 2015). We collect bank loans statistics for all provinces in China from 2000 to 2007 from the Almanac of China's Finance and Banking, which covers all bank loan information (short-term loans, long-term loans and all credit). Table 14 presents the bank loan ratios: one is the ratio of all credit (including short- and long-term credit) to GDP, whereas the other includes only long-term loans.

We observe that the credit to GDP ratio ranges from 0.66 (Hunan) to 2.29 (Beijing) across provinces. Province-equivalent municipal cities, such as Beijing, Shanghai, and the special economic zone of Shenzhen, usually enjoy better credit supplies than other areas. Specifically, the bank loan to GDP ratio is very high in Beijing, greater than in any other province. If we consider the statistics for city-level credit supply in more detail, we observe that due to strategic development planning (development campaigns), the western region enjoys more credit than their counterparts in the eastern region, although major, first-tier cities (such as Beijing and Shanghai) exhibit larger ratios than lower-tier cities.

In addition to regional imbalances in the credit supply, access to credit largely depends on ownership rather than on productivity. In China, private firms are thought to be discriminated against in the credit market, especially by state-owned banks, while state-owned firms typically experience soft budget constraints and are able to obtain large loans from the banking system. Those patterns are well documented in the previous literature, e.g., Cull et al. (2013), Allen et al. (2005), and Poncet et al. (2010). Table 1 shows the differences in implied interest rates between SOEs and non-SOEs. For all years from 1998 to 2009, SOEs paid lower interest rates than their private sector peers, and the differences are as large as 100 basis points.[5]

Although SOEs have easier access to bank credit, they usually show inferior performance compared to private firms. During 1998 to 2009, the number of SOEs dropped significantly, but the remaining firms have grown increasingly larger (see Figs. 2 and 3 in appendix). If we compare the productivity of SOEs and non-SOEs, we find that the total factor productivity (median) of SOEs improved after reforms in the 90s but still lagged behind that of the private sector (see Fig. 1). This is considered one of the major structural distortions in China and has increasingly become an impediment to its urgently needed transition to a more sustainable growth path.

Those above-mention external factors, e.g., locations and ownership types, affect firm's credit access to loans. They may also hinder firms' investments in R & D activities, which potentially increase productivity. Although firms may use their own profits from production for investments, the presence of external constraints may force firms to forgo their optimal investments and, hence, reduce the growth rate of productivity.

In addition, depending on the industry's demand for external financing, liquidity constraint affects firm to different degrees. Some industries, such as clothing, may require smaller fixed costs to upgrade production; thus, the threat of credit constraint is not that severe. Other industries, such as machinery, may require large investments to enhance productivity, and thus, the external credit constraint is critical. Therefore, we take the nature of each industry into consideration when measuring the potential effects of credit constraints on firms' productivity improvements.

[4] Although these informal loans may not be entirely representative, it is interesting to note that their average interest rate was over 20%, whereas the base rate at year end charged by banks on loans with maturities of < 6 months was 5.35% in 2010.

[5] It should be noted that as our dataset includes only information on liabilities, which are usually larger than debt. Thus, the implied interest rates tend to be underestimated.

Table 1
Implied interest rate, median.

Year	All firms	Non-SOEs	SOEs	Difference
1998	3.80	4.25	3.04	1.21
1999	3.02	3.36	2.35	1.01
2000	2.61	2.87	1.94	0.93
2001	2.41	2.60	1.74	0.86
2002	2.25	2.37	1.72	0.65
2003	2.13	2.19	1.66	0.53
2004	2.02	2.07	1.56	0.51
2005	2.22	2.27	1.58	0.69
2006	2.27	2.32	1.56	0.75
2007	2.43	2.45	1.60	0.85
2008	2.83	2.86	1.88	0.98
2009	2.50	2.53	1.69	0.84
Average	2.54	2.68	1.86	0.82

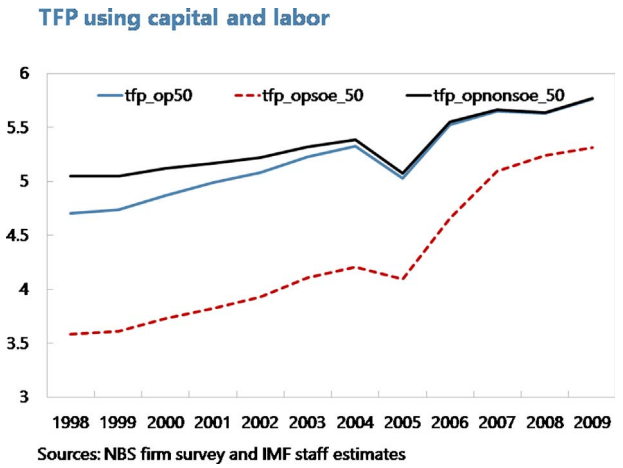

Fig. 1. Productivity: SOEs v.s. non-SOEs.

4. Data and measurements

4.1. Firm-level data

The source for firm-level production data is the annual survey of Chinese manufacturing firms, which is conducted by the National Bureau of Statistics of China (NBSC). This database covers all state-owned enterprises (SOEs) and non-state-owned enterprises with annual sales of at least 5 million RMB. The sample period ranges from 1998 to 2009. The approximate number of firms covered by the NBSC database ranges from 152,200 in 1998 to 317,140 in 2009. The final sample is an unbalanced panel covering a total of 600,000 firms.

This database has been widely used in studies of the Chinese economy. It contains detailed firm-level information about manufacturing enterprises in China, such as their ownership structure, employment, capital stock, gross output, value added, firm identification (e.g., company name, telephone number, zip code, contact person), and complete information on the three major accounting statements (i.e., balance sheets, profit and loss accounts, and cash flow statements). Of all the information contained in the NBSC database, we are most interested in the variables related to firms' total factor productivity and credit constraints (i.e., credit accessibility-related information). We compute the mean value of firm-level key characteristics for each ownership category, including productivity, leverage, return to sales ratio, liquidity ratio, age, capital to labor ratio and so on. The summary statistics of the firm-level data are listed in Table 2.

4.2. Measurements

We describe firms' access to finance from two perspectives: internal and external. Internal finance access is measured by internal cash flow. Regarding external finance, from the firm point of view, both demand and supply of credit are taken into account. Thus, this study examines the role of both external credit demand (via an external finance dependence measure) and external credit supply (via the supply of bank loans to firms) in shaping firm productivity. External finance access is proxied by both the geographical external credit supply and the external finance demand at the industry level. It is worth mentioning that our measures of external

Table 2
Summary statistics.

