Exports and Credit Constraints under Incomplete Information: Theory and Evidence from China*

Robert C. Feenstra† Zhiyuan Li‡ Miaojie Yu§

Forthcoming in *Review of Economics and Statistics*

April 8, 2013

Abstract

This paper examines why credit constraints for domestic and exporting firms arise in a setting where banks do not observe firms' productivities. To maintain incentive-compatibility, banks lend below the amount that firms' would need for optimal production. The longer time needed for export shipments induces a tighter credit constraint on exporters than on purely domestic firms, even in the exporters' home market. In our application to Chinese firms, we find that the credit constraint is more stringent as a firm's export share grows, as the time to ship for exports is lengthened, and as there is greater dispersion of firms' productivities reflecting more incomplete information.

JEL: F1, F3, D9, G2

Keywords: Export, credit constraint, incomplete information, heterogeneous productivity, Chinese firms

*We thank Kyle Bagwell, Kalina Monova, Larry Qiu, David Weinstein, and seminar participants at the NBER, Harvard, Tsinghua University, the University of Queensland, University of Victoria, and University of California, Irvine and San Diego for their helpful comments and suggestions.

†Department of Economics, University of California-Davis and NBER. Email: rcfeenstra@ucdavis.edu

‡School of Economics, Shanghai University of Finance and Economics, Shanghai, China, 200433, and Key Laboratory of Mathematical Economics (SUFE), Ministry of Education, Shanghai, China, 200433. Tel: +86-21-65903123, Email: zhyli@mail.shufe.edu.cn.

§China Center for Economic Research (CCER), National School of Development, Peking University, Beijing, China. Email: mjyu@ccer.pku.edu.cn.

1 Introduction

The financial crisis of 2008 has led researchers to ask whether credit constraints faced by exporters played a significant role in the fall in world trade. There are a wide range of answers: Amiti and Weinstein (2011) argue that trade finance was important in the earlier Japanese financial crisis of the 1990s and for the United States recently, and Chor and Manova (2012) find that financially vulnerable sectors in source countries did indeed experience a sharper drop in monthly export to the United States. In contrast, Levchenko, Lewis and Tesar (2010) find no evidence that trade credit played a role in restricting imports or exports for the United States, while for Belgium, Behrens, Corcos and Mion (2010) argue that to the extent that financial variables impacted exports, they also impacted domestic sales to the same extent. Of course, the potential causal link between financial development and international trade at country level was recognized long before the recent crisis. For example, Kletzer and Bardhan (1987; see also Beck, 2002, Matsuyama, 2005) argued that credit-market imperfections would adversely affect exporters needing more finance and hence influence trade patterns. That theme was modeled by Chaney (2005) in a Melitz (2003) framework, and implemented by Manova (2012), who argues that credit constraints have systematically different effects depending on the financial vulnerability of the exporter's sector and financial development of their country.[1]

In view of the divergent findings on the role of credit constraints during the crisis, we believe that it is useful to go back to the theory and ask why credit for exports should be allocated any differently than credit for domestic sales. Amiti and Weinstein (2011) argue forcefully for two reasons: there is a longer time-lag between production and the receipt of sales revenue; and exporters also face inherently more risk, since it is more difficult to enforce payment across country boundaries. They define "trade finance" (as distinct from "trade credit") to be the financial contracts that arise to offset these risks for exporters. We will pick up on the first of these reasons, the longer "time to ship" for exports, which is also discussed in relation to the financial crisis by Berman *et al* (2012).[2] The goal of this paper is to build time to ship into a model of heterogeneous firms obtaining working-capital loans from a bank, to see whether exports are indeed treated differently from domestic sales

[1] Other papers dealing with trade and finance include Qiu (1999), Greenaway, Guariglia and Kneller (2007), Harrison and McMillan (2003), Muûls (2008), Buch, *et al* (2008), Héricourt and Poncet (2009), Poncet, Steingress and Vandenbussche (2009), and Egger and Keuschnigg (2011).

[2] In our working paper (Feenstra, Li and Yu, 2011), we also included the risk faced by exporters in international markets. But because that risk was taken as exogenous (in contrast to Ahn (2011), for example), it had little impact on the theory and could not be tested with our Chinese firm-level data, so that extension is omitted here. Berman *et al* (2012) also take the risk of default as exogenous but model it as depending on the time to ship, so that it plays an important role in their model and estimation.

in theory. We test the predictions of the model using firm-level data for China.

The key feature of our model is that the bank has incomplete knowledge of firms, in two respects. First, the bank cannot observe the productivity of firms. We believe this assumption is realistic in rapidly growing economies such as China with rapid entry, and perhaps more generally. The bank will confront firms with a schedule specifying the amount of the loan and the interest payments to maximize its own profits. From the revelation principle, without loss of generality we can restrict attention to schedules that induce firms to truthfully reveal their productivity. Second, the bank cannot verify whether the loan is used to cover the costs of production for domestic sales or for exports. This second assumption means that we are not really modeling the loans from the bank as "trade finance": such loans would typically specify the names of the buying and selling party, at least, so the bank could presumably verify whether the loan was for exports or not.[3] Rather, the loans being made by the bank are for "working capital", to cover the costs of current production, regardless of where the output is sold. The assumption that banks cannot follow a loan once the money enters the firm is made in a different context by Bolton and Scharfstein (1990), for example.

