Money in Motion and Firms' Credit Constraints

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Abstract：Financial shocks affect firms' performance through credit constraints. Factors that determine credit constraints, however, are not sufficiently investigated in existing literature. This paper identifies, analyses, and tests one such factor, the Cash Conversion Cycle (i.e. CCC). Specifically, we develop a "Bank-Firm" model which incorporates incomplete information in the sense that firms' productivities are private information for the bank. In a heterogeneous firm setting, incomplete information delivers endogenous credit constraints that are optimal to the bank. In such optimal credit constraints, firms CCC plays a critical role, determing the level of the credit constraint. We show empirically that: (1) CCC is an important factor affecting the credit constraint; (2) given other condition constant, the longer CCC, the stronger credit constraint the firm faces. Such evidence provides strong support to our theoretical model.

Keywords：heterogeneity; productivity; CCC; credit constraint

JEL Classification: D21; G20; M21

1. Introduction

The financial crisis of 2008 has seriously shocked the real economy, and then the mechanism through which the real economy would be impacted by financial shock has become the focus of the academic circles. It is widely believed that the credit constraint plays a key role on the mechanism, but which factors determines the firms' credit constraints in the existing researches lacks sufficient discussion. This article identifies, analyzes and tests a key factor to influence the credit constraints, namely the Cash Conversion Cycle (i.e. CCC), which measures the average time from paying money to get it back in the firm's whole process of production and sales. The longer CCC means that the firms need longer time to get their money back, thus, the cost and risk of capital using will increase. On this basis, our study finds that the CCC would affect the firms' credit constraints caused by the bank. Specifically, under the heterogeneous firms setting and the condition of incomplete productivity information, the bank designs the credit contracts that satisfied the incentive compatibility to firms, in order to overcome the incomplete information. Thus, CCC would entry the optimal credit contract which is endogenously chosen by the bank, and then affects the firms' credit constraints.

Studies of capital using time may affect credit constraints began with Amiti and Weinstein (2011). Their research firstly points out that exporters need to offset the greater business risk in the Trade Finance contract, for their longer time to get money back from production to sales. Berman et al. (2012) finds that the negative impact of the financial crisis to the firms' exporting increased with the increasing of the shipping time. Because of longer shipping time, the exporters face a higher risk of default, thus amplifying the influence of the finance on the exporters. Feenstra et al. (2013) theorized the above ideas, built a heterogeneous-firms model that taking the longer capital recycling time as the key to distinguish exporters from non-exporters, and then verified that the exporters would face tighter credit constraints.

Based on these literatures, our paper generalizes the impact of capital using time on the firms' credit constraints. The above literatures focus on the exporters' long capital using time due to their long transportation time in the trade, thus the finds of these literatures are only applicable to exporters. However, the influencing factors of CCC are not only the exporting products' transporting time. Our paper introduces the concept of CCC from the Accounting literature to measure the average time from paying money to get it back in the firms' whole process of production and sales. Obviously, this measure contains both exporters' transportation time, and other factors that may affect firms' capital using time. Therefore, our studies are applicable to all industries and firms, and the research conclusions are more general.

First of all, through building a theoretical model, this paper expounds the mechanism of the capital recovering time entering into the firms' credit constraints. The key setting of the model is that the firms' productivity is the incomplete information for the bank. This assumption has a realistic foundation that, in most industries the firms' entering and exiting is frequent in Chinese high-speed economic development. Thus, it is difficult for the bank to identify each firm's productivity level, when the bank provides loans to the firms. But, according to the revelation principle, the bank can design the credit contracts that satisfied the incentive compatibility to identify the firms' real productivity and maximize its profit. However, these incentive compatibility contracts may lead the size of the firm's production and sales less than the optimal one, which is a credit constraint. The intuition is that, by choosing a smaller suboptimum size of the production and sales, the firm reduces borrowing and pays less interest, thus gains no less than the case of optimal size under the condition of complete information. The contribution of our theoretical model is to introduce the firm's CCC, which can measure the costs and risks of the loans, into the loans contracts designed by the bank, and become the important factor affecting the firm's credit constraint. The theoretical analysis results show that, the longer capital recovering time the firms need, the stronger credit constraints the firms face, given other things equal. And the credit constraints affect the extensive margin and intensive margin of the firms' production. In the empirical aspect, we directly construct a structure equation linking the firms' sales incomes and their interest expenditures, based on the equilibrium solution of the credit constraints, and estimate the main parameters of the structure equation using Chinese manufacturing firm data. The regression results show that CCC has a positive impact on the firm's credit constraint; also, this conclusion is very robust.

There are other two kinds of literatures related to our research. The first kind of studies discussed how the credit constraints affect the firms in the area of the International Trade, generally taking the credit constraints as the exogenous variables. Manova (2012) investigated the influence of the financial contracts and the tangible assets on the firms' exporting trade. Li and Yu (2013) derived an empirical equation from the heterogeneous firm model, and took the firms with high project success rate or foreign-owned as a category that with weaker credit constraints, in order to test the conclusion that weak credit constraints may be beneficial to the firms' exporting. Muûls (2015) used the credit scores from an independent credit insurance company as a measure of credit constraints, empirically check that the credit constraints not only restrain firms' exports, but also reduce their imports. Our paper furtherly investigates the source of credit constraints, so as to provide a more solid foundation for the above studies.

The second kind of literatures discussed what causes the credit constraints. Chaney (2005) introduced the firms' liquidity constraints into the heterogeneous-firms model, and found that the firms with high liquidity may face weak credit constraints. But Chaney (2005) focused on the issues of endogenous financing. Feenstra et al. (2013) took the long transportation time as a key factor to explain the strong credit constraints of the exporters. Our study integrates these factors mentioned in those two papers, and forms a single variable as CCC, combing with other factors that may affect the liquidity. On the one side, this expands the study of Chaney (2005), for that liquidity is just one factor for CCC; on the other side, this also expands Feenstra (2013), for that the concerns about credit constraints are no longer just focused on the exporters.

In addition, the view that the incomplete information is the reason for credit constraints in the Information Economics is expanded in our study. The classic lending model, such as Laffont and Martimort (2002), structured only two kinds of representative firms, as high efficiency firm and low efficiency firm, and explained why the incentive compatibility loans contracts designed by the bank would encourage the firms to choose suboptimal production scale rather than the optimal production scale. But, under the representative-firms setting, the degree of incomplete information can’t be measured, thus the influence of incomplete information on credit constraints can’t be tested. Also, this kind of model is a bit far from the real economy; meanwhile, the scalability of this model is not strong. So that, it is difficult to introduce other factors that may affect credit constraints. The heterogeneous-firm model coming from Melitz (2003) provides a useful analysis tool for in-depth discussing and expanding the problem of credit constraints. Based on the heterogeneous-firm model, our research introduces the lending problem, to analyze the impact of CCC on credit constraints and test the effect of the productivity incomplete information.

The rest of this paper is organized as follows. Section 2 builds a “Bank-Firm” loaning model with productivity incomplete information, under the heterogeneous-firms setting, and defines the concept of credit constraints based on the optimal production decision, and theoretically analyzes the factors that may affect credit constraints. Section 3 constructs the structural econometric equations based on the analysis conclusions of the theoretical model, and introduces the processing of the data and variables. Section 4 describes the empirical results and some related testing. Section 5 concludes.

2. Theoretical Model

We assume that there are three kinds of participators, consumers, firms and a bank. Each consumer provides 1 unit of labor as the only production factor, and total number of consumers is L. There are two sectors, where the first produces a single homogeneous good with constant return to scale technology and chosen as numeraire. And labor is allowed to freely flow between the two sectors, thus the marginal output of labor in this sector determines the level of wage (w). The second sector produces a continuum of differentiated goods under monopolistic competition, as in Melitz (2003).