Variables	Private	Joint venture	Multinational	SOE	All types
TFP using OP method	26.36	29.80	31.92	25.29	28.34
TFP using OLS method	21.79	23.60	25.69	15.50	21.64
ROS	0.12	0.07	0.05	0.04	0.07
Leverage	0.58	0.55	0.50	0.74	0.60
Cashflow	8030	14,460	16,210	1230	9982
Liquidity	−0.01	0.07	0.06	−0.13	0.00
Age	10	8	7	29	13
Labor	445	501	610	710	566
Value-added	129	125	148	120	131
Capital/labor ratio	0.36	0.32	0.33	0.46	0.37
Coverage	0.83	0.71	0.94	0.67	0.79
Export/sales	0.11	0.37	0.52	0.06	0.26

Notes: Columns 2–5 include summary statistics for firms with different ownerships. Variables include firm's TFP level and TFP growth rate, which calculated by both OP and OLS methods; return to sales ratio (ROS); leverage ratio; cash flow; firms' age; liquidity which is measured as working capital to total assets; capital–labour ratio and export intensity which is calculated as export to sales ratio.

credit supply and external credit demand (dependence) are obtained at either the provincial level or the industry level and are not firm-level variables. Thus, they are immune from potential endogeneity issued related to firms' choices.

4.2.1. Internal finance/internal cash flow (cash flow)

This measures the amount of internal cash flow generated by operations scaled by the total assets of the firm. This figure indicates the sufficiency of internal financing. Firms internal financing is calculated as (net income + depreciation)/total assets, which denotes the availability of internal cash flows (Chen and Guariglia, 2013).

4.2.2. External credit supply (EFS)

External finance supply is a regional indicator of the supply of bank loans, which is calculated as the ratio of total credit (or long-term bank loans) to GDP at province level (see Fan et al., 2015). It is measured as the ratio of all credit and long-term loans to GDP for the province or city in which the firm is located.

Our sample records the credit supplies of 31 provincial-level regions (including 22 provinces, 4 municipalities, and 5 autonomous regions). The data source for bank loans is the Almanac of China's Finance and Banking (1998–2009). There is significant variation in credit supply across provinces, e.g., the long-term credit to GDP ratio ranges from 0.32 (Hunan) to 1.27 (Beijing),which is displayed in Table 14.

4.2.3. External credit demand/external finance dependence (EFD)

This index is computed as the share of capital expenditures not financed by cash flows from operations for each industry (Manova, 2013; Manova et al., 2015). This measure is constructed following the methodology of Rajan and Zingales (1998) and Claessens and Laeven (2002).

Industry-level external finance dependence builds upon the idea that if an industry is more financially vulnerable, it is more likely to face binding credit constraints. This measure has been widely used in the literature on the role of credit constraints in international trade and growth.

It should be noted that this measure of external finance dependence is meant to reflect the technologically determined characteristics of each industry that are beyond the control of individual firms. Therefore, this measure of industrial financial vulnerability is inherent to the nature of the industry, which should be viewed as exogenously given for each individual firm. If external finance dependence is higher, the industry is more financially vulnerable and has higher credit needs.

It is worth mentioning that industry-level measurements of external credit dependence are calculated based on US figures. As those measures reflect the inert nature of industries, the ranking of credit needs across industries shows a similar pattern across countries. Manova (2013) argues that the ranking of industries in terms of financial vulnerability remains relatively stable across countries. Thus, US-based measures may also represent the rest of the world. A nice property of using US data to compute the credit constraint measurements is that as the US is financially developed with mature credit market, there are no concerns of credit shortages when calculating these indicators. Otherwise, shortages of credit supply tend to distort the real credit needs of an industry.

4.2.4. Other firm-level, credit-related variables

We include leverage and liquidity in our empirical analysis. Following the literature (e.g., Chen and Guariglia, 2013), we define leverage as the sum of current liabilities and non-current liabilities divided by total assets, where current liabilities include bank loans, accounts payable, and other current liabilities. Liquidity is computed as current assets net of current liabilities divided by total assets. Other firms' level, e.g., firm age, capital intensity and export intensity, are also included into the estimation as firm level factors. Firm's age measures how many years since the firm's establishment; capital intensity measures firm's capital-to-labor ratio; export intensity is calculated as firm's export value over its total sales.

4.2.5. Total factor productivity (TFP)

We look at both firm TFP values and firm growth rates of TFP (denoted ΔTFP). Two approaches are employed to calculate TFP: OLS estimation and the augmented OP (1996) method. To compute TFP, we first use a Cobb–Douglas production function as an estimation specification, where the production output of a firm is a function of labor, capital and intermediate inputs.

We use deflated firm value-added to measure production output. Due to simultaneity concerns between input choices and productivity shocks, as well as sample selection bias in OLS estimation, we employ the augmented Olley–Pakes (OP) approach to TFP estimation. In our OP approach, we incorporate a WTO entry dummy and an import/export dummy following Amiti and Konings (2007). The detailed calculation of TFP is listed in Appendix B. The other productivity measurement, the growth rate of TFP, is the difference between a firms current TFP and that of the previous period.

5. Credit constraints and firm productivity: an empirical study

We use a panel of Chinese firms (1998–2009) to investigate the effects of credit constraints on firm productivity. In the empirical tests, we define an equation to explore the determinants of firm TFP and the growth rate of firm TFP. For the econometric models, we apply both fixed effects panel regressions and difference-GMM dynamic panel estimation.

In the regression with internal credit constraints, all regressors are at the firm level. There is concern about endogeneity and simultaneity in the regression. We use dynamic panel GMM regression to better address endogeneity and simultaneity among regressors in the model, which are based on Arellano and Bond (1991) and Blundell and Bond (1998). This approach exploits the additional moments in the finite sample and treat the regressors as endogenous. Specially, we instrument the regressors using their lagged levels in the difference equations, and their lagged difference in the level equations. In the fixed effects panel regression, we control for 2-digit industry fixed effects and year fixed effects in the main results, and we control for firm fixed effects in a robustness analysis.

5.1. Effects of internal finance on firm productivity

To test the effects of internal finance on firm productivity, we regress the TFP and TFP growth rate (ΔTFP) of firm i on its cash flow with a set of firm-level control variables, including leverage (measured as total liabilities to total assets), liquidity (measured as working capital to total assets), firm age, capital intensity (measured by the capital–labor ratio) and export intensity. The econometric specification is given by the following equation:

$$\mathrm{TFP}_{it} = \beta_1 \mathrm{CashFlow}_{it} + \beta_2 \mathrm{Leverage}_{it} + \beta 3 \mathrm{Liquidity}_{it} + \beta X_{it} + \nu_t + \nu_k + \varepsilon_{it} \quad (1)$$

where the cash flow of firm i in year t denotes the firms internal finance situation. Note that all variables in our regression have been transformed in logarithmic form. We include leverage and liquidity to control for other potential confounding factors in firms credit situations. Here, X_{it} is a vector containing all other firm-level controls, including firm *i*s age, capital–labour ratio and export intensity. Additionally, ν_t is year fixed effect, and ν_k denotes industry fixed effects, where firm i belongs to industry k. We estimate the regression based on Eq. (1) with TFP or ΔTFP as the dependent variables using both fixed effect panel regression and difference-GMM dynamic panel regressions. The productivity TFP is calculated by following both “OP” and “OLS” methods, denoted as TFP-OP and TFP-OLS respectively.