With these assumptions, in section 2 we derive the incentive-compatible loan schedule by the bank that maximizes its own profits. Sales revenue of firms is less than would occur at their optimal production, i.e. the incentive-compatible loans impose credit constraints on firms. The reason for these credit constraints is that a firm suffers only a second-order loss in profits from producing slightly less than the production with complete information and borrowing less from the bank, but obtains a first-order gain from reducing its interest payments in this way. So a firm that is not credit constrained will never reveal its true productivity and borrow enough to produce at the level with complete information; hence, incentive-compatibility requires that the firm is credit constrained. Furthermore, because banks cannot follow a loan once it enters the firm, the credit constraint applies to the exports and domestic sales of a firm engaged in both these activities – which we refer to as an exporting firm. Because exports take longer in shipment, such exporting firms face a tighter credit constraint on both markets than purely domestic firms

So our answer to the question "is credit for exports and domestic sales treated differently?" is nuanced: when these activities occur in the same firm, the bank treats them equally; but when these activities occur in an exporting firm and a purely domestic firm respectively, they are indeed treated differently. The tighter credit constraint on exporting firms comes from the longer time-lag between production and receipt of sales revenue, and reduces exports on both the intensive and extensive margins. These theoretical results are tested using a rich panel data set of Chinese

[3] Ahn (2011) provides an information-based model of trade finance.

manufacturing firms over the period of 2000-2008, in sections 3 and 4. This application is of special interest because China's exports experienced unprecedented growth over the past decades, while it is believed that Chinese firms faced severe credit constraints: according to the Investment Climate Assessment surveys in 2002, China was among the group of countries that had the worst financing obstacles (Claessens and Tzioumis, 2006).

We estimate a structural equation under which sales revenue depends on interest payments, the export share and other variables. We obtain robust empirical evidence that exporting firms face more severe credit constraints than purely domestic firms. The credit constraint is more stringent as a firm's export share grows, as the time to ship for exports is lengthened, and as there is greater dispersion of firms' productivities reflecting information incompleteness. These results go beyond Manova (2012), who focuses on the financial vulnerability of sectoral exports, by showing how production characteristics of the firm (i.e. it's export share and mode of transport) and industry (i.e. information incompleteness) influence the credit constraint. But as in Manova (2012), we find that higher collateral can offset the credit constraint and expand exports. Conclusions and directions for further research are discussed in section 5, and an online Appendix includes additional theoretical and empirical results.[4]

2 Incentive-Compatible Loans

2.1 The Model

We suppose there are two countries, home and foreign (henceforth foreign counterparts of the variables are denoted with an asterisk $*$). Labor is the only factor for production and the population is of size L at home. There are two sectors, where the first produces a single homogeneous good that is freely traded and chosen as numeraire. Both countries produce in this sector with constant return to scale technology and thus home wage (w) is fixed by productivity in this sector. The second sector produces a continuum of differentiated goods under monopolistic competition, as in Melitz (2003).

2.1.1 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

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

[4] The Appendix is available at http://www.econ.ucdavis.edu/faculty/fzfeens/papers.html.

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

$$q(\omega) = \frac{Y}{P}\left(\frac{p(\omega)}{P}\right)^{-\sigma}, \tag{1}$$

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

2.1.2 Firms and the Bank

Firms in the differentiated sector need to borrow working capital to finance a fraction δ 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 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. With the resulting loans, firms choose markets to serve and produce. Revenues are then realized and the bank collects payments.

Notice that the loan and interest payment schedules are worked out initially by the bank, and then firms self-select into the export market and choose the quantity to produce accordingly. Thus, the bank cannot take into account firm's export status and production as extra information when it chooses the loan and interest payment schedule. But under the incentive compatible loan contract, the bank can perfectly predict whether a firm will be an exporter or not.

The bank faces an opportunity cost of i – the interest rate – on its loans. We assume that the loans for domestic (export) projects are paid back after τ_d (τ_e) periods, and further assume that $\tau_e > \tau_d$, reflecting the longer time-lags involving in the shipping of exports.

2.2 Domestic Firms' Decision

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 $M_d(x')$ and interest payments $I_d(x')$ 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 domestic firm's profit maximization problem is:

$$\max_{x',q_d} \pi_d(x,x') = p_d q_d - (1-\delta)\left(\frac{q_d w}{x} + C_d\right) - \left(M_d(x') + I_d(x')\right), \tag{2}$$

$$\text{s.t. } \pi_d(x,x) \geq \pi_d(x,x'),$$

$$\pi_d(x,x) \geq 0,$$

$$M_d(x') \geq \delta\left(\frac{q_d w}{x} + C_d\right),$$

and also subject to the domestic demand function in (1), where C_d is the fixed cost.[5] The first constraint is the incentive compatibility constraint, the second ensures that profits are non-negative, and the third specifies that the amount of the loan must cover the fraction δ of fixed and variable costs at the chosen production level q_d.

Using the fact that the third constraint above will be binding in equilibrium, we take the derivative of the profit respect to announced productivity, x', to obtain the first-order condition:

$$\left[\Phi_d\left(x, M_d(x)\right) - 1\right] \frac{M_d'(x)}{\delta} = I_d'(x), \tag{3}$$

where

$$\begin{aligned} \Phi_d\left(x, M_d(x)\right) &\equiv \left[p_d\left(\frac{\sigma-1}{\sigma}\right)\right] / \frac{w}{x}, \\ &= \left(\frac{\sigma-1}{\sigma}\right)\left(\frac{M_d(x)}{\delta} - C_d\right)^{-\frac{1}{\sigma}}\left(\frac{xP}{w}\right)^{\frac{\sigma-1}{\sigma}} Y^{\frac{1}{\sigma}}. \end{aligned} \tag{4}$$

The value of Φ_d in the first line of (4) is recognized as the ratio of marginal revenue to marginal costs. A firm without any need to borrow will produce where $\Phi_d = 1$, while a firm that produces less due to insufficient loans will have $\Phi_d > 1$. This means that Φ_d is a measure of the firm's credit constraint, and the larger is Φ_d then the lower is the quantity produced due to this constraint. The second line of (4) is obtained by using the binding quantity level in the third constraint and its corresponding price from demand in (1). It is apparent that having lower loans $M_d(x)$ will raise Φ_d, 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 us suppose that the bank lends more to higher productivity firms, and also collects more in interest payments.[6] Then in (3), both $M_d'(x)$ and $I_d'(x)$ are positive. It follows that the expression in brackets on the left must be positive, so it follows that the firm must be credit constrained, i.e. $\Phi_d > 1$. The reason this condition is needed is that, if the bank specifies loan and interest schedules

[5] Notice here we assume away risks. Including risks and collateral in the problem would not affect our main results, as shown in a more comprehensive version of the model in Feenstra, Li and Yu (2011).