In the second sector, the productivities of firms are private information, satisfied a certain distribution which is a public information. Firms in the differentiated sector need to borrow working capital to finance a fraction (δ) of their fixed and variable costs from a single and monopolistic bank. And the bank charges interest payments to maximize its profits. The timing of events is as follows. The bank specifies a loan and interest payment schedule based on publicly known productivity distribution. Then the firms draw their productivities and borrow from the bank. When borrowing from the bank, a firm will claim a productivity level to maximize its profit taking the loan and interest payment schedule as given. By the revelation principle, the bank can do no better than to design a loan-interest payment schedule that induces firms to reveal their true productivity.

2.1 Consumers

Consumers are endowed with one unit of labor and the preference over the differentiated good displays a constant elasticity of substitution. The utility function of the representative consumer is:

$$U = q_0^{1-\mu}\left(\int_{\omega\in\Omega} q(\omega)^{\frac{\sigma-1}{\sigma}}\, d\omega\right)^{\frac{\sigma}{\sigma-1}\mu} \quad (1)$$

where ω denotes each variety, Ω is the set of varieties available to the consumer, σ>1 is the constant elasticity of substitution between each variety, and τ is the share of expenditure on the differentiated sector. Accordingly, the demand for each variety is:

$$q(\omega) = \frac{Y}{P}\left(\frac{p(\omega)}{P}\right)^{-\sigma} \quad (2)$$

where $Y \equiv \mu wL$ is the total expenditure on the differentiated good at home, *p(ω)* is the price of each variety and $P = \left(\int_{\omega\in\Omega} p(\omega)^{1-\sigma}\, d\omega\right)^{\frac{1}{1-\sigma}}$ is the aggregate price index in the differentiated sector.

2.2 Firms

Firms in the differentiated sector need to borrow working capital to finance a fraction of their fixed and variable costs. Firms borrow from a single, monopolistic bank, and the bank charges interest payments to maximize its profits. The timing of events is as follows. The bank species a loan and interest payment schedule based on publicly known productivity distribution. Then the firms draw their productivities and borrow from the bank. When borrowing from the bank, a firm will claim a productivity level to maximize its profit taking the loan and interest payment schedule as given. With the resulting loans, firms choose market serve and produce. Revenues are then realized and the bank collects payments.

The bank faces an opportunity cost of *i* - the interest rate - on its loan. We assume that the loans for the projects are paid back after τ periods.Under incomplete information, the bank does not observe the productivity level, x, of a firm coming to it for a loan. In order to maximize profits, the bank will design a schedule of loans $M(x^{'})$ and interest payments $I(x^{'})$ contingent on firms' announced productivity level $x^{'}$.

By the revelation principle, the bank can do no better than to design a loan-interest payment schedule that induces firms to reveal their true productivity, $x^{'} = x$. Adding this incentive compatibility condition as a constraint, the firm's profit maximization problem is:

$$\begin{aligned}
&\max_{x',q} \pi(x,x') = pq-(1-\delta)\left(\frac{qw}{x}+C\right)-\left(M(x')+I(x')\right) \\
&s.t. \quad \pi(x,x)\geq \pi(x,x') \\
&\qquad\ \ \pi(x,x)\geq 0 \\
&\qquad\ \ M(x')\geq \delta\left(\frac{qw}{x}+C\right)
\end{aligned} \tag{3}$$

Where q is the consumers' demand function the same as (2), and C is the fixed cost. The first constraint is the incentive compatibility constraint; the second ensures that profits are non-negative, and the third species that the amount of the loan must cover the fraction of the fixed and variable cost at the chosen production level (q). Using the fact that the third constraint will be binding in equilibrium, then at point, $x'=x$, we can obviously get that:

$$q=\left(\frac{M(x)}{\delta}-C\right)\frac{x}{w} \tag{4}$$

And, we take the derivative of the profit respect to announced productivity, x', to obtain the first-order condition:

$$\left[\Phi\left(x,M\left(x\right)\right)-1\right]\frac{M'\left(x\right)}{\delta}=I'\left(x\right) \tag{5}$$

where

$$\begin{aligned}
\Phi\left(x,M(x)\right) &\equiv \left(p\frac{\sigma-1}{\sigma}\right)\Big/\left(\frac{w}{x}\right) \\
&= \frac{\sigma-1}{\sigma}\left(\frac{M(x)}{\delta}-C\right)^{-\frac{1}{\sigma}}\left(\frac{xP}{w}\right)^{\frac{\sigma-1}{\sigma}}Y
\end{aligned} \tag{6}$$

The value of Φ in the first line of (6) is recognized as the ratio of marginal revenue to marginal cost. A firm without any need to borrow will produce where Φ=1, while a firm that produce less due to insufficient loans will have Φ>1. This means that Φ is a measure of firm’s credit constraint, and the larger is Φ then the lower is the quantity produced due to this constraint. The second line of (6) is obtained by using the binding quantity level in the third constraint and its corresponding price from demand in (2). It is apparent that having lower loans *M(x)* will raise Φ, indicating that the credit constraint is tightened.

We can now develop some intuition as to why the bank might need to impose credit constraints. Let’s suppose that the bank lends more to higher productivity firms, and also collects more in interest payments. Then in (5), both $M'(x)$ and $I'(x)$ are positive. It follows that the expression in brackets on the left must be positive, therefore, the firm must be credit constrained, i.e. Φ>1. The reason this condition is needed is that, if the bank specifies loan and interest schedules such that firms are not credit constrained and all profits are paid back to the bank, a firm that is supposed to produce at the monopoly optimum with marginal revenue equal to marginal cost would have only a second-order loss in profits from announcing a slightly smaller productivity $x^{'}$, and producing slightly less. But the firm would have a first-order gain from the reduction in interest payments $I^{'}(x)>0$. So, a firm at the monopoly optimum would always understate its productivity, and it follows that a credit constraint is needed to ensure incentive compatibility.

2.3 Bank's Decision

The monopolistic bank chooses the loan given to domestic firm subject to the incentive-compatibility condition (5). Then the bank's problem is to choose M(x) and I(x) to maximize its profits:

$$\max_{M,I} \int_{\underline{x}}^{\infty} \left(I(x) - i\tau M(x) \right) f(x) dx$$

$$s.t. \quad \left[\Phi(x, M(x)) - 1 \right] \frac{M^{'}(x)}{\delta} = I^{'}(x), \quad if \quad x \in [\underline{x}, \infty) \tag{7}$$

Where i is the opportunity cost of leading the loan for one unit of period and τ is the length of the periods that the firm need to recovery the capital. In the model, τ is an exogenous parameter in objective function of the bank. Actually, it can be measured by the Cash Conversion Cycle of firm. And, τ is affected by the attributes of firm itself and the sector it belongs to. For example, exporters may need longer time to from production and sales to recovery the capital than non-exporters, and a firm in the capital-intensive industry may have a bigger τ comparing with the firm in the labor-intensive industry (Feenstra et al., 2013). And, f(x) is the probability density function of firms' productivity distribution. The variable $\underline{x}$ is the productivity of the cutoff firm. As in Melitz (2003) and Feenstra et al. (2012), firms will enter into production based on the profitability. It means that the cutoff firm with productivity $\underline{x}$ is defined by zero-cutoff-profit condition $\pi(\underline{x}, \underline{x})=0$. Obviously, the cutoff productivity must differ from that in Melitz (2003), because of the influence by credit constraints offered by the bank.

The bank's problem (7) is solved in two steps. First, solve the loan schedule that maximizes bank's profit, which is an optimal control problem analyzed in the Appendix. But that still leaves open the initial level of interest payments for the cutoff firm: this initial interest payment will in fact determine the productivity level $\underline{x}$ for the cutoff firm. And the second step in the optimization problem for the bank is to determine the optimal initial interest payments for the cutoff firm, or equivalently, solving for the optimal cutoff productivity and consequently obtain the implied initial interest payments. It is shown in the Appendix that the optimal loan schedules for the bank are such that:

$$\Phi = (1 + i\tau\delta) \left[1 - \frac{\sigma - 1}{\sigma} \frac{1 - F(x)}{x f(x)} \right]^{-1} \tag{8}$$

Where, F(x) is the distribution function of the productivity x. To simplify the solution, we further assume that x satisfies a Pareto distribution, i.e. $F(x)=1-(1/x)^{\theta}$, $x \geq 1$, where θ is the shape parameter and $\theta>2$ (otherwise, there is no Std. Dev). So, Φ is that:

$$\Phi = (1 + i\tau\delta) \left(1 - \frac{\sigma - 1}{\sigma\theta} \right)^{-1} \tag{9}$$

Obviously, we can see that credit constraint for firms apply, means that Φ>1, even if *i*=0 in (9). Thus, even when the bank has no opportunity cost of making loans, a credit constraint is still needed to ensure incentive compatibility. When *i*>0, the credit constraint is further increased, and it is intuitive that the bank will restrict credit more as its opportunity cost rises. More importantly, we still have two finds: (1) the incomplete information of firms' productivities is the reason for credit constraint, especially, the higher is the degree of incomplete information (i.e. θ is bigger), the tighter is the credit constraint; (2) the longer is the time needed to recovering the capital (i.e. τ is bigger), the tighter is the credit constraint. These two finds would be tested in our empirical study.