In Table 3, we find that the key explanatory variable, Cash Flow, is positive and significant in predicting both the TFP level (see specifications 1–2 and 5–6) and the TFP growth rate (see specifications 3–4 and 7–8). This means that internal finance (via the firms own cash flow) has a significant positive effect on firm productivity. Additionally, note that both leverage and liquidity show significant positive signs in all specifications, which indicates that a sound internal finance status improves firm productivity. Columns 1–4 in Table 3 use fixed effects panel regression, while columns 5–8 in Table 3 adopt the dynamic panel regression approach. The results based on these two different approaches are very similar. We add industry fixed effect in the regressions.[6] The positive effect of internal finance on firm productivity is consistent with the recent literature on credit constraints (e.g., Chen and Guariglia, 2013).

Other variables, leverage, by definition, can reflect the debt to total assets ratio because most non-current liabilities are debt or bank loans. Therefore, firm-level leverage information could also reflect the credit access of the firm. In the baseline result, the positive coefficient of leverage suggests that high leverage firm tend to have higher level of productivity. The significant positive coefficients of liquidity suggests higher liquidity ratio stimulates firm's productivity. Negative coefficients of export intensity suggests that export-oriented firms show lower productivity level and growth rate. For capital intensity, the results suggest that firms with higher capital ratio usually display higher productivity level, but lower productivity growth rate.

5.2. Effect of external credit supply on firm productivity

We now turn to the external credit supply. From the firms point of view, external credit is usually controlled by bank policies and can be viewed as exogenous to the firm. In this part, we use local bank loans to GDP ratio to capture the variation of external credit supply across different provinces or cities in China. Two alternative measures are employed: the all credit to GDP ratio and the long-

[6] Note that if we use firm fixed effects instead of industry fixed effects, the results still hold.

Table 3
Effect of internal finance on firm TFP and TFP growth.

Dependent variable	Panel				Dynamic panel			
	TFP-OP (1)	TFP-OLSs (2)	ΔTFP-OP (3)	ΔTFP-OLS (4)	TFP-OP (5)	TFP-OLS (6)	ΔTFP-OP (7)	ΔTFP-OLS (8)
Cash flow	0.044***	0.043***	0.014***	0.013***	0.019***	0.018***	0.018***	0.017***
	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
Leverage	0.086***	0.079***	0.043***	0.041***	0.022***	0.021***	0.019***	0.019***
	(0.006)	(0.006)	(0.003)	(0.003)	(0.005)	(0.005)	(0.007)	(0.007)
Liquidity	0.170***	0.162***	0.023***	0.022***	0.040***	0.041***	0.024***	0.025***
	(0.004)	(0.004)	(0.002)	(0.002)	(0.004)	(0.004)	(0.005)	(0.005)
Export intensity	−0.034***	−0.035***	−0.026***	−0.025***	−0.108***	−0.108***	−0.145***	−0.145***
	(0.003)	(0.004)	(0.005)	(0.005)	(0.009)	(0.009)	(0.013)	(0.013)
Capital/labor	−0.002***	0.005***	0.006***	0.007***	−0.025***	−0.014***	−0.040***	−0.027***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.002)	(0.002)
Year fixed effect	Yes	Yes	Yes	Yes				
Industry fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	1,590,841	1,590,841	1,117,288	1,117,288	718,124	718,124	474,842	474,842

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Notes: Robust standard errors in parentheses. Constants are included in all regressions. Columns 1–4 use fixed effects panel regression, while columns 5–8 adopt the dynamic panel regression approach. Dependent variables include firm's TFP level and TFP growth rate, calculated by both OP and OLS methods. Independent variable leverage is measured as total liabilities to total assets; liquidity is measured as working capital to total assets; capital intensity is measured by the capital–labor ratio and export intensity is calculated as export to sales ratio.

term loans to GDP ratio. Then, we regress TFP and TFP growth on external credit supply, internal finance, and other firm-level controls in Tables 4 and 5, respectively, according to the following equation:

$$\mathrm{TFP}_{it} = \beta_1 \mathrm{CashFlow}_{it} + + \beta_s \mathrm{EFS}_{pt} + \beta_2 \mathrm{Leverage}_{it} + \beta_3 \mathrm{Liquidity}_{it} + \beta X_{it} + \nu_t + \nu_k + \varepsilon_{it} \quad (2)$$

Note that the measure of external credit supply (EFS) of province *p* is based on firm is location. In Table 4, after controlling for internal finance and other firm-level characteristics, the effects of the all credit to GDP ratio and the long-term loan to GDP ratio remain positive and significant in determining firm's TFP level. In Table 5, we find that both measures of external credit supply significantly increase firms' TFP growth rates.

Internal finance indicator, i.e., cash flow, displays positive and significant coefficient in both TFP level and TFP growth rate. Also, in Tables 4 and 5, we find that all coefficients on leverage and liquidity are significant and positive. This finding supports the idea that the credit supply in general significantly facilitates firm productivity growth after controlling for internal finance.

5.3. Interaction effect between internal finance and external credit supply on firm productivity

We are interested in understanding whether the positive effect of internal finance on firm productivity has an interaction effect with external credit supply. A reasonable conjecture is that internal and external finance may serve as substitutes. If so, we expect to see a negative interaction effect between internal finance and external finance. To test this, we estimate the following regression:

$$\mathrm{TFP}_{it} = \beta_1 \mathrm{CashFlow}_{it} + + \beta_{x1} \mathrm{Cashflow}_{it} \times \mathrm{EFS}_{pt} + \beta_2 \mathrm{Leverage}_{it} + \beta 3 \mathrm{Liquidity}_{it} + \beta X_{it} + \nu_t + \nu_k + \varepsilon_{it} \quad (3)$$

We are interested in examining the sign of the coefficient on the interaction term, *Cashflow* × *EFS*. The results are presented in Table 6 for TFP level and in Table 7 for TFP growth. The results are based on both fixed effect panel regression and dynamic panel regression. Both tables report significant negative coefficients on the interaction term between internal finance and external credit supply (when measured by the all credit to GDP ratio or the long-term loans to GDP ratio). This result suggests that the positive effect of internal finance on productivity is weaker in regions with larger external credit supplies. In other words, external credit substitutes, to some extent, for internal finance. Thus, internal finance has a weaker stimulating effect on productivity where the supply of external finance is larger. In this sense, external credit is a substitute for cash flow in facilitating productivity improvements.