[6] We show in the Appendix that these monotonicity conditions hold in the optimal schedules for the bank.

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 $I_d'(x) > 0$. 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 Exporters' Decision

We assume that the monopolistic bank cannot enforce different contracts to separate loans for domestic market and export market. Rather, exporters are free to determine how to allocate the loan to both markets. An exporter thus chooses quantities to produce at domestic market and export market and claims a productivity x' to maximize its profit:

$$\begin{aligned} \max_{x', q_d, q_e} \pi_e(x, x') = p_d q_d + p_e q_e - (1-\delta)\left(\frac{q_d w}{x} + C_d + \frac{q_e w}{x} + C_e\right) \\ - \left(M_e(x') + I_e(x')\right), \\ \text{s.t. } \pi_e(x, x) \geq \pi_e(x, x') \\ \pi_e(x, x) \geq \pi_d(x, x) \\ M_e(x') \geq \delta\left(\frac{q_d w}{x} + C_d + \frac{q_e w}{x} + C_e\right), \end{aligned} \tag{5}$$

and subject to export demand, $q_e = \frac{Y^*}{P^*}\left(\frac{p_e}{P^*}\right)^{-\sigma}$, where Y^* is the foreign total expenditure on the differentiated good.[7] The total loan received by the exporter is denoted by M_e and total interest payments are I_e, while C_e is the fixed cost of exporting.

The first two constraints above are analogous to those for the domestic firm, but the third constraint is different and important. It states that the total amount of the loan given to the exporter must cover the working-capital needs of both domestic and export production costs. From the exporting firm's perspective, these funds are fully fungible so the bank is making a single loan and likewise receiving a single interest payment.

Solving the problem for the choice of q_d and q_e, it is readily shown that the firm will maximize its profit by choosing quantities in the two markets such that:

$$p_d\left(\frac{\sigma-1}{\sigma}\right) = p_e\left(\frac{\sigma-1}{\sigma}\right). \tag{6}$$

[7] We do not make explicit the transportation costs to the export market for expositional convenience, but that iceberg cost can readily be incorporated into the definition of the "effective" foreign expenditure on the differentiated good Y^*. That is, including iceberg transport costs $\tau > 1$ then export demand is $q_e = (\tilde{Y}^*/P^*)(\tau p_e/P^*)^{-\sigma}$, which equals that shown in the export demand by defining $Y^* = \tilde{Y}^* \tau^{-\sigma}$.

This condition states that the loan will be allocated within the firm so that marginal revenue in the domestic and export markets are equalized. It means that for any given loan, the bank will know exactly how production is allocated between the two markets. Thus for notational convenience, we break up the total loan $M_e(x')$ into the component intended to cover domestic costs $M_e^d(x')$, and the component intended to cover export costs $M_e^e(x')$. That is, we will define the loans allocated to each market as,

$$
\begin{aligned}
M_e^d(x') &\equiv \delta\left(\frac{q_d w}{x} + C_d\right) \\
M_e^e(x') &\equiv \delta\left(\frac{q_e w}{x} + C_e\right).
\end{aligned} \tag{7}
$$

Using domestic and export demand, combined with the requirement from (6) that the prices p_d and p_e are equalized, it immediately follows that the loans to the two markets are related by:

$$
\frac{M_e^e(x)/\delta - C_e}{M_e^d(x)/\delta - C_d} = \frac{\eta_e}{\eta_d}, \tag{8}
$$

where we define the shares of demand coming from the domestic and foreign markets as:

$$
\eta_d = \frac{YP^{\sigma-1}}{YP^{\sigma-1} + Y^* P^{*\sigma-1}} \text{ and } \eta_e = \frac{Y^* P^{*\sigma-1}}{YP^{\sigma-1} + Y^* P^{*\sigma-1}}. \tag{9}
$$

Using the optimal quantity sold in each market from (7) and its associated price, we can rewrite the firms' profits as a function of productivity, x, and the amount borrowed for domestic market, $M_e^d(x')$. Similar to the problem for domestic firms, by taking derivative of profits respect to x', we obtain the first-order condition for incentive compatibility:

$$
\left[\Phi_e^d\left(x, M_e^d(x)\right) - 1\right]\frac{M_e^{d\prime}(x)}{\delta} + \left[\Phi_e^e\left(x, M_e^e(x)\right) - 1\right]\frac{M_e^{e\prime}(x)}{\delta} = I_e'(x), \tag{10}
$$

where,

$$
\begin{aligned}
\Phi_e^d\left(x, M_e^d(x)\right) &\equiv \left[p_d\left(\frac{\sigma-1}{\sigma}\right)\right]/\frac{w}{x} \\
&= \left(\frac{\sigma-1}{\sigma}\right)\left(\frac{M_e^d(x)}{\delta} - C_d\right)^{-\frac{1}{\sigma}}\left(\frac{xP}{w}\right)^{\frac{\sigma-1}{\sigma}} Y^{\frac{1}{\sigma}}, \\
\Phi_e^e\left(x, M_e^e(x)\right) &\equiv \left[p_e\left(\frac{\sigma-1}{\sigma}\right)\right]/\frac{w}{x} \\
&= \left(\frac{\sigma-1}{\sigma}\right)\left(\frac{M_e^e(x)}{\delta} - C_e\right)^{-\frac{1}{\sigma}}\left(\frac{xP^*}{w}\right)^{\frac{\sigma-1}{\sigma}} Y^{*\frac{1}{\sigma}},
\end{aligned} \tag{11}
$$

and from the equality of marginal revenues in (6) we have that,

$$
\Phi_e^d\left(x, M_e^d(x)\right) = \Phi_e^e\left(x, M_e^e(x)\right). \tag{12}
$$

The interpretation of these conditions is analogous to what we obtained for domestic firms. The values Φ_e^d and Φ_e^e are the ratio of marginal revenue to marginal costs in the two markets served by the exporter. Credit constraints would mean that $\Phi_e^e = \Phi_e^d > 1$, so the firm would be selling less in both markets than would be optimal in the absence of any constraints. We now determine the magnitude of credit constraints that are optimal for the bank.