In addition, we can get the optimal loan schedules for the bank and the cutoff productivity in the equilibrium. The optimal loan schedules i.e. M(x) and I(x) satisfy that:

$$I(x) = (\Phi - 1)\frac{M(x)}{\delta}, \quad \forall x \in [\underline{x}, \infty)$$

$$\frac{M(x)}{\delta} = \left(\frac{\sigma - 1}{\sigma} \left(\frac{xp}{w} \right)^{\frac{\sigma-1}{\sigma}} Y^{\frac{1}{\sigma}} \right)^{\sigma} \Phi^{-\sigma} + C, \quad \forall x \in [\underline{x}, \infty) \tag{10}$$

The cutoff productivity satisfies that:

$$\underline{x} = w \left(\frac{\sigma}{\sigma - 1} \left(\frac{(\sigma-1)C}{YP^{\sigma-1}} \right)^{\frac{1}{\sigma}} \Phi \right)^{\frac{\sigma}{\sigma-1}} \tag{11}$$

From (8), we can find that, under credit constraint condition, the cutoff productivity level is lower, comparing with the conclusion in Melitz (2003). Thus, the credit constraint not only affects the intensive margin of firm's production decision, also affects its extensive margin.

3. Estimation Equation and Data

3.1 Empirical Specification

We can use our results above to derive a linear equation linking the revenue of the firm to its interest payments, and we shall estimate that equation using data on Chinese firms. The basic relationship between firms' revenue and interest payments is linear in these variables, as we show below, but the coefficient on interest payments is a nonlinear function of credit constraint faced by the firms. Also, the firm's credit constraint, Φ, is affected by two important factors: one is the capital recovering time τ, which can be calculated using the firms' financial variables; the other is the degree of the incomplete information of firms' productivities, related to θ (in fact, 1/θ(θ-2)), which can be calculated using the firms' production variables.

To derive the basic relationship between firms' revenue and interest payments, start with the definition of the credit constraint, Φ, as the first line of (6) shows. Combing with (4) and the first line of (10), we can easily get that:

$$pq = \frac{\sigma}{\sigma-1}\Phi\left(\frac{I(x)}{\Phi-1}-C\right) \quad (11)$$

Using these, we obtain a linear relation between revenue and interest payment for firm *j* in year *t*:

$$r(x_{jt}) = \beta_0 C_{jt} + \beta_1 I(x_{jt}) \quad (12)$$

Where, the coefficients are obtained from above as:

$$\beta_0 = -\frac{\sigma}{\sigma-1}\Phi < 0$$

$$\beta_1 = \frac{\sigma}{\sigma-1}\left(\frac{\Phi}{\Phi-1}\right) = \frac{\sigma}{\sigma-1}\left(\frac{1}{1-\frac{1}{\Phi}}\right) > 0 \quad (13)$$

The coefficient β_0 is negative because higher fixed costs reduce the amount of the loan available to cover variable costs, and therefore reduce the revenue. β_1, which multiplies the interest payment, is positive (since $\Phi>1$), indicating that larger interest payments are associated with larger revenues. Also, we can see that β_1 is a random coefficient because of (9). Especially, β_1 is affected by the variable, τ, and the influence channel is that:

$$\tau\uparrow \;\Rightarrow\; \Phi\uparrow \;\Rightarrow\; \beta_1\downarrow \quad (14)$$

It means that the longer time needed to recovery the capital leads the tighter credit constraint, then, the tighter credit constraint leads the smaller β_1. In order to capture this prediction, we take β_1 as a function of τ, and make a first-order Taylor expansion on τ.

$$\beta_1 = g(\tau) \approx \gamma_1 + \gamma_2 \tau \quad (15)$$

Where,

$$\gamma_1 = \frac{\sigma}{\sigma-1}\frac{\left(1-\frac{\sigma-1}{\sigma\theta}\right)^{-1}}{\left(1-\frac{\sigma-1}{\sigma\theta}\right)^{-1}-1} > 0, \quad \gamma_2 = -\frac{\sigma}{\sigma-1}\frac{\left(1-\frac{\sigma-1}{\sigma\theta}\right)^{-1} i\delta}{\left\{\left(1-\frac{\sigma-1}{\sigma\theta}\right)^{-1}-1\right\}^2} < 0$$

Therefore, (12) changes as

$$\begin{aligned} r(x_{jt}) &= \beta_0 C_{jt} + \left(\gamma_1 + \gamma_2 \tau_{jt}\right) I(x_{jt}) \\ &= \beta_0 C_{jt} + \gamma_1 I(x_{jt}) + \gamma_2 I(x_{jt})\tau_{jt} \quad (16) \end{aligned}$$

Where, $\gamma_2<0$ captures the negative effect of τ on β_1, and tests the prediction of (14), for that the bigger τ may lead a tighter credit constraint. Since β_1 must be positive in (12), we still need to check that $\gamma_1+\gamma_2\tau_{jt}>0$.

While (16) summarizes the basic equilibrium relationship between the revenue and the interest payment in our theoretical model, it is written this equation has no error term. That limitation occurs because revenue $r(x_{jt})$ appearing on the left depends on the productivity *x* that is known by each firm: we can think of this as *ex-ante* productivity, and distinguish it from *ex-post* productivity that would incorporate a host of random factors outside our model, including unanticipated problems in production, abnormal delays in shipping, government intervention, etc. So we denote by R_{jt} the actual revenue earned each firm, which differs from anticipated revenues.

$$R_{jt} = r(x_{jt}) + \varepsilon_{jt}, \textit{with} \quad E(\varepsilon_{jt} \mid x_{jt}) = 0$$

The presence of this error term, however, immediately leads to endogeneity issues in our explanatory variables. We expect that the observed interest payments I_{jt} in the data differ from the theoretical schedule $I(x_{jt})$, as follow.

$$I_{jt} = I(x_{jt}) + \mu_{jt}, with \quad E(\mu_{jt} \mid x_{jt}) = 0$$

And then, get the basic estimation equation:

$$R_{jt} = \beta_0 + \gamma_1 I_{jt} + \gamma_2 I_{jt} \tau_{jt} + v_{jt} \quad (17)$$

Where, $v_{jt}=\varepsilon_{jt}-(\gamma_1+\gamma_2\tau_{jt})\mu_{jt}$. Obviously, the explanatory variable, I_{jt}, is correlated with the error term, v_{jt}. Accordingly, we treat interest payments as endogenous and so we need an instrument that is uncorrelated with the errors ε_{jt} and μ_{jt}. One such variable is the *ex-ante* productivity that is anticipated by firms. We will use the technique of Olley and Pakes (1996) to make a distinction between total factor productivity (TFP) of the firm inclusive of the unanticipated, random productivity shocks (what we call TFP1), and TFP of the firms exclusive of these unanticipated shocks (what we call TFP2). The first of these is the standard firm-level measure of productivity, whereas the second makes use of the firm's investment decision to infer the productivity that is anticipated by the firm, so it is correlated with x_{jt} but not with the unanticipated shocks ε_{jt} and μ_{jt}.