5.4. Effect of external credit demand on firm productivity

In previous section, we explore the effect from external finance supply side, and thus turn to external finance demand in this subsection. Given internal finance and external credit supplies, we now introduce a measure of external financing demand (EFD), external finance dependence. Recall that this measure has been widely used in the emerging literature on credit constraints to capture financial vulnerability at the industry level. That is, an industry with a higher level of external finance dependence will generally

Table 4
Effect of external credit supply on firm TFP.

Dependent variable	Panel				Dynamic panel			
	TFP-OP (1)	TFP-OLS (2)	TFP-OP (3)	TFP-OLS (4)	TFP-OP (5)	TFP-OLS (6)	TFP-OP (7)	TFP-OLS (8)
All credit	0.044***	0.044***			0.027***	0.026***		
	(0.001)	(0.001)			(0.005)	(0.005)		
Long-term loan			0.098***	0.098***			0.111***	0.112***
			(0.002)	(0.002)			(0.008)	(0.008)
Cash flow	0.045***	0.043***	0.045***	0.044***	0.019***	0.019***	0.020***	0.020***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Leverage	0.082***	0.075***	0.081***	0.074***	0.022***	0.021***	0.022***	0.021***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)
Liquidity	0.165***	0.157***	0.164***	0.155***	0.041***	0.041***	0.039***	0.039***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Export intensity	−0.035***	−0.036***	−0.034***	−0.035***	−0.108***	−0.108***	−0.110***	−0.110***
	(0.004)	(0.004)	(0.003)	(0.004)	(0.009)	(0.009)	(0.009)	(0.009)
Capital/labor	−0.003***	0.005***	−0.002***	0.005***	−0.025***	−0.014***	−0.027***	−0.016***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
Industry fixed effect	Yes	Yes	Yes	Yes				
Year fixed effect	Yes	Yes	Yes	Yes				
N	1,590,841	1,590,841	1,590,841	1,590,841	718,124	718,124	718,124	718,124

* $p < 0.10$
** $p < 0.05$.
*** $p < 0.01$.

Notes: Robust standard errors in parentheses. Constants are included in all regressions. Columns 1–4 use fixed effects panel regression, while columns 5–8 adopt the dynamic panel regression approach. Dependent variables include firm's TFP level, calculated by both OP and OLS methods. Independent variable leverage is measured as total liabilities to total assets; liquidity is measured as working capital to total assets; capital intensity is measured by the capital–labor ratio and export intensity is calculated as export to sales ratio.

Table 5
Effect of external credit supply on TFP growth.

Dependent variable	(1) ΔTFP-OP	(2) ΔTFP-OLS	(3) ΔTFP-OP	(4) ΔTFP-OLS
All credit	0.082***	0.079***		
	(0.008)	(0.008)		
Long-term loan			0.093***	0.091***
			(0.012)	(0.012)
Cash flow	0.019***	0.019***	0.018***	0.018***
	(0.001)	(0.001)	(0.001)	(0.001)
Leverage	0.020***	0.020***	0.020***	0.019***
	(0.007)	(0.007)	(0.007)	(0.007)
Liquidity	0.025***	0.026***	0.023***	0.025***
	(0.005)	(0.005)	(0.005)	(0.005)
Export intensity	−0.145***	−0.145***	−0.145***	−0.145***
	(0.013)	(0.013)	(0.013)	(0.013)
Capital/labor	−0.040***	−0.027***	−0.040***	−0.028***
	(0.002)	(0.002)	(0.002)	(0.002)
N	474,842	474,842	474,842	474,842
m4 (*p*-value)	0.043	0.037	0.043	0.037

* $p < 0.10$
** $p < 0.05$.
*** $p < 0.01$.

Notes: Robust standard errors in parentheses. Constants are included in all regressions. All tests follow dynamic panel regression approach. Dependent variables include firm's TFP growth rate, calculated by both OP and OLS methods. Independent variable leverage is measured as total liabilities to total assets; liquidity is measured as working capital to total assets; capital intensity is measured by the capital–labor ratio and export intensity is calculated as export to sales ratio.

show higher demand for external credit. Thus, firms in those industries will be more likely to experience binding credit constraints. We regress firm productivity and productivity growth on external finance dependence given external credit supply, internal finance, and other firm-level controls according to the following equation:

$$\mathrm{TFP}_{it} = \beta_1 \mathrm{CashFlow}_{it} + + \beta_s \mathrm{EFS}_{pt} + \beta_D \mathrm{EFD}_k + \beta_2 \mathrm{Leverage}_{it} + \beta 3 \mathrm{Liquidity}_{it} + \beta X_{it} + \nu_t + \nu_k + \varepsilon_{it} \quad (4)$$

Table 6
Interaction effect between internal finance and external credit supply on TFP.

Dependent variable	(1) Panel	(2)	(3)	(4)	(5) Dynamic panel	(6)	(7)	(8)
	TFP-OP	TFP-OLS	TFP-OP	TFP-OLS	TFP-OP	TFP-OLS	TFP-OP	TFP-OLS
Cash flow × all credit	−0.014***	−0.014***			−0.008***	−0.007***		
	(0.000)	(0.000)			(0.001)	(0.001)		
Cash flow × long-term loan	−0.029***	−0.028***			−0.018***	−0.018***		
	(0.001)	(0.001)			(0.002)	(0.002)		
Cash flow	0.059***	0.057***	0.056***	0.054***	0.027***	0.027***	0.027***	0.026***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Leverage	0.083***	0.076***	0.083***	0.076***	0.022***	0.021***	0.022***	0.021***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)
Liquidity	0.167***	0.158***	0.165***	0.157***	0.041***	0.041***	0.040***	0.040***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Export intensity	−0.035***	−0.035***	−0.034***	−0.035***	−0.108***	−0.108***	−0.109***	−0.109***
	(0.004)	(0.004)	(0.003)	(0.004)	(0.009)	(0.009)	(0.009)	(0.009)
Capital/labor	−0.002***	0.005***	−0.002***	0.005***	−0.025***	−0.014***	−0.026***	−0.015***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
Industry fixed effect	Yes	Yes	Yes	Yes				
Year fixed effect	Yes	Yes	Yes	Yes				
N	1,590,841	1,590,841	1,590,841	1,590,841	718,124	718,124	718,124	718,124

* $p < 0.10$
** $p < 0.05$.
*** $p < 0.01$.
Notes: Robust standard errors in parentheses. Constants are included in all regressions. Columns 1–4 use fixed effects panel regression, while columns 5–8 adopt the dynamic panel regression approach. Dependent variables are firm's TFP level, calculated by both OP and OLS methods. Independent variable leverage is measured as total liabilities to total assets; liquidity is measured as working capital to total assets; capital intensity is measured by the capital–labor ratio and export intensity is calculated as export to sales ratio.