2.4 Bank's Decision

The monopolistic bank chooses the loans given to domestic firms subject to the incentive-compatibility condition (3), and chooses the loans given to exporters for the domestic market ($M_e^d(x)$) and for export market ($M_e^e(x)$), subject to the incentive-compatibility conditions (10) and the equality of marginal revenue (12). The bank's problem is then to choose $M_d(x), M_e^d(x), M_e^e(x), I_d(x)$ and $I_e(x)$ to maximize its profits:

$$\max_{M,I} \int_{\underline{x}_d}^{\underline{x}_e} (I_d(x) - i\tau_d M_d(x)) f(x)\, dx + \int_{\underline{x}_e}^{\infty} \Big(I_e(x) - i\tau_d M_e^d(x) - i\tau_e M_e^e(x) \Big) f(x)\, dx \tag{13}$$
$$s.t.\ (3) \text{ if } x \in [\underline{x}_d, \underline{x}_e), \text{ and } (10) \text{ and } (12) \text{ if } x \in [\underline{x}_e, \infty),$$

where $f(x)$ is the probability density function of firms' productivity distribution. The variables $\underline{x}_d$ and $\underline{x}_e$ are the productivities of the cutoff domestic firm and the cutoff exporter respectively.

As in the Melitz (2003) model, firms will enter into domestic production and export based on the profitability of these activities. This means that the cutoff domestic firm with productivity $\underline{x}_d$ is defined by the zero-cutoff-profit condition $\pi_d(\underline{x}_d,\underline{x}_d) = 0$, and the cutoff exporter with productivity $\underline{x}_e$ by the condition $\pi_d(\underline{x}_e,\underline{x}_e) = \pi_e(\underline{x}_e,\underline{x}_e)$. These cutoff productivities can differ from in the Melitz (2003) model, of course, because here they are influenced by the credit conditions offered by the bank.

The maximization problem (13) is solved in two steps. First, we determine 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 domestic and exporting firms: these initial interest payments will in fact determine the productivity levels $\underline{x}_d$ and $\underline{x}_e$ for these firms. So the second step in the optimization problem for the bank is to determine the optimal initial interest payments for these cutoff firms, or equivalently, solving for the optimal cutoff productivities and consequently obtain the implied initial interest payments.

To simplify the solution, we consider a Pareto distribution for firms productivity, $F(x) = 1 - (1/x)^{\theta}, x \geq 1$, where θ is the shape parameter.[8] It is shown in the Appendix that the optimal

[8] We assume $\theta > 1$ as is needed for the mean of the Pareto distribution to be finite.

loan schedules for the bank are such that:

$$\Phi_d\left(x, M_d(x)\right) = \overline{\Phi}_d \equiv \left(1 + i\delta\tau_d\right)\left(1 - \frac{\sigma - 1}{\sigma\theta}\right)^{-1}, \tag{14}$$

$$\Phi_e^d\left(x, M_e^d(x)\right) = \Phi_e^e\left(x, M_e^e(x)\right) = \overline{\Phi}_e \equiv \left[1 + i\delta\left(\tau_d\eta_d + \tau_e\eta_e\right)\right]\left(1 - \frac{\sigma - 1}{\sigma\theta}\right)^{-1}.$$

Examining the features of these solutions, we see that credit constraints for domestic firms and exporters apply, meaning that $\overline{\Phi}_d > 1$ and $\overline{\Phi}_e > 1$, even if $i = 0$ in (14). Thus, even when the banks has no opportunity cost of making loans, a credit constraint is still needed to ensure incentive compatibility. When $i > 0$ then the credit constraint is further increased, and it is intuitive that the bank will restrict credit more as its opportunity cost rises. The opportunity cost is measured relative to the time required for the domestic and foreign loans, or τ_d and τ_e, respectively. We have assumed that $\tau_e > \tau_d$, from which it follows that the credit constraint $\overline{\Phi}_e$ for exporters in *either* their domestic or export markets exceeds $\overline{\Phi}_d$ for domestic firms in (14), when $i > 0$. The extra constraint faced by exporters will be the key testable implication in our empirical application.

While the solution for the credit constraints imply the slope for the interest payment schedules, from (3) and (10), we still need to determine the initial interest payments. Considering first domestic firms, by taking the first derivative of (13) with respect to $\underline{x}_d$, we can obtain,

$$I_d(\underline{x}_d) = \left(\overline{\Phi}_d - 1\right)\frac{M_d(\underline{x}_d)}{\delta}.$$

Consequently, from (3) and (14), the interest payment for domestic firms is:

$$I_d(x) = \left(\overline{\Phi}_d - 1\right)\frac{M_d(x)}{\delta}. \tag{15}$$

It is shown in the Appendix that the lowest productivity domestic firm, $\underline{x}_d$, is *above* the cutoff productivity in Melitz (2003).