3.2 Firm-Level Data

The sample used in this paper comes from a rich Chinese …rm-level panel data set which covers more than 160,000 manufacturing firms per year for the years 2000-2008. The number of firms doubled from 162,885 in 2000 to 412,212 in 2008. The data are collected and maintained by China's National Bureau of Statistics in an annual survey of manufacturing enterprises. It covers two types of manufacturing firms: (1) all state-owned enterprises (SOEs); (2) non-SOEs whose annual sales are more than five million RMB. The non-SOEs can be either multinationals or not. The data set includes more than 100 financial variables listed in the main accounting sheets of all these firms.

Although this data set has an original sample of 2,235,438 and contains rich information, a few variables in the data set are noisy and misleading due, in large part, to the mis-reporting by some firms. We hence clean the sample for mis-measurement and for very small firms by using the following criteria: first, the key financial variables (such as total assets, net value of fixed assets, sales, gross value of industrial output) cannot be missing; otherwise those observations are dropped. Secondly, the number of employees hired for a firm must not be less than 10 people. In addition, following Cai and Liu (2009), and guided by the General Accepted Accounting Principles, we delete observations if any of the following rules are violated: (i) the total assets must be higher than the liquid assets; (ii) the total assets must be larger than the total fixed assets; (iii) the total assets must be larger than the net value of the fixed assets; (iv) the established time must be valid.17 More importantly, (v) a firm's identification number cannot be missing and must be unique; (vi) a firm's sales must be no lower than RMB 5 million; and (vii) a firm's interest payment must be non-negative.

3.3 Firm-level and industry-level CCC

In the estimation equation (17), the variable τ captures the time lag that the firm needs to recovery capital. Combing with the firm's production process, it is nearly the same as the time span that the firm will take from new producing-investment to getting money back after selling the products, if the firm repays in time. So, we can use cash conversion cycle (CCC), which measures how long a firm will be deprived of cash if it increases its investment in resources in order to expand customer sales in management accounting, as a measure of τ. The definition of CCC is that:

$$CCC = \frac{Avg.Inventory}{COGS} + \frac{Avg.Receivables}{Sales} - \frac{Avg.Payables}{COGS}$$

Where COGS is the Cost of Goods Sold and "Avg." means the average value of the initial and ending values. All the variables in the above are contained in our data that from 2004 to 2007 year. We use the firm-level data to calculate the firm-level CCC, but we worry about that inventory, receivable and payable maybe correlated with sales. This will lead the endogenous problem of CCC. Because the firm may adjust these indicators according to sales revenue in order to tax avoidance. So, we have another way to get the f CCC, as industry-level CCC. At every year, we choose the median CCC of all firms' in the same 4-digit industry as their CCC. Since the mean values are affected by the outliers, we avoid using it. Then, in the next empirical work, we use both two kinds CCC to check our theoretical prediction.

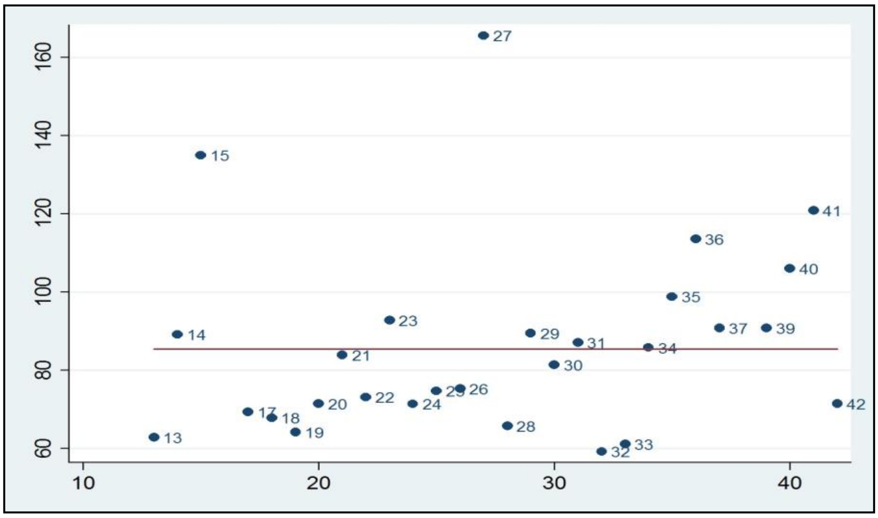

Figure 2: The difference of CCC among the industries

Note: Vertical Axis marks with days; Line is the average CCC for all firms; Numbers marking on the points are the 2-Digit Code for every industry.

In Figure 2, we show the average CCC of every 2-Digit industries, to provide a qualitative understanding of the difference of CCC for different industries. In the Figure, the line shows the average CCC for all firms, at about 85 days. On average, the shortest CCC comes from Smelting and Pressing of Ferrous Metals (2-Digit Code: 32), which is about 59 days; and Smelting and Pressing of Non-Ferrous Metals (2-Digit Code: 33) is the second, about 61 days. The longest CCC comes from Drugs Manufacturing (2-Digit Code: 27), about 165 days; Beverages Manufacturing (2-Digit Code: 15) is another industry with longer CCC, about 135days. Obviously, Figure 2 reflects one important fact that the difference of CCC among the industries or firms is larger. Thus, it is reasonable that the bank may design the loan schedules according to time-lag τ.

3.4 Measure of TFP

We use the augmented Olley and Pakes (1996) approach to estimate and calculate the rms' TFP. This method is applied to our dataset of Chinese firms as follows. First, given that the measure of TFP requires real terms of firm's inputs (labor and capital) and output, we need to adopt different price deflator for inputs and outputs. Data on outputs deflators are directly from Brandt et al:(2009), and we use deflated firm's value-added to measure production since we do not include intermediate inputs (materials) as one kind of factor input. But the one important input-capital- is a bit hard to get the real term, we use perpetual inventory method to calculate the real capital stock (take 2003 year nominal fixed assets as the initial values).

As discussed above, we estimate firm's anticipated productivity level (TFP2) rather than the con-ventional TFP measure. To motivate this from the Olley and Pakes (1996) framework, consider a standard Cobb-Douglas production function:

$$\ln Y_{jt} = \gamma_k \ln K_{jt} + \gamma_l \ln L_{jt} + x_{jt} + \xi_{jt}$$

Where, Y_{jt} is the value-added production of firm j at year t. The conventional measure of productivity is to take the difference between log value-added and log factor inputs times their estimated coefficients:

$$TFP1_{jt} = \ln Y_{jt} - \gamma_k \ln K_{jt} - \gamma_l \ln L_{jt}$$

Under this approach, the firm productivity (*TFP1*) is clearly correlated with value-added and with the ex-post productivity shock ξ_{jt}. But the Olley-Pakes technique suggests a second measure of productivity. The starting point for this technique is to suppose that investment V_{jt} depends on the anticipated productivity $TFP2_{jt}$ of the firm according to a functional relation: $V_{jt} = h^{-1}(TFP2_{jt}; lnK_{jt})$, where K_{jt} denotes firms' capital. When this relation is estimated and inverted, we can solve for anticipated productivity as:

$$TFP2_{jt} = h^{-1}(V_{jt}, \ln K_{jt})$$

The second measure of productivity (*TFP2*) corresponds to what is observed *ex-ante* by the firm, which is closer to Melitz-style productivity described in our model and, by construction, is independent of ξ_{jt}. *TFP2* will be used as an instrument in our estimation of (17).

3.5 Other Variables

In our regression, we use the sales and interest payment variables in the data as the measures of R_{jt} and I_{jt}. In addition, we further control the time fixed effect, industry fixed effect, and regional fixed effect. Among them, the industry fixed effect is controlled by using 2-Digit industry dummy, and the regional fixed effect is controlled by using Province (which the firm belongs to) dummy.

$$\text{tangasset\_ratio}=1-\frac{\text{intang\_assets}}{\text{tot\_assets}}$$

In the extensive analysis, we induce the collateral variable. And, we consider using the ratio of tangible assets to total assets as the proxy of the collateral, according to Manova(2008), as the above formula shows. Where, the intang_assets says intangible assets and tot_assets says total assets.