Table 7
Interaction effect of internal finance and external credit supply on TFP growth.

Dependent variable	(1) ΔTFP-OP	(2) ΔTFP-OLS	(3) ΔTFP-OP	(4) ΔTFP-OLS
Cash flow × all credit	−0.012***	−0.012***		
	(0.002)	(0.002)		
Cash flow × long-term loan			−0.013***	−0.013***
			(0.003)	(0.003)
Cash flow	0.032***	0.031***	0.024***	0.023***
	(0.002)	(0.002)	(0.001)	(0.001)
Leverage	0.020***	0.019***	0.020***	0.019***
	(0.007)	(0.007)	(0.007)	(0.007)
Liquidity	0.025***	0.026***	0.024***	0.025***
	(0.005)	(0.005)	(0.005)	(0.005)
Export intensity	−0.145***	−0.145***	−0.145***	−0.145***
	(0.013)	(0.013)	(0.013)	(0.013)
Capital/labor	−0.040***	−0.027***	−0.040***	−0.027***
	(0.002)	(0.002)	(0.002)	(0.002)
N	474,842	474,842	474,842	474,842

* $p < 0.10$
** $p < 0.05$.
*** $p < 0.01$.
Notes: Robust standard errors in parentheses. Constants are included in all regressions. All tests follow dynamic panel regression approach. Dependent variables are firm's TFP growth rate, calculated by both OP and OLS methods. Independent variable leverage is measured as total liabilities to total assets; liquidity is measured as working capital to total assets; capital intensity is measured by the capital–labor ratio and export intensity is calculated as export to sales ratio.

We expect the coefficient, β_D, on external finance dependence to be negative. The results are presented in Table 8 and are consistent with our expectations. Note that external finance dependence is the median result at the industry level when averaging over time to avoid short-run shocks. This is standard practice in the literature on external finance dependence. Therefore, we use firm fixed effect to replace the previous industry fixed effect in this table. The results in Table 8 present significant, negative coefficients on external finance dependence, indicating that firms in financially vulnerable industries generally have lower TFP levels and slower

Table 8
Effect of external finance dependence on TFP and TFP growth.

Dependent variable	(1) Panel	(2)	(3)	(4)	(5) Dynamic panel	(6)	(7)	(8)
	TFP-OP	TFP-OLS	ΔTFP-OP	ΔTFP-OLS	TFP-OP	TFP-OLS	ΔTFP-OP	ΔTFP-OLS
Cash flow	0.031***	0.031***	0.019***	0.019***	0.019***	0.019***	0.019***	0.019***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
All credit	−0.000	−0.002	0.013**	0.013**	0.027***	0.026***	0.081***	0.079***
	(0.004)	(0.004)	(0.006)	(0.006)	(0.005)	(0.005)	(0.008)	(0.008)
EFD	−0.098***	−0.065***	−0.059***	−0.039***	−0.097***	−0.063***	−0.111***	−0.072***
	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.005)	(0.005)
Leverage	0.039***	0.037***	0.027***	0.026***	0.022***	0.021***	0.019***	0.019***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.007)	(0.007)
Liquidity	0.062***	0.061***	0.021***	0.021***	0.040***	0.041***	0.024***	0.026***
	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)
Export intensity	−0.050***	−0.050***	−0.043***	−0.044***	−0.108***	−0.108***	−0.145***	−0.145***
	(0.014)	(0.014)	(0.015)	(0.015)	(0.009)	(0.009)	(0.013)	(0.013)
Capital/labor	−0.023***	−0.013***	−0.023***	−0.015***	−0.026***	−0.015***	−0.041***	−0.028***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Firm fixed effect	Yes	Yes	Yes	Yes				
Year fixed effect	Yes	Yes	Yes	Yes				
N	1,590,841	1,590,841	1,117,288	1,117,288	718,124	718,124	474,842	474,842

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.
Notes: Robust standard errors in parentheses. Constants are included in all regressions. Columns 1–4 use fixed effects panel regression, while columns 5–8 adopt the dynamic panel regression approach. Dependent variables include firm's TFP level and TFP growth rate, calculated by both OP and OLS methods. Independent variable leverage is measured as total liabilities to total assets; liquidity is measured as working capital to total assets; capital intensity is measured by the capital–labor ratio and export intensity is calculated as export to sales ratio.

Table 9
Interaction between internal finance and external finance dependence.

Dependent variable	(1) Panel	(2)	(3)	(4)	(5) Dynamic panel	(6)	(7)	(8)
	TFP-OP	TFP-OLS	ΔTFP-OP	ΔTFP-OLS	TFP-OP	TFP-OLS	ΔTFP-OP	ΔTFP-OLS
Cash flow	0.046***	0.044***	0.014***	0.013***	0.028***	0.024***	0.029***	0.025***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Cash flow × EFD	0.001***	0.001***	0.000	−0.000	0.014***	0.009***	0.016***	0.010***
	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
All credit	0.044***	0.044***	−0.021***	−0.020***	0.026***	0.025***	0.079***	0.078***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.005)	(0.005)	(0.008)	(0.008)
Leverage	0.082***	0.075***	0.044***	0.043***	0.022***	0.021***	0.020***	0.019***
	(0.006)	(0.006)	(0.003)	(0.003)	(0.005)	(0.005)	(0.007)	(0.007)
Liquidity	0.165***	0.157***	0.025***	0.024***	0.041***	0.041***	0.025***	0.026***
	(0.004)	(0.004)	(0.002)	(0.002)	(0.004)	(0.004)	(0.005)	(0.005)
Export intensity	−0.035***	−0.036***	−0.026***	−0.025***	−0.108***	−0.108***	−0.145***	−0.145***
	(0.004)	(0.004)	(0.005)	(0.004)	(0.009)	(0.009)	(0.013)	(0.013)
Capital/labor	−0.003***	0.005***	0.006***	0.008***	−0.025***	−0.014***	−0.040***	−0.027***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.002)	(0.002)
Industry fixed effect	Yes	Yes	Yes	Yes				
Year fixed effect	Yes	Yes	Yes	Yes				
N	1,590,841	1,590,841	1,117,288	1,117,288	718,124	718,124	474,842	474,842

* $p < 0.10$
** $p < 0.05$.
*** $p < 0.01$.
Notes: Robust standard errors in parentheses. Constants are included in all regressions. Columns 1–4 use fixed effects panel regression, while columns 5–8 adopt the dynamic panel regression approach. Dependent variables include firm's TFP level and TFP growth rate, calculated by both OP and OLS methods. Independent variable leverage is measured as total liabilities to total assets; liquidity is measured as working capital to total assets; capital intensity is measured by the capital–labor ratio and export intensity is calculated as export to sales ratio.