Similarly, taking the first derivative of (13) with respect to $\underline{x}_e$, we obtain the solution for the initial interest payment for the cutoff exporter:

$$I_e(\underline{x}_e) = \left(\overline{\Phi}_e - 1\right)\frac{M_e(\underline{x}_e)}{\delta} + i\Theta, \tag{16}$$

where the final parameter in the above equation is:

$$\Theta \equiv \frac{\delta\left(\tau_e - \tau_d\right)}{\left(1 - \frac{\sigma - 1}{\sigma\theta}\right)}\left(\eta_d C_e - \eta_e C_d\right).$$

Consequently, the interest payment schedule for exporters is:

$$I_e(x) = \left(\overline{\Phi}_e - 1\right)\frac{M_e(x)}{\delta} + i\Theta.$$

It is also shown in the Appendix that the lowest productivity exporting firm, $\underline{x}_e$, is above the cutoff productivity for exporters in the Melitz model.

3 Estimating Equation and Data

3.1 Empirical Specification

We can use our results above to derive an 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 implied by our model is linear, as we show below, where the coefficient on interest payments depends on the credit constraints faced by domestic firms and exporters. But the credit constraint in (14) depends in a nonlinear fashion on the firms' share of exports, as shown by η_e and $\eta_d = 1 - \eta_e$. So we will end up with an estimating equation that is nonlinear in the export share, which we treat as an endogenous variable: both these features create complications in the estimation that we shall address.

To derive the basic relationship between firms' revenue and interest payments, start with domestic firms. The loans $M_d(x)/\delta$ are needed to finance total costs, so $M_d(x)/\delta - C_d$ are needed for variable costs. The ratio of marginal revenue to marginal costs is $\overline{\Phi}_d$, and the ratio of price to marginal revenue for CES demand is $\sigma/(\sigma-1)$. Therefore, the total sales revenue $p_d q_d$ obtained from the working-capital loans of $M_d(x)$ are $p_d q_d = [M_d(x)/\delta - C_d]\,\overline{\Phi}_d \sigma/(\sigma-1)$. Substituting from (15), we obtain:

$$p_d q_d = \frac{\sigma}{\sigma-1}\overline{\Phi}_d \left(\frac{I_d(x)}{\overline{\Phi}_d - 1} - C_d \right).$$

A similar line of argument will show that the relationship between revenue and interest payments for an exporting firm is,

$$p_d q_d + p_e q_e = \frac{\sigma}{\sigma-1}\overline{\Phi}_e \left(\frac{I_e(x) - i\Theta}{\overline{\Phi}_e - 1} - C_d - C_e \right).$$

Summarizing the above relations, let us denote the interest payments and firm revenue as,

$$I(x) \equiv \begin{cases} I_d\,(x) & \text{if x} \in [\underline{\text{x}}_d, \underline{\text{x}}_e] \\ I_e\,(x) & \text{if x} \in [\underline{\text{x}}_e, \infty] \end{cases}, \; r(x) \equiv \begin{cases} p_d q_d & \text{if x} \in [\underline{\text{x}}_d, \underline{\text{x}}_e] \\ p_d q_d + p_e q_e & \text{if x} \in [\underline{\text{x}}_e, \infty] \end{cases}.$$

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

$$r(x_{jt}) = \beta_0 C_d + \beta_1 I(x_{jt}) + g_{1jt} I(x_{jt}) + g_{2jt} C_d + g_{3jt}, \tag{17}$$

where the coefficients are obtained from above as:

$$\beta_0 = -\frac{\sigma}{\sigma-1}\overline{\Phi}_d < 0, \tag{18}$$

$$\beta_1 = \frac{\sigma}{\sigma-1}\left(\frac{\overline{\Phi}_d}{\overline{\Phi}_d - 1} \right) > 0,$$

and,

$$
\begin{aligned}
g_{1jt} = g_1(\eta_{ejt}) &= \frac{\sigma}{\sigma-1}\left(\frac{\overline{\Phi}_e}{\overline{\Phi}_e - 1} - \frac{\overline{\Phi}_d}{\overline{\Phi}_d - 1}\right) \leq 0, \\
g_{2jt} = g_2(\eta_{ejt}) &= -\frac{\sigma}{\sigma-1}\left(\overline{\Phi}_e - \overline{\Phi}_d\right) \leq 0, \\
g_{3jt} = g_3(\eta_{ejt}) &= -\frac{\sigma}{\sigma-1}\left[\left(\frac{\overline{\Phi}_e}{\overline{\Phi}_e - 1}\right)\Theta i_t + \overline{\Phi}_e C_e\right]\mathbf{1}_{\{x_{jt} \geq \underline{x}_e\}}.
\end{aligned} \tag{19}
$$

We define $\mathbf{1}_{\{x \geq \underline{x}_e\}}$ as an indicator variable that takes one for $x \geq \underline{x}_e$ and zero otherwise, and the term $\overline{\Phi}_e$ appearing above depends on the export share η_{ejt} from (14).

The coefficients β_0 is negative because higher fixed costs reduce the amount of the loan available to cover variable costs, and therefore reduce revenue. The coefficient β_1, which multiplies the bank payments, is positive, indicating that larger payments are associated with larger revenues. The remaining variables in (17) have coefficients g_{ijt}, $i = 1, 2, 3$, that are actually functions of the export share η_{ejt}. Notice that from the definition of the credit constraints in (14), $g_{ijt}(0) = 0$, while for $i = 1, 2$, these functions are strictly negative for positive export shares provided that $\tau_e > \tau_d$ and $i > 0$, so that $\overline{\Phi}_e > \overline{\Phi}_d$. Thus, the extra terms involving g_{ijt} in (17) apply only to exporters and indicate additional credit constraints on those firms.

To interpret these extra terms, consider first the function $g_{1jt}(\eta_{ejt})$, which is negative for exporters under the condition mentioned above but *less than* β_1 in absolute value. So for exporters, bank payments of $I(x_{jt})$ are associated with revenue of $\beta_1 + g_{1jt}(\eta_{ejt})$,which is positive but less than β_1. This reduced coefficient on payments therefore lowers the sales revenue for exporters, reflecting the extra credit constraint imposed on them. A similar logic applies to the fixed costs on domestic sales C_d that all firms face, which reduces revenue by the amount $\beta_0 + g_{2jt}(\eta_{ejt})$ for exporters but only by β_0 for domestic firms. So exporters are constrained in what they can earn due to the extra credit constraint that they face via both their bank payments and the fixed costs C_d.