4. Estimation Results

4.1The benchmark regressing results

According to the regression results of (17), firstly, make use of the interests and sales of an enterprise to make a simple OLS regression, then we can find that interest payments have a significant positive impact on sales. When joining the interest payments and capital in OLS regression cycle (CCC), we can find that the cross terms of the coefficient of the interest payments is still positive (γ_1 significantly greater than zero). However, the positive impact on sales becomes longer and less, which is consistent to the prediction of theory. This shows that the longer the caption conversation cycle is, the more credit constraints cycle enterprises will face. However, the impact of the caption cycle is not significant. Although at the enterprise level, CCC cases reached 10% significance level. At the industry level CCC situation, it is not significant and positive.

This may be the result of endogenous problems. After using the instrumental variable further, the results are consistent with theoretical predictions. Under the CCC case enterprise level, the negative influence from the OLS regression cycle - 44.11 into a 2 SLS regression - 93.33, and increased to 1% significance level. In the situation of 4-Digit industry-level CCC, the negative impact becomes significant. Meanwhile, the result also shows that though the CCC will reduce the positive influence of the payment of interest and the income of sales, it can also insures that the influence is positive.(That is to say that when CCC is an average number or 90 quantile, g(CCC) will always be a positive number).

In regard to the test of instrumental variable, we mainly consider two aspects. Firstly, we will consider the correlation of instrumental variable and endogenous variable. The disturbance term In this econometric model is the heteroscedasticity ($v_{jt}\sim iid(0,\sigma_i^2)$).However, Canonical Correlation Likelihood-Ratio Test that we usually use is only suitable to the situation with the homoskedasticity of variance. Therefore, using Kleibergen and Paap’s rk LM statistics to test whether instrumental variables relate to the endogenous variables, we refuse the model that the null hypothesis was low recognition (Under - Identified) under the significance level of 0.01.After that, we test the Weak instrumental variable again, the regression results of 2SLS will be unpersuasive. Using Kleibergen and Paap’s rk LM statistics (Kleibergen and Paap, 2006), We refuse the model that the null hypothesis was low recognition (Under-Identified), Under the significance level of 0.01.Therefore, these tests confirm that instrumental variables work well.

Table 1: Basic Regression Results

DV：sales	Firm level CCC			Industry level CCC(4-digit)		
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	2SLS	OLS	OLS	2SLS
interest(γ_1)	64.21***	69.35***	104.9***	62.60***	60.52***	115.2***
	(17.63)	(16.75)	(23.71)	(20.10)	(10.15)	(18.92)

interest*CCC(γ_2)		-44.11*	-93.33***		15.00	-118.9***
		(-2.57)	(-14.14)		(0.43)	(-4.25)
Constant(β_0)	474696.1*	465790.0*	-198913.5***	-27179.8	-25967.9	-351203.
	(2.23)	(2.12)	(-3.78)	(.)	(-0.00)	(.)
CCC^{mean}	-	0.23	0.23	-	-	0.19
$g(CCC^{mean})$	-	59.20	80.43	-	-	92.61
CCC^{90th}	-	0.50	0.50	-	-	0.30
$g(CCC^{90th})$	-	47.30	58.23	-	-	79.53
K-P rk LM	-	-	299.798†	-	-	47.701†
K-P rk Wald F	-	-	109.029†	-	-	24.015†
Time Effect	Yes	Yes	Yes	Yes	Yes	Yes
Industry Effect	Yes	Yes	Yes	Yes	Yes	Yes
Regional Effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	146656	146656	146656	365318	365318	365318
R^2	0.6242	0.6280	0.4934	0.5664	0.5665	0.3690

Note: we control the heteroscedasticity, and t-values are reported in (); * p< 0.10, ** p<0.05, *** p <0.01, †p<0.01.

In the result of the benchmark return, there is something different between the performance of Constant term and theoretical prediction. The reasons that the constant term is positive or negative may be two points. The first one is that there are some coefficients with no control of endogeneity. We can be found that at the enterprise level CCC situation, controlling the endogenous variables don’t work very well.

Actually, the judgment of a bank mainly depends on the effect of the industry .In this way, the Robustness of the conclusion is very important at the enterprise level CCC. When it comes to solve the problem of Constant term, we may consider the second reason, that is to say we cannot overlook the effect of guarantee when considering collateral problem.

Guarantee ability of an enterprise often decided by fixed assets. If the guarantee ability cannot be controlled, it will be uncertain to add fixed assets in constant term, and this will make constant term becomes of no significance or stability. We consider controlling the collateral problems and improve the quality of regression.

4.2 The regression result with controlling the collateral variable

It is easy to add collateral to our model. Set the enterprise reimbursement of probability for ρ and then there are $1-\rho$ banks will get the collateral A. After that ,(6) expected revenue of a banks will change from $I(x)$ to [$\rho I(x)+(1-\rho)A$].Then, I_{jt} will conversely become [$\rho I_{jt}+(1-\rho)A_{jt}$] in The regression equation. We can rewrite the equation (17).

$$R_{jt} = \beta_0 + \gamma_1 I_{jt} + \gamma_2 I_{jt} \tau_{jt} + \beta_1 A_{jt} + v_{jt} \quad (18)$$

In this equation, the impact β_1 of payment of interest and income of sales can still be divided into $(\gamma_1+\gamma_2\tau_{jt})$.In the regression equation, what we need to confirm is whether$\gamma_1>0$，$\gamma_2<0$ 和

$\gamma_1+\gamma_2\tau>0$. $\gamma_2<0$ is the Key indicator to confirm CCC's impacts on Corporate credit constraints. The coefficient of the firm's collateral A_{jt} is β_1, but, we do not resolute it further in this paper. The reason is that we cannot find the directly measurements of the collateral. We only rely on the measures of Manova（2012, taking the proportion of tangible assets in total assets of the firm as the proxy variable of collateral. The reason why we do so is that banks tends to accept collateral of tangible assets (of course, the more the fixed assets are, the more tangible assets are).Therefore, a firm with more tangible assets has a stronger ability of collateral. But in the result of the empirical research, we need to confirm whether $\beta_1>0$

Table 2: The Regression Results with Controlling the Collateral Variable

DV：sales	Firm level CCC	Industry level CCC(4-digit)
	2SLS	2SLS
interest(γ_1)	104.6***	116.3***
	(23.74)	(11.36)
interest*CCC(γ_2)	-92.73***	-128.0*
	(-14.15)	(-2.23)
tangasset_ratio（β_1）	183215.4***	157131.9***
	(7.58)	(10.86)
Constant（β_0）	-375899.9***	-623998.3***
	(-6.28)	(-4.53)
CCC^{mean}	0.23	0.19
$g(CCC^{mean})$	83.27	91.98
CCC^{90th}	0.50	0.30
$g(CCC^{90th})$	58.24	77.90
K-P rk LM	297.023†	47.445†
K-P rk Wald F	107.580†	23.886†
Time Effect	Yes	Yes
Industry Effect	Yes	Yes
Regional Effect	Yes	Yes
Observations	146656	365318
R^2	0.4934	0.3690

Note: we control the heteroscedasticity, and t-values are reported in (); * p< 0.10, ** p<0.05, *** p <0.01, †p<0.01.

There is still endogenous problem as (17). In consistent to the analysis above, we need to use *ex-ante* productivity as an instrumental variable to control the endogeneity. At the same time, (18) separate the disturbances from the effect of collateral and after that the positive and negative impact of fixed assets can be separate either. Therefore, what can be prediction in the result (13) is that β_0 should be negative. The regression results of table2 controls the endogeneity. We can find that the result of regression and the result predicted in the model are consistent. Firstly, with

CCC in the enterprise and industry CCC metrics, consistent terms are all negative, and it is very obvious. Secondly, coefficient of Guarantee variable β_1 is positive obviously, corresponding to the prediction. Most important of all is that at the enterprise level CCC situation, Cash cycle will have stronger negative impact on Credit constraints. The last point is consistent with intuition. Banks tend to consider the Cash cycle depending on Industry characteristics. Then, it is more reasonable to use industry CCC metrics and it can also control the endogenous problem of enterprise CCC metrics.