Table 10
SOEs vs. non-SOEs with internal finance (dynamic panel).

Dependent variable	(1) TFP-OP	(2) TFP-OLS	(3) ΔTFP-OP	(4) ΔTFP-OLS
Cash flow	0.0973***	0.0723***	0.0210***	0.0182***
	(0.0007)	(0.0011)	(0.0004)	(0.0007)
SOE	−0.165***	−0.0316**	−0.0231***	−0.0187
	(0.0103)	(0.0147)	(0.0076)	(0.0114)
Cash flow × SOE	−0.0207***	−0.00456	−0.00375**	−0.00153
	(0.0025)	(0.0037)	(0.0019)	(0.0029)
EFS	0.0374***	0.142***	0.0210***	0.0789***
	(0.0056)	(0.0089)	(0.0050)	(0.0076)
EFD	−0.00118***	−0.00136***	−0.000173***	−0.000168**
	(0.0003)	(0.0003)	(0.0001)	(0.0001)
Size	−0.156***	−0.186***	−0.0257***	−0.0301***
	(0.0004)	(0.0008)	(0.0003)	(0.0005)
Age2	0.00448***	−0.00180***	0.000338***	−0.0000566
	(0.0004)	(0.0003)	(0.0001)	(0.0001)
Export intensity	−0.0872***	−0.114***	−0.104***	−0.137***
	(0.0057)	(0.0084)	(0.0074)	(0.0113)
Capital/labor	−0.476***	−0.499***	−0.0580***	−0.0628***
	(0.0019)	(0.0033)	(0.0013)	(0.0022)
Leverage	0.0918***	0.203***	−0.00136	0.0138**
	(0.0065)	(0.0099)	(0.0043)	(0.0065)
Liquidity	0.112***	0.181***	0.0154***	0.0193***
	(0.0045)	(0.0075)	(0.0025)	(0.0040)
N	870,226	592,015	868,307	590,343

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.
Notes: Robust standard errors in parentheses. Constants are included in all regressions. Columns 1–4 use fixed effects panel regression, while columns 5–8 adopt the dynamic panel regression approach. Dependent variables include firm's TFP level and TFP growth rate, calculated by both OP and OLS methods. Independent variable leverage is measured as total liabilities to total assets; liquidity is measured as working capital to total assets; capital intensity is measured by the capital–labor ratio and export intensity is calculated as export to sales ratio.

productivity growth rates. Again, we use fixed effect panel regression in specifications 1–4 and dynamic panel regression in specifications 5–8. All results are similar and support the negative effect of external finance dependence on firm productivity.

5.4.1. Interaction between internal finance and external finance dependence

Does external finance dependence, as a measure of external credit demand, change the marginal effect of internal finance on firm productivity? We regress the following equation to test this interaction effect:

$$\mathrm{TFP}_{it} = \beta_1 \mathrm{CashFlow}_{it} + \beta_{x2} \mathrm{CashFlow}_{it} \times \mathrm{EFD}_k + \beta_2 \mathrm{Leverage}_{it} + \beta 3 \mathrm{Liquidity}_{it} + \beta X_{it} + \nu_t + \nu_k + \varepsilon_{it} \quad (5)$$

The results are reported in Table 9. In specifications 1–4, we use fixed effect panel regression, and in specifications 5–8, we use dynamic panel regression. We find that the interaction term between internal finance and external finance dependence are, in most cases, significant and positive. This implies that internal finance has stronger positive effect on TFP in financially vulnerable sectors. In other words, if firms are in financially vulnerable industries, internal finance (through their own cash flow) is particularly important in promoting productivity. Internal cash flow encourages firm productivity in general, and this effect is particularly important in industries that are more dependent on external finance.

5.5. SOEs vs. non-SOEs

Since firm's external credit accessibility largely depends by firm's ownership type in China, We introduce a dummy variable, SOE, to investigate the productivity difference between SOEs and non-SOEs. We estimate regressions of TFP and TFP growth rate on SOE, conditioning on internal finance, external credit supply, external credit demand, and other firm-level controls. The coefficients on SOE are significantly negative, suggesting that SOEs generally have lower productivity and lower productivity growth rates compared with other firms, controlling for internal finance, external credit supply, and external finance dependence (see Tables 12 and 13 in appendix[7]).

[7] Table 12 reports the results for the panel regression with industry fixed effects in specifications 1–4 and with firm fixed effects in specifications 5–8. Table 13 reports the results of the dynamic panel regressions.

Table 11
Interaction between SOE and credit supply and external finance dependence.

Dependent variable	TFP-OP Panel	TFP-OLS	ΔTFP-OP	ΔTFP-OLS	TFP-OP Dynamic panel	TFP-OLS	ΔTFP-OP	ΔTFP-OLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cash flow	0.019***	0.019***	0.019***	0.019***	0.019***	0.019***	0.019***	0.019***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
All credit	0.031***	0.029***	0.083***	0.081***	0.027***	0.026***	0.081***	0.079***
	(0.005)	(0.005)	(0.008)	(0.008)	(0.005)	(0.005)	(0.008)	(0.008)
All credit × SOE	−0.025***	−0.024***	−0.021***	−0.020***				
	(0.005)	(0.005)	(0.008)	(0.008)				
External finance	−0.097***	−0.063***	−0.111***	−0.072***	−0.097***	−0.064***	−0.111***	−0.072***
	(0.003)	(0.003)	(0.005)	(0.005)	(0.003)	(0.003)	(0.005)	(0.005)
External finance × SOE					0.008	0.012**	−0.002	0.003
					(0.005)	(0.005)	(0.008)	(0.008)
Leverage	0.022***	0.021***	0.020***	0.019***	0.022***	0.021***	0.019***	0.019***
	(0.005)	(0.005)	(0.007)	(0.007)	(0.005)	(0.005)	(0.007)	(0.007)
Liquidity	0.040***	0.041***	0.024***	0.026***	0.040***	0.041***	0.024***	0.026***
	(0.004)	(0.004)	(0.005)	(0.005)	(0.004)	(0.004)	(0.005)	(0.005)
Export intensity	−0.108***	−0.108***	−0.145***	−0.145***	−0.108***	−0.108***	−0.145***	−0.145***
	(0.009)	(0.009)	(0.013)	(0.013)	(0.009)	(0.009)	(0.013)	(0.013)
Capital/labor	−0.026***	−0.015***	−0.041***	−0.028***	−0.026***	−0.015***	−0.041***	−0.028***
	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.002)
N	718,124	718,124	474,842	474,842	718,124	718,124	474,842	474,842

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Notes: Robust standard errors in parentheses. Constants are included in all regressions. Columns 1–4 use fixed effects panel regression, while columns 5–8 adopt the dynamic panel regression approach. Dependent variables include firm's TFP level and TFP growth rate, calculated by both OP and OLS methods. Independent variable leverage is measured as total liabilities to total assets; liquidity is measured as working capital to total assets; capital intensity is measured by the capital–labor ratio and export intensity is calculated as export to sales ratio.