In addition, exporters face a reduction in revenue from any increase in the interest rate i_t, as shown by the final term $g_{3jt}(\eta_{ejt})$ appearing in (17), which also incorporates the extra fixed costs C_e faced by exporters. The presence of this term can be traced back to Θ in (16), which determines the interest payments for the cutoff exporter. As interest rates rise, or the time-lag for exports increases, the bank faces higher opportunity costs in making export loans and passes these on as higher interest payments, thereby reducing the extensive margin of exports.

While (17) summarizes the basic equilibrium relationship between firms' interest payments and revenue in our model, we must confront three challenges in its estimation. First, as it is written this equation has no error term: it holds exactly in the model. 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 by $R_{jt} = r(x_{jt}) + \varepsilon_{jt}$ with $E(\varepsilon_{jt}|x_{jt}) = 0$, which will introduce an error term into (17).

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 $I(x_{jt})$ so we write $I_{jt} = I(x_{jt}) + u_{jt}$ with $E(u_{jt}|x_{jt}) = 0$. The error u_{jt} is likely correlated with the error ε_{jt} in revenue, because unanticipated problems of production and delivery can equally well impact interest payments to the bank. Accordingly, we treat interest payments as endogenous and so we need an instrument that is uncorrelated with the errors ε_{jt} and u_{jt}. One such variable is the *ex-ante* productivity that is anticipated by firms. We will use the 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 u_{jt}.

A second challenge arises from the coefficients $g_{ijt} = g_i(\eta_{ejt})$, $i = 1, 2, 3$, that are functions of the export shares and differ across firms due to these shares. These coefficients should therefore be treated as random across firms, and so the goal of our estimation will be to estimate a mean value of the coefficients. But the decision to export is endogenous in our model through the determination of $\underline{x}_e$ in (16), so that only firms with productivity $x_{jt} > \underline{x}_e$ are exporters. The export share η_{ejt} is therefore endogenous.

Our estimating equation thus has random coefficients that are correlated with the endogenous export share, so it is a correlated random coefficients (CRC) model. To see the challenge that this creates in estimation, substitute $R_{jt} = r(x_{jt}) + \varepsilon_{jt}$ and $I_{jt} = I(x_{jt}) + u_{jt}$ into (17) to obtain:

$$R_{jt} = \beta_0 C_d + \beta_1 I_{jt} + g_{1jt} I_{jt} + g_{2jt} C_d + g_{3jt} - (\beta_1 + g_{1jt}) u_{jt} + \varepsilon_{jt}. \tag{20}$$

Even with $E(u_{jt}|x_{jt}) = 0$, we would not expect to have $E(g_{1jt} u_{jt}|x_{jt}) = 0$ because of the correlation between g_{1jt} and u_{jt}. It follows that x_{jt} is no longer a valid instrument on its own.

Heckman and Vytlacil (1998) recommend replacing the endogenous variable in a CRC model – or the export share in our case – with its predicted value. In the next section we will estimate the export share with a Type-II Tobit model, or Heckman procedure, using the exogenous variables Z_{jt} that include x_{jt}. Let us therefore rewrite the functions g_{ijt} using their expected values as, $g_{ijt} = E(g_{ijt}|Z_{jt}) + v_{ijt}$ with $E(v_{ijt}|Z_{jt}) = 0$, $i = 1, 2, 3$. We substitute these relations into (20) and simplify to obtain:

$$R_{jt} = \beta_0 C_d + \beta_1 I_{jt} + E(g_{1jt}|Z_{jt}) I_{jt} + E(g_{2jt}|Z_{jt}) C_d + E(g_{3jt}|Z_{jt}) + w_{jt}, \tag{21}$$

where the error term is $w_{jt} = v_{1jt} I(x_{jt}) + v_{2jt} C_d + v_{3jt} - [\beta_1 + E(g_{1jt}|Z_{jt})] u_{jt} + \varepsilon_{jt}$. All the terms appearing within this error have zero expected value conditional on Z_{jt}, so that w_{jt} is conditionally uncorrelated with these instruments and they can be used for estimation.[9]

The final challenge is to deal with the nonlinear form of the functions $g_i(\eta_{ejt})$, as seen from the credit constraints in (14). Estimating (17) as a nonlinear structural equation, in the presence of endogenous explanatory variables as well as a first-stage Heckman procedure, is computationally burdensome. Accordingly, we simplify the estimation by taking certain approximations to the functions $g_i(\eta_{ejt})$, as described in the remainder of this section.

We will simplify the functions g_i, $i = 1, 2, 3$, in different ways. Substituting from (14), we express g_1 as:

$$g_1(\eta_{ejt}) = -\frac{\sigma}{\sigma - 1} \frac{i\delta\eta_{ejt}(\tau_e - \tau_d)}{\left[i\delta(\tau_d(1 - \eta_{ejt}) + \tau_e \eta_{ejt}) + \frac{\sigma-1}{\sigma\theta}\right]\left(i\delta\tau_d + \frac{\sigma-1}{\sigma\theta}\right)}. \tag{22}$$

We take into account the nonlinearity of $g_1(\eta_{ejt})$ in the estimation by using a second-order Taylor series approximation around the point $\eta_{ejt} = 0$,

$$\begin{aligned} g_1(\eta_{ejt}) &\simeq -\frac{\sigma}{\sigma - 1} \frac{1}{\left(i\delta\tau_d + \frac{\sigma-1}{\sigma\theta}\right)} \left(\left(\frac{i\delta(\tau_e - \tau_d)}{i\delta\tau_d + \frac{\sigma-1}{\sigma\theta}} \right) \eta_{ejt} - \left(\frac{i\delta(\tau_e - \tau_d)}{i\delta\tau_d + \frac{\sigma-1}{\sigma\theta}} \right)^2 \eta_{ejt}^2 \right) \\ &\equiv \beta_2 \eta_{ejt} + \beta_3 \eta_{ejt}^2. \end{aligned}$$