4.3. The regression result after excluding exporting companies:

Feenstra et al. (2013) considered that, compared with the non-exporting companies, the exporting companies require more time to complete the whole process of manufacturing, selling and recovery of funds and they use the fitted-value of the shares of exporting enterprise as the measurement of the difference to demonstrate that the exporting companies facing more pressure and restriction on the credit constraints and capital financing. However, the international transportation time of the exporting enterprise will be taken considered into the CCC, therefore the regression result that mentioned above maybe affected by the factor of exporting companies. To rule out this possibility, we conducted another regression analysis by eliminating all exporting companies and the new regression result will be presented on the table 3.

According to the table three, we can found that the new regression result was perfected matched with theatrical predication. The cross coefficient is significantly negative that reflect the influence of the CCC on the credit constraint. Meanwhile, the partial effect of interest expense is positive which satisfied the required conditions of structural equation and both the guarantee variable and constant coefficient are same as the predicted result of structural equation. Therefore, we can make a general conclusion that the longer the CCC, the stronger the credit constraint, which extended the research of Fenestra et al. (2013).

Table 3: The Regression Results with Excluding Exporters

DV：sales	Firm Level CCC	Industry Level CCC(4-digit)
	2SLS	2SLS
interest(γ_1)	106.6***	108.3***
	(11.04)	(14.22)
interest*CCC(γ_2)	-73.09***	-98.97***
	(-10.13)	(-4.70)
tangasset_ratio（β_1）	124025.4***	102576.7***
	(5.23)	(8.42)
Constant（β_0）	-85087.2***	-215965.6**
	(-3.42)	(-2.91)
CCC^{mean}	0.16	0.17
$g(CCC^{mean})$	94.31	91.97
CCC^{90th}	0.31	0.26

$g(CCC^{90th})$	83.34	82.27
K-P rk LM	233.175†	55.802†
K-P rk Wald F	126.024†	30.295†
Time Effect	Yes	Yes
Industry Effect	Yes	Yes
Regional Effect	Yes	Yes
Observations	89714	258036
R^2	0.2081	0.1736

Note: we control the heteroscedasticity, and t-values are reported in (); * p< 0.10, ** p<0.05, *** p <0.01, †p<0.01.

4.4. The influence of Incomplete Information

The result of empirical analysis, that the longer the CCC, the stronger the credit constraint. However, from the analysis of theatrical model, we can find that the incomplete information is the essential factor which generates the credit constraint during the process of corporate lending.

The influence of incomplete information, during the empirical analysis, requires us to be tracked back to the analysis of (12). In the equation (12), we find that the variable coefficient β_1 not only is affected by τ , but the incomplete information-θ also exert the influence on it, the influence of result is as follows:

$$\tau \uparrow \ \Rightarrow \ \Phi \uparrow \ \Rightarrow \ \beta_1 \downarrow$$

$$imcomplet\_infomation \uparrow \ \Rightarrow \ \theta \downarrow \ \Rightarrow \ \Phi \uparrow \ \Rightarrow \ \beta_1 \downarrow$$

The incomplete information mainly represents the degree of dispersion of company productivity. The more dispersed the company productivity among industry, the stronger the credit constraint that the bank exerted on the lending company, which can be reflected on the Incentive-Compatible requirement in the loan agreement that the bank devised, and the stronger credit constraint will generate a negative effect on the optimal-production scale of lending company, which can be reflected by the lower β_1. In order to capture the influence of τ and the dispersion, we can regard the β_1 as the two-variable function of τ and θ, which can be defined as $\beta_1=g(\tau,\theta)$, and we can make a first-order Taylor Expansion on the τ and $\theta(>2)$, therefore, the influence of τ and θ on β1 can be decomposed. The result is as follows:

$$g(\tau,\theta)=\gamma_1+\gamma_2\tau+\gamma_3(\theta-2)$$

The Taylor expansion is made when $\tau=0$ and $\theta=2$ because the CCC of company is not lower that 0 generally and the requirement of $\theta>2$ must be satisfied to guarantee the existence of variance of productivity distribution among industry. Therefore, the coefficient resulted from the Taylor expansion is as follows:

$$\gamma_1=\frac{2\sigma^2}{(\sigma-1)^2}>0,\quad \gamma_2=-\frac{2i\delta\sigma^2(\sigma+1)}{(\sigma-1)^3}<0,\quad \gamma_3=\frac{\sigma^2}{(\sigma-1)^2}>0$$

The $(\theta\text{-}2)$ represents the degree of incomplete information, which has a negative correlation with the degree of productivity dispersion. Therefore, the sign of γ_3 need to be changed when the degree of productivity dispersion is used into the function, and after taking the influence of collateral variable in consider and rewriting (17), the new regression function can be got as follows:

$$R_{jt} = \beta_0 + \gamma_1 I_{jt} + \gamma_2 I_{jt} \tau_{jt} - \gamma_3 I_{jt} dispersion_t + \beta_1 A_{jt} + v_{jt}$$

However, one point needs to be noticed that the value of TFP2_st.dev of company productivity among industry cannot be used as the value of industry dispersion directly, when we use the company productivity dispersion among industry as the measurement of Industry Incomplete Information. Because when the banks make the loan agreement with companies, they prefer the high productivity company when take the industry average productivity into consideration.

Table 4: The Regression Results with Controlling Incomplete Information

DV：sales	Firm level CCC	Industry level CCC(4-digit)
	2SLS	2SLS
interest(γ_1)	214.3***	245.6***
	(6.89)	(6.59)
interest*CCC(γ_2)	-95.22***	-145.7***
	(-12.70)	(-4.82)
interest*dispersion(-γ_3)	-449.5***	-528.9***
	(-3.93)	(-3.93)
tangasset_ratio（β_1）	170392.3***	126645.1***
	(7.65)	(11.28)
Constant（β_0）	-599749.1***	-526012.3***
	(-6.50)	(-3.63)
CCC^{mean}	0.23	0.19
$dispersion^{mean}$	0.02	0.02
$g(CCC^{mean},dispersion^{mean})$	183.41	207.34
CCC^{90th}	0.50	0.30
$dispersion^{90th}$	0.04	0.04
$g(CCC^{90yh},dispersion^{90yh})$	148.71	180.734
K-P rk LM	50.488†	39.711†
K-P rk Wald F	16.340†	12.992†
Time Effect	Yes	Yes
Industry Effect	Yes	Yes
Regional Effect	Yes	Yes
Observations	146656	365318
R^2	0.5942	0.5080

Note: we control the heteroscedasticity, and t-values are reported in (); * p< 0.10, ** p<0.05, *** p <0.01, †p<0.01.

The influence of the industry average productivity- *TFP2_mean* needs to be controlled when measuring the degree of industry productivity dispersion. Therefore, the COV (coefficient of variation) of industry productivity is used as the value to represent as the degree of productivity dispersion in this paper. The control on the incomplete information mainly reflected on the two-digit code industry level, the industry dispersion and each interest expense of company among industry are the new explanatory variables in the Equation 14. During the regression result, the predicted result is $\gamma_1>0$，$\gamma_2<0$，$-\gamma_3<0$；$g(dispersion)=\gamma_1+\gamma_2\tau+\gamma_3 dispersion>0$；$\beta_0<0$，$\beta_1>0$.

The endogenous problem is controlled during the regression analysis of Equation 14, the specified results, under firm-level CCC and Industry-level CCC conditions, are presented in the table 4. Obviously, the captured result of the influence of the incomplete information on the company's credit constraint during the empirical study is same as the prediction of theoretical model. Meanwhile the influence of the CCC on the company's credit constraint is significant.

4.5 The conclusion of empirical analysis

The equilibrium solution of credit constraint based on the theoretical model can be used to conduct the structure equation that link the company input and the interest output, that is Equation 12. Therefore, the test of the statement, that the longer the CCC, the stronger the credit constraint, can be transferred into the judgement of the coefficient of structural equation. The criterion of the judgement is the cross-coefficient between CCC and interest expenditure must be negative value significantly, and meanwhile the value of the partial effect of the interest expenditure on the sales revenue must be positive constantly. This paper takes the index of Company CCC and Industry CCC into consideration as well as the endogenous problem when the TFP2 is used as the instrumental variable to control the expenditure variable-Interest expense, and the regression result meets the restricted criteria of theoretical prediction and structural equation. In addition, the regression result still significantly demonstrate the conclusion, that the longer the CCC, the stronger the credit constraint, in three conditions- 1) considering the company collateral variable, 2) eliminating the sample of exporting companies and 3) adding the degree of productivity dispersion among industry. Moreover, the correlation between the degree of company productivity dispersion and the credit constraint is analysis and tested, that is the larger of the degree of the productivity, the stronger the credit constraint.