We are interested in examining the interaction effect between external credit supply and SOEs as well as the interaction effect between external credit demand and SOEs. We first regress firm productivity and productivity growth rates on the interaction term between internal cash flow and the SOE dummy. In Table 10, the interaction item displays significant negative coefficients when using TFP-OP to measure the productivity level and the productivity growth rate and insignificant negative coefficients when using TFP-OLS to measure productivity. The negative interaction term shows that the marginal effect of internal financing is weaker for SOEs. We control for external finance supply and demand and other firm-level characteristics in the regression; it suggests that, holding other external conditions constant, SOEs are less efficient at enhancing productivity with internal financing.

We also regress firm productivity and productivity growth rate on the interaction term between external credit supply and the SOE dummy. The results of the dynamic panel regressions are presented in columns 1–4 in Table 11. We find significant negative coefficients on the interaction term between the SOE dummy and credit supply. This suggests that the marginal effects of the external credit supply on productivity is weaker for SOEs, conditioning on internal finance, external credit supply, and external finance dependence.

We then regress productivity and productivity growth on the interaction term between the SOE dummy and external finance dependence. These results are presented in specifications 5–8 in Table 11. These coefficients are not very significant in most cases. This pattern implies that SOEs and non-SOEs in industries with different levels of external credit demand do not differ substantially. Perhaps this result reflects that external finance dependence is an industry-level measure that mainly captures the technological nature of the industry. Thus, it is difficult to identify significant differences between SOEs and non-SOEs regarding the marginal effect of external credit demand.

6. Concluding remarks

The above empirical investigation indicates the importance of financing for firm productivity through both internal finance and external finance, where external finance includes external finance supply and external finance demand, especially when internal financing is not sufficient. There might be a wedge between supply and demand compared to a frictionless financial market. The size of the wedge has especially important policy implications since China gradual liberalization of its financial market and easing of restrictions on interest rates.

We use a panel of more than 600,000 Chinese firms (1998–2009) to investigate the effects of credit constraints on firm productivity. We consider both internal finance and external finance to obtain a full picture of credit constraints. Within external finance,

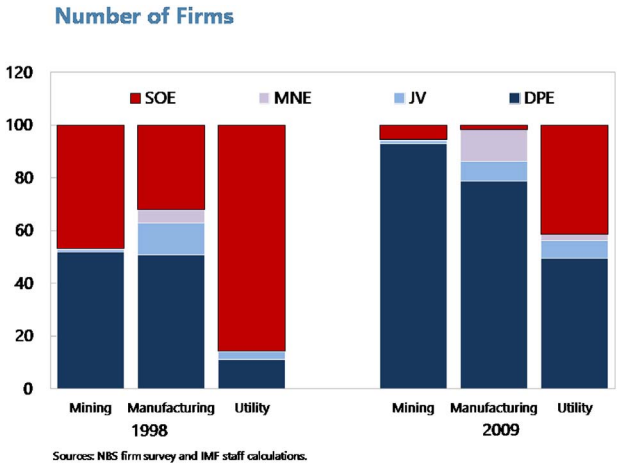

Fig. 2. Number of firms.

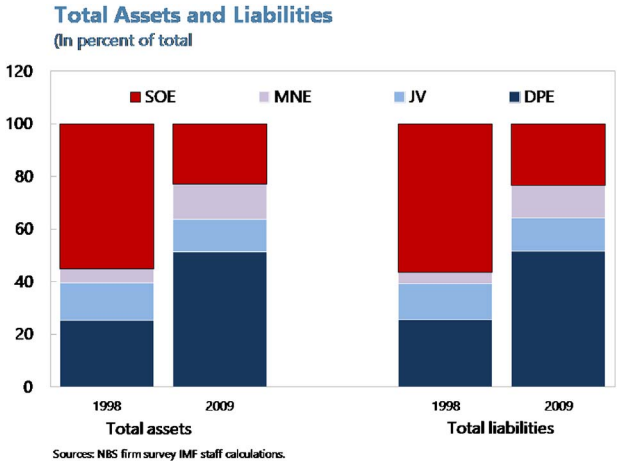

Fig. 3. Share of assets and liabilities.

we study both demand and supply side of credits from the firm point of view. Thus, we explore the role of both external credit demand (via an external finance dependence measure) and external credit supply (via the supply of bank loans to firms) in shaping firm productivity and productivity growth.

We obtain the following key findings. First, both internal finance through a firms own cash flow and external credit supply significantly promote firm productivity and productivity growth rates. Second, there is a substitution effect between internal finance and external credit supply: the marginal effect of internal finance on firm productivity is weaker when firms have sufficient external credit. Third, firms in industries with higher external credit demand (i.e., more financially vulnerable industries) have lower productivity levels and lower productivity growth rates. Internal finance is more important for firms in those financially vulnerable industries. Finally, we find that SOEs generally exhibit lower productivity levels and slower productivity growth and that the positive effect of both external credit supply and internal finance on firm productivity is weaker for SOEs.

Appendix A. Credit supply by locations

Table 12
SOEs vs. non-SOEs.