From this definition of the coefficients β_2 and β_3, it follows that we can obtain an exact value for the function g_1 in (22) as:

$$g_1(\eta_{ejt}) = -\frac{\beta_2^2}{\beta_3} \left(\frac{1}{1 - [\beta_2/(\beta_3 \eta_{ejt})]} \right). \tag{23}$$

To be consistent with our model we should find that $\beta_2 < 0$ and $\beta_3 > 0$. That sign pattern will be enough to ensure that $g_1(\eta_{ejt}) < 0$ for $\eta_{ejt} > 0$ from (23), so that exporters face an additional

[9] Note that the troublesome term $v_{1jt} u_{jt}$ appears twice in w_{jt} after the substitutions are made, but with oposite sign, so it cancels out. That occurs because, unlike Heckman and Vytlacil (1998), we start with a exact theoretical relation in (17) and then add the errors. The term analogous to $v_{1jt} u_{jt}$ did not vanish in Heckman and Vytlacil, so they had to make a conditional homoskedasticity assumption on it to ensure that it would not bias the estimation. That additional assumption is not needed here.

credit constraint. In addition, we can use formula (23) to check that $|g_1(\eta_{ejt})| < \beta_1$, which always holds in the model and ensures that while exporters face a tighter credit constraint there is still a positive relationship between bank payments and revenue. To check that this condition also holds in our estimates, it is readily seen that (23) is decreasing in the export share provided that $\beta_2 < 0$ and $\beta_3 > 0$. So we can confirm that $|g_1(\eta_{ejt})| < \beta_1$ by checking that this inequality holds when $\eta_{ejt} = 1$. Using $\eta_{ejt} = 1$, $\beta_2 < 0$ and $\beta_3 > 0$, from (23) it can be shown that $|g_1(1)| < \beta_1$ holds if and only if $\beta_2^2 + \beta_1\beta_2 - \beta_1\beta_3 < 0$. By solving this quadratic equation as an equality, we can conclude that the inequality holds for values of β_2 in the range:

$$\beta_2 \in \left(-\frac{1}{2}(\beta_1 + \sqrt{\beta_1^2 + 4\beta_1\beta_3}), 0 \right). \tag{24}$$

To summarize, the sign pattern $\beta_2 < 0$ and $\beta_3 > 0$ ensures that $g_1(\eta_{ejt}) < 0$ for $\eta_{ejt} > 0$ and that $|g_1(\eta_{ejt})|$ is an increasing function of the exporting share η_e, which means that exporting firms face more stringent credit constraints if their export share is higher. On the other hand, (24) together with $\beta_3 > 0$ give us sufficient conditions, expressed in term of the estimated parameters, to ensure that $|g_1(\eta_e)| < \beta_1$ for any value of the export share $\eta_e \in [0, 1]$. These two theoretical predictions will be tested in our estimation.

Turning to the function g_2, it is expressed simply as,

$$\begin{aligned} g_2(\eta_{ejt}) &= -\frac{\sigma}{\sigma - 1} i\delta\eta_{ejt} (\tau_e - \tau_d) \left(1 - \frac{\sigma - 1}{\sigma\theta}\right)^{-1} \\ &\equiv \beta_4\eta_{ejt}, \end{aligned}$$

where $\beta_4 < 0$. So estimating the coefficient β_4 does not involve any Taylor series approximation.[10] Lastly, we will not attempt to express g_3 as a function of the export share, but will model this extra impact on exporters by simply using a coefficient β_5 times the export indicator $\mathbf{1}_{\{x_{jt} \geq \underline{x}_e\}}$.[11]

Substituting the above expressions for g_i into our estimating equation (21), and also absorbing the fixed costs C_d within the coefficients β_0 and β_4, we obtain:

$$R_{jt} = \beta_0 + [\beta_1 + \beta_2 E(\eta_{ejt}|Z_{jt}) + \beta_3 E(\eta_{ejt}^2|Z_{jt})]I_{jt} + \beta_4 E(\eta_{ejt}|Z_{jt}) + \beta_5 \mathbf{1}_{\{x_{jt} \geq \underline{x}_e\}} + w_{jt}. \tag{25}$$

Let $\widehat{\eta}_{jt}$ denote the fitted value of the export share using a type-II Tobit model, described below. We use this estimated share to replace $E(\eta_{ejt}|Z_{jt})$ in the estimation. In the Appendix we show

[10] Like β_2 and β_3, there is still an approximation involved in β_4 by treating it as constant across firms. All these coefficients depend on the difference $(\tau_e - \tau_d)$ in the time to receive payment for exporters and domestic firms. We will allow these coefficients to vary for sea exports versus non-sea exports in our later estimation.

[11] In our working paper (Feenstra, Li and Yu, 2011) we allowed the coefficient β_5 to vary over years as suggested by i_t, but because the results were not that robust, we omit them here. Also, in principal we should be using the expected value of $\mathbf{1}_{\{x_{jt} \geq \underline{x}_e\}}$conditional on Z_{jt} in the estimating equation (25), but in practice have found that using the indicator variable itself as a control results in more stable coefficients.

how to estimate the second moment $E(\eta_{ejt}^2|Z_{jt})$, which exceeds $\widehat{\eta}_{jt}^2$ by Jensen's inequality, and also use that estimated second moment which we denote by $\widehat{\eta_{jt}^2}$ to replace $E(\eta_{ejt}^2|Z_{jt})$. Making these replacements in (25) assumes that the Tobit model used to estimate the export share is the *true* model.[12] After these substitutions, it follows that the appropriate instruments used to estimate (25) are x_{jt} and its interaction with $\widehat{\eta}_{jt}$ and $\widehat{\eta_{jt}^2}$. Of course, a correction to the standard errors must be made to reflect our use of estimated regressors in (25), as we shall implement by bootstrapping.