5. Conclusions

Based on the heterogeneous-firm model of Melitz (2003), we develop a "Bank-Firm" model which incorporates incomplete information in the sense that firms' productivities are private information for the bank. By inducing Cash Conversion Cycle (i.e. CCC), we endogenously deduce the optimal credit constraint for firms that are optimal to the bank, and clarify the relationship between CCC and credit constraint: the longer CCC may lead the tighter credit constraint, given others equal. According to the definition and the equilibrium solution of credit constraint, we build a structural equation linking the revenue and interest payment of a firm, as a basic of our empirical analysis. Using Chinese Manufacturing Firms Data, we estimate the *ex-ante* productivities of the firms as the instrument variable, to control the endogenous issue. The regression results strongly support our theoretical predictions.

The research value of our paper may be two points. Firstly, only a few literatures in international trade focus on the issue that the exporters may more easily be affected by the financial crisis due to their long capital recovering time. This paper explores a general linking between the capital recovering time and credit constraint. Secondly, most literatures which focus on the effects of credit constraints for firms, take the credit constraint as exogenous given. This paper endogenously explores the causes and influence factors of credit constraint, especially taking CCC as an example. So, our paper is a supplement to these literatures. In fact, in addition to the characteristics of the financial system outside the firms, quite a few factors that affect credit constraint come from the firms themselves or the industry characteristics. Our theoretical model may a useful analysis tool to continue to explore the credit constraint problem.

References

Amiti Mary, and David Weinstein, 2011, “Exports and Financial Shocks”, Quarterly Journal of Economics, 126(4), 1841-1877.

Buch, Claudia, Iris Kesternich, Alexander Lipponer, and Monkia Schnitzer, 2008, “Real versus Financial Barriers to Multinational Activity”, mimeo, University of Tuebingen.

Berman Nicolas, José De Sousa, Philippe Martin, and Thierry Mayer, 2012, “Time to Ship during Financial Crises”, NBER working paper, No.18274.

Chaney, Thomas, 2005, “Liquidity Constraint Exporters”, mimeo, University of Chicago.

Cai Hongbin, Qiao Liu, 2009, “Competition and Corporate Tax Avoidance: Evidence from Chinese Industrial Firms”, Economic Journal, 119, pp. 764-795.

Feenstra Robert, Zhiyuan Li, and Miaojie Yu, 2013, “Exports and Credit Constraints Under Private Information: Theory and Application to China”, Reviews of Economics and Statistics, forthcoming.

Frank Kleibergen, and Richard Paap, 2006, “Generalized Reduced Rank Tests using the Singular Value Decomposition”, Journal of Econometrics, 133(1), 97-126.

Laffont J. J., and D. Martimort, 2002, “The Theory of Incentives: The Principal-Agent Model”, Chapters 1-3, Princeton and Oxford: Princeton University Press.

Manova Kalian, 2008, ”Credit Constraint, Heterogeneous Firms and International Trade”,NBER working Paper, No:14531.

Melitz Marc, 2003, “The Impact of Trade on Intra-industry Reallocations and Aggregate Industry productivity”, Econometrica, 71(6), 1695-1725.

Muûls Mirabelle, 2015, “Exporters, importers and credit constraints” Journal of International Economics, (95), pp. 333-343.

Olley Steven, and Ariel Pakes, 1996, “The Dynamic of Productivity in the Telecommunications Equipment Industry”, Eonometrica 64(6), 1263-1297.

Zhiyuan Li, and Miaojie Yu, 2013, “Exports，Productivity and Credit Constraints: A Firm-Level Empirical Investigation of China”, Economic Research Journal (in Chinese), (6), 85-99.

Appendix:

A.1 Solve the firm's decision problem

$$\max_{x^{'},q} \pi(x,x^{'}) = pq-(1-\delta)\left(\frac{qw}{x}+C\right)-\left(M(x^{'})+I(x^{'})\right)$$
$$s.t.\quad \pi(x,x)\geq \pi(x,x^{'})$$
$$\pi(x,x)\geq 0$$
$$M(x^{'})\geq \delta\left(\frac{qw}{x}+C\right)$$

Since, the third constraint must be strictly equal at the equilibrium, then

$$\left(\frac{qw}{x}+C\right)=\frac{M(x^{'})}{\delta}\Rightarrow q=\left(\frac{M(x^{'})}{\delta}-C\right)\frac{x}{w} \quad \text{(A1)}$$

Thus, the object function for the firm can be:

$$\pi(x,x^{'}) = pq-(1-\delta)\frac{M(x^{'})}{\delta}-\left(M(x^{'})+I(x^{'})\right)$$

Combing with the first constraint, get that :

$$\frac{\partial \pi(x,x^{'})}{\partial x^{'}}|_{x^{'}=x}=0$$
$$\Rightarrow\left[p\frac{\partial q}{\partial x^{'}}+q\frac{\partial p}{\partial q}\frac{\partial q}{\partial x^{'}}-(1-\delta)\frac{M^{'}(x^{'})}{\delta}-\left(M^{'}(x^{'})+I^{'}(x^{'})\right)\right]|_{x^{'}=x}=0$$
$$\Rightarrow\left[\frac{p\frac{\sigma-1}{\sigma}}{\frac{w}{x}}-1\right]\frac{M^{'}(x)}{\delta}=I^{'}(x) \quad \text{(A2)}$$

Where, p and q satisfy the form in the paper. Combing with (A1), get:

$$\frac{\partial q}{\partial x^{'}}=\frac{M^{'}(x^{'})}{\delta}\frac{x}{w}$$
$$\frac{\partial p}{\partial q}=P^{\frac{\sigma-1}{\sigma}}Y^{\frac{1}{\sigma}}(-\frac{1}{\sigma})q^{-\frac{1-\sigma}{\sigma}}=(-\frac{1}{\sigma})\frac{p}{q}$$

Define:

$$\Phi(x,M(x))\equiv\frac{p\frac{\sigma-1}{\sigma}}{\frac{w}{x}}=\frac{\sigma-1}{\sigma}\left(\frac{M(x)}{\delta}-C\right)^{-\frac{1}{\sigma}}\left(\frac{xP}{w}\right)^{\frac{\sigma-1}{\sigma}}Y^{\frac{1}{\sigma}} \quad \text{(A3)}$$

Then, (A2) can be reduced as:

$$\left[\Phi(x,M(x))-1\right]\frac{M^{'}(x)}{\delta}=I^{'}(x) \quad \text{(A4)}$$

A.2 Solve the bank's problem

$$\max_{M,I} \int_{\underline{x}}^{\infty} \left(I(x) - i\tau M(x) \right) f(x) dx$$

$$s.t. \;\; \left[\Phi(x, M(x)) - 1 \right] \frac{M^{'}(x)}{\delta} = I^{'}(x), \quad if \quad x \in [\underline{x}, \infty)$$

Construct a Hamilton function as:

$$\ell = \left(I(x) - i\tau M(x) \right) f(x) + \lambda(x) \left(\left[\Phi(x, M(x)) - 1 \right] \frac{M^{'}(x)}{\delta} - I^{'}(x) \right)$$

Then, the first-order conditions for the optimal M(x) and I(x) are:

$$\frac{\partial \ell}{\partial I} - \frac{d}{dx}\frac{\partial \ell}{\partial I^{'}} = 0, \qquad \frac{\partial \ell}{\partial M} - \frac{d}{dx}\frac{\partial \ell}{\partial M^{'}} = 0 \tag{A5}$$