Dependent variable	(1) Panel	(2)	(3)	(4)	(5) Dynamic panel	(6)	(7)	(8)
	TFP-OP	TFP-OLS	ΔTFP-OP	ΔTFP-OLS	TFP-OP	TFP-OLS	ΔTFP-OP	ΔTFP-OLS
Cash flow	0.045***	0.043***	0.014***	0.014***	0.031***	0.031***	0.019***	0.019***
	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
All credit	0.045***	0.044***	−0.022***	−0.021***	−0.000	−0.002	0.013**	0.013**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.004)	(0.004)	(0.006)	(0.006)
EFD					−0.098***	−0.065***	−0.059***	−0.039***
					(0.002)	(0.002)	(0.003)	(0.003)
SOE dummy	−0.017***	−0.012***	0.023***	0.022***	−0.005	−0.004	−0.003	−0.003
	(0.002)	(0.002)	(0.002)	(0.002)	(0.004)	(0.004)	(0.006)	(0.006)
Leverage	0.082***	0.075***	0.044***	0.042***	0.039***	0.037***	0.027***	0.026***
	(0.006)	(0.006)	(0.003)	(0.003)	(0.005)	(0.005)	(0.005)	(0.005)
Liquidity	0.165***	0.157***	0.026***	0.025***	0.062***	0.061***	0.021***	0.021***
	(0.004)	(0.004)	(0.002)	(0.002)	(0.003)	(0.003)	(0.004)	(0.004)
Export intensity	−0.036***	−0.036***	−0.026***	−0.024***	−0.050***	−0.050***	−0.043***	−0.044***
	(0.004)	(0.004)	(0.005)	(0.004)	(0.014)	(0.014)	(0.015)	(0.015)
Capital/labor	−0.003***	0.005***	0.006***	0.008***	−0.023***	−0.013***	−0.023***	−0.015***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
Industry fixed effect	Yes	Yes	Yes	Yes				
Firm fixed effect					Yes	Yes	Yes	Yes
N	1,590,841	1,590,841	1,117,288	1,117,288	1,590,841	1,590,841	1,117,288	1,117,288

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Notes: Robust standard errors in parentheses. Constants are included in all regressions. Columns 1–4 use fixed effects panel regression, while columns 5–8 adopt the dynamic panel regression approach. Dependent variables include firm's TFP level and TFP growth rate, calculated by both OP and OLS methods. Independent variable leverage is measured as total liabilities to total assets; liquidity is measured as working capital to total assets; capital intensity is measured by the capital–labor ratio and export intensity is calculated as export to sales ratio.

Table 13
SOEs vs. non-SOEs (dynamic panel).

Dependent variable	(1) ΔTFP-OP	(2) ΔTFP-OLS	(3) ΔTFP-OP	(4) ΔTFP-OLS
Cash flow	0.019***	0.019***	0.019***	0.019***
	(0.001)	(0.001)	(0.001)	(0.001)
All credit	0.027***	0.025***	0.081***	0.079***
	(0.005)	(0.005)	(0.008)	(0.008)
EFD	−0.097***	−0.063***	−0.111***	−0.072***
	(0.003)	(0.003)	(0.005)	(0.005)
SOE dummy	−0.023***	−0.022***	−0.015*	−0.013
	(0.006)	(0.006)	(0.009)	(0.009)
Leverage	0.022***	0.021***	0.020***	0.019***
	(0.005)	(0.005)	(0.007)	(0.007)
Liquidity	0.040***	0.041***	0.024***	0.026***
	(0.004)	(0.004)	(0.005)	(0.005)
Export intensity	−0.108***	−0.108***	−0.145***	−0.145***
	(0.009)	(0.009)	(0.013)	(0.013)
Capital/labor	−0.026***	−0.015***	−0.041***	−0.028***
	(0.001)	(0.001)	(0.002)	(0.002)
N	718,124	718,124	474,842	474,842

* $p < 0.10$
** $p < 0.05$.
*** $p < 0.01$.

Notes: Robust standard errors in parentheses. Constants are included in all regressions. All tests are adopted the dynamic panel regression approach. Dependent variables include firm's TFP growth rate, calculated by both OP and OLS methods. Independent variable leverage is measured as total liabilities to total assets; liquidity is measured as working capital to total assets; capital intensity is measured by the capital–labor ratio and export intensity is calculated as export to sales ratio.

Appendix B. TFP calculation

We use two methods OLS and OP to calculate firm level TFP. In a simple OLS method, we based the estimation on a Cobb–Douglas production function.

$$Y_{it} = A_{it} L_{it}^{\beta_l} M_{it}^{\beta_m} K_{it}^{\beta_k} \tag{6}$$

Taking log form to the production function, we have log form production of firm i at time t as the following:

$$y_{it} = a_{it} + \beta_l l_{it} + \beta_m m_{it} + \beta_k k_{it} + e_{it} \tag{7}$$

Where l stands for labor input, k stands for real capital and a represents for TFP of firm i at time t. For each sector, we first estimate from firms production information data set to generate function form. Then we insert each individual firms output y_{it}, labor l_{it} and capital input k_{it} into the estimated production equation, and the residual between firms real output and fitted output is firms log TFP, i.e., a_{it}.

$$a_{it} = y_{it} - \widetilde{\beta}_l l_{it} + \widetilde{\beta}_m m_{it} + \widetilde{\beta}_k k_{it} \tag{8}$$

In the simple OLS method, there is concern of simultaneity between input choices and productivity shocks as well as sample selection bias, so we employ the augmented Olley–Pakes (OP) approach to improve TFP estimation (following Amiti and Konings, 2007). We incorporate firms decision of import/export as additional state variable, and take into account of Chinas entry WTO.

In the augmented OP approach, there are three steps: (1) Firstly, we estimate coefficients for labor and intermediate inputs in production function. Using a fourth-order polynomial function which includes investment, capital, export/import dummy and WTO shock, we estimate the coefficient of capital after controlling simultaneity problem. (2) Secondly, we use probit function to estimate firms survival probability and then put the ratio into the forth-order polynomial function. (3) Thirdly, we finally use nonlinear least squares to estimate the coefficients for all inputs in TFP equation.

Table 14
Average bank loan to GDP ratio by province (2001–2007).

Province	All credit	Long-term loan
Hunan	0.66	0.32
Tibet Autonomous Region	0.66	0.34
Hebei	0.70	0.27
Inner Mongolia Autonomous Region	0.71	0.36
Henan	0.72	0.26
Heilongjiang	0.74	0.27
Shandong	0.75	0.25
Jiangxi	0.80	0.33
Guangxi Zhuang Autonomous Region	0.80	0.43
Anhui	0.84	0.32
Fujian	0.86	0.36
Hubei	0.87	0.41
Jiangsu	0.90	0.31
Xinjiang Uygur Autonomous Region	0.91	0.40
Sichuan	1.00	0.46
Jilin	1.01	0.40
Guangdong	1.05	0.48
Gansu	1.06	0.49
Liaoning	1.06	0.42
Shanxi	1.10	0.56
Hainan	1.11	0.68
Shanxi	1.11	0.46
Guizhou	1.17	0.72
Yunnan	1.20	0.59
Qinghai	1.24	0.79
Chongqing City	1.25	0.60
Tianjin Municipality	1.33	0.58
Zhejiang	1.35	0.44
Ningxia Hui Autonomous Region	1.44	0.78
Shanghai Municipality	1.61	0.78
Beijing Municipality	2.29	1.27

Source: Almanac of China's Finance and Banking 2007.

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