So that,

$$\frac{\partial \ell}{\partial I} = f(x)$$

$$\frac{\partial \ell}{\partial I^{'}} = \lambda(x) \Rightarrow \frac{d}{dx}\frac{\partial \ell}{\partial I^{'}} = \lambda^{'}(x)$$

$$\frac{\partial \ell}{\partial M} = -i\tau f(x) + \lambda(x) \frac{\partial \Phi}{\partial M} \frac{M^{'}(x)}{\delta}$$

$$\frac{\partial \ell}{\partial M^{'}} = \frac{\lambda(x)}{\delta} \left[\Phi(x, M(x)) - 1 \right] \Rightarrow \frac{d}{dx}\frac{\partial \ell}{\partial M^{'}} = \frac{\lambda^{'}(x)}{\delta}(\Phi - 1) + \frac{\lambda(x)}{\delta}\frac{d\Phi}{dx}$$

$$\frac{d\Phi}{dx} = \frac{\partial \Phi}{\partial x} + \frac{\partial \Phi}{\partial M} M^{'}(x)$$

Substitute into (A5), get：

$$f(x) + \lambda^{'}(x) = 0$$

$$i\tau f(x) + (\Phi - 1)\frac{\lambda^{'}(x)}{\delta} + \frac{\lambda(x)}{\delta}\frac{\sigma - 1}{\sigma}\frac{\Phi}{x} = 0 \tag{A6}$$

Considering the transversality condition, $\lambda(\infty) = 0$, get:

$$\int_{x}^{\infty} \lambda(t) dt = -\int_{x}^{\infty} f(t) dt \Rightarrow \lambda(\infty) - \lambda(x) = -\left(1 - F(x)\right)$$

$$\Rightarrow \lambda(x) = 1 - F(x) \tag{A7}$$

Combing with (A6), get:

$$\Phi = (1 + i\tau\delta) \left[1 - \frac{\sigma - 1}{\sigma} \frac{1 - F(x)}{xf(x)} \right]^{-1} \tag{A8}$$

Suppose x satisfying Pareto Distribution as:

$$F(x) = 1 - \left(\frac{1}{x}\right)^{\theta}, \quad x > 1$$

Then,

$$\Phi = (1 + i\tau\delta)\left(1 - \frac{\sigma - 1}{\sigma\theta}\right)^{-1} \quad \text{(A9)}$$

And, (A3) induces the relation between optimal M(x) and productivity x, (A4) induces the relation between optimal M(x) and I(x):

$$\frac{M(x)}{\delta} = \left(\frac{\sigma - 1}{\sigma}\left(\frac{xp}{w}\right)^{\frac{\sigma-1}{\sigma}} Y^{\frac{1}{\sigma}}\right)^{\sigma} \Phi^{-\sigma} + C \quad \text{(A10)}$$

$$\int_{\underline{x}}^{x} (\Phi - 1)\frac{M^{'}(t)}{\delta} dt = \int_{\underline{x}}^{x} I^{'}(t) dt$$

$$\Rightarrow I(x) = I(\underline{x}) + (\Phi - 1)\frac{M(x) - M(\underline{x})}{\delta} \quad \text{(A11)}$$

Until now, the lower bar, $\underline{x}$, in (A10) and (A11) is unknown. Use the condition, $\pi(\underline{x}, \underline{x}) = 0$, to solve it.

$$I(\underline{x}) = \left(\frac{\sigma}{\sigma - 1}\Phi - 1\right)\frac{M(\underline{x})}{\delta} - \frac{\sigma}{\sigma - 1}\Phi C \quad \text{(A12)}$$

Put (A11)back into the bank's problem:

$$\max_{\underline{x}} \int_{\underline{x}}^{\infty} \left(I(\underline{x}) + (\Phi - 1)\frac{M(x) - M(\underline{x})}{\delta} - i\tau M(x)\right) f(x) dx$$

And get the first-order condition:

$$\left(\frac{dI(\underline{x})}{d\underline{x}} - (\Phi - 1)\frac{dM(\underline{x})}{d\underline{x}}\frac{1}{\delta}\right)\int_{\underline{x}}^{\infty} f(x) dx = \left(I(\underline{x}) - i\tau M(\underline{x})\right) f(\underline{x}) \quad \text{(A13)}$$

(A12) and (A9) lead that:

$$\left(\frac{dI(\underline{x})}{d\underline{x}} - (\Phi - 1)\frac{dM(\underline{x})}{d\underline{x}}\frac{1}{\delta}\right) = \frac{1}{\sigma - 1}\Phi\frac{dM(\underline{x})}{d\underline{x}}\frac{1}{\delta}$$

$$\frac{dM(\underline{x})}{d\underline{x}}\frac{1}{\delta} = \frac{\sigma - 1}{\underline{x}}\left(\frac{M(\underline{x})}{\delta} - C\right)$$

Put them back into (A13):

$$\frac{M(\underline{x})}{\delta} = \sigma C \quad \text{(A14)}$$

Put (A14) back into (A9):

$$\underline{x} = w\left(\frac{\sigma}{\sigma - 1}\left(\frac{(\sigma - 1)C}{YP^{\sigma-1}}\right)^{\frac{1}{\sigma}}\Phi\right)^{\frac{\sigma}{\sigma-1}} \quad \text{(A15)}$$

Put (A14) into (A12):

$$I(\underline{x}) = (\Phi - 1)\sigma C = (\Phi - 1)\frac{M(\underline{x})}{\delta} \quad \text{(A16)}$$

Put (A16) into (A11), and get:

$$I(x) = (\Phi - 1)\frac{M(x)}{\delta}, \quad \forall x \in [\underline{x}, \infty) \quad \text{(A17)}$$

So, the lower bar of productivity satisfies (A15), the optima loan schedules satisfy (A10) and (A17).

A.3 The estimation of production function for each industry using Olley-Pakes approach:

行业代码	γ_l	γ_k	TFP1		TFP2	
			mean	st.dev	mean	st.dev
13	0.4495	0.3767	3.7583	0.2737	3.7583	0.0511
14	0.4614	0.4187	3.1144	0.3169	3.1144	0.0900
15	0.4881	0.4595	2.7373	0.3617	2.7373	0.1197
17	0.4674	0.3435	3.5626	0.2264	3.5626	0.0498
18	0.5282	0.2615	3.9198	0.2026	3.9198	0.0481
19	0.4486	0.3857	3.5613	0.2405	3.5613	0.0697
20	0.4089	0.4615	3.2347	0.2672	3.2347	0.0813
21	0.5796	0.2507	3.8773	0.2157	3.8773	0.0578
22	0.5101	0.4568	2.4320	0.3574	2.4320	0.1057
23	0.4681	0.3131	3.8215	0.2196	3.8215	0.0661
24	0.4894	0.3461	3.3838	0.2359	3.3838	0.0658
25	0.3324	0.2534	5.3211	0.2162	5.3211	0.1039
26	0.3754	0.4556	3.2880	0.2832	3.2880	0.0675
27	0.5135	0.4782	2.2719	0.4445	2.2719	0.1413
28	0.4278	0.1973	5.1386	0.1911	5.1386	0.0967
29	0.4292	0.3408	3.8941	0.2175	3.8941	0.0636
30	0.4338	0.3685	3.5414	0.2400	3.5414	0.0545
31	0.3503	0.4699	3.1100	0.2945	3.1100	0.0896
32	0.4944	0.4179	3.3853	0.2936	3.3853	0.0707
33	0.3998	0.3655	4.2028	0.2585	4.2028	0.0507
34	0.4302	0.3677	3.6802	0.2349	3.6802	0.0589
35	0.4769	0.3711	3.4344	0.2396	3.4344	0.0572
36	0.4781	0.4552	2.7528	0.3293	2.7528	0.1069
37	0.5201	0.3209	3.7147	0.2310	3.7147	0.0653
39	0.4782	0.3421	3.6944	0.2495	3.6944	0.0742
40	0.4991	0.2663	4.4783	0.2175	4.4783	0.0734
41	0.4431	0.3177	4.2573	0.2162	4.2573	0.0717

42	0.4587	0.2737	4.1104	0.2028	4.1104	0.0524