To summarize, we interpret (25) as an equilibrium relation that holds in our model, and aim to test whether this relation with the sign patterns indicated in (18)-(19) also holds in the data. If so, we would interpret those results as evidence supporting the presence of extra credit constraints on exporters. The key restrictions on the coefficients to ensure these extra credit constraints hold are $\beta_2 < 0$ and $\beta_3 > 0$, so that a higher export share leads to a tighter export constraint but at a diminishing rate. That sign pattern will be enough to ensure that $g_1(\eta_{ejt}) < 0$ for $\eta_{ejt} > 0$, so that exporters face an additional credit constraint. In addition, we can use formula (23) to check that $|g_1(\eta_{ejt})| < \beta_1$, so that higher interest payments are still associated with higher revenue. A sufficient condition for this inequality to hold is that β_2 lies in the range shown by (24).

3.2 Firm-level Data

The sample used in this paper comes from a rich Chinese firm-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.[13] 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 *Renminbi* (which is equivalent to around \$770,000 under current exchange rate).[14] 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

[12] In addition, as explained below, while the first-step of the Tobit procedure uses the variables Z_{jt} including x_{jt}, the second step omits x_{jt}. We also need to assume that this exclusion restriction is correct.

[13] Data in 2008, which is still not formally released and only available in a trial version, do not have information on firm's ID. So we use other available common variables to merge with data on 2007 and obtain 336,480 observations, which is almost identical to the number of observations in 2007 (*i.e.*, 336,768 firms).

[14] Since smaller Chinese firms are more likely to be financially constrained, the effects of financial frictions estimated in the paper may be underestimated. Our finding shall be interpreted as a minimum of the credit constraint faced by Chinese firms. We thank a referee for pointing this out.

firms.[15] 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.[16] 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.

After this rigorous filter, we obtain $963,180$ observations, or roughly one-half of the original data set. The last three criteria account for about 60% of the attrition. Within this sample, there are $36,637$ observations on pure exporters, $926,543$ observations for other Chinese firms including the Hong Kong/Macao/Taiwan-invested firms, and $99,742$ observations for foreign firms.

As shown in Table 1, pure exporters for which firm revenue equals firm exports have much smaller revenue and interest payments as compared to other firms. Since such pure exporters do not fit with our theory, where firms make a decision in both domestic and international markets, we exclude such observations from our sample. For state-owned enterprises, the number of observations was relatively small ($39,419$ or 4.1% of the sample), and they did not fit the independent structure of firms and the bank in our model, so we also dropped them.

Multinationals do not appear to directly apply to our theory, since they may have additional channels to finance their working capital (Harrison and McMillan, 2003; Manova, Wei and Zhang, 2011). So we distinguish them from Chinese firms and run separate regressions initially, and then exclude them from the sample.[18] As seen from Table 1, on average, foreign firms have higher revenue and interest payments, more exporting firms, and larger export shares than Chinese-owned firms.

[15] For example, information on some family-based firms, which usually did not set up formal accounting systems, is based on a unit of *one Renminbi*, whereas the official requirement is a unit of 1,000 *Renminbi*.

[16] Levinsohn and Petrin (2003) suggest to include all Chilean plants with at least 10 workers, and we follow their criterion. Brandt, Van Biesebroeck and Zhang (2012) suggest dropping firms with less than eight employees as such firms "fall in a different regime" in China. We also experimented with such a looser criteria to include more of the sample, but found that our estimation results were not significantly changed.

[17] In particular, observations in which the opening year is after 2008 or the opening month is later than December or earlier than January are dropped.

[18] There are 300,372 Chinese firms and 42,612 foreign firms (i.e., MNEs) in our sample for regressions.

One other variable, not reported in Table 1, is also used in the estimation. As discussed above, we estimate firms' anticipated productivity level (TFP2) rather than the conventional TFP measure. To motivate this from the Olley-Pakes (1996) framework, consider a standard Cobb-Douglas production function:

$$\ln Y_{jt} = \gamma_k \ln K_{jt} + \gamma_l \ln L_{jt} + x_{jt} + \varepsilon_{jt}, \tag{26}$$

where Y_{jt} is the value-added production of firm j at year t.[19] The conventional measure of productivity is to take the difference between log value-added and log factor inputs times their estimated coefficients:

$$TFP1_{jt} = \ln Y_{jt} - \hat{\gamma}_k \ln K_{jt} - \hat{\gamma}_l \ln L_{jt}. \tag{27}$$

Under this approach, firm productivity (TFP1) is clearly correlated with value-added and with the ex-post productivity shock ε_{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} (not be be confused with interest payments of I_{jt} in our model) depends on the *anticipated* productivity $TFP2_{jt}$ of the firm according to a functional relation: $V_{jt} = h_1(TFP2_{jt}, \ln K_{jt})$, where K_{jt} denotes firms' capital. When this relation is estimated and inverted, we can solve for anticipated productivity as:

$$TFP2_{jt} = h_1^{-1}(V_{jt}, \ln K_{jt}). \tag{28}$$

We discuss this approach in more detail in the Appendix. The second measure of productivity (TFP2) corresponds to what is observed *ex ante* by the firm, which is closer to the Melitz-style productivity described in our model and, by construction, is independent of ε_{jt}.TFP2 will be used as an instrument in our estimation of (25), and also in a Heckman procedure used to obtain predicted export shares.

In addition to the firm-level production data, we rely on highly disaggregated product-level trade data obtained from Chinese Customs, which record information such as modes of shipments and their export values, to merge with the firm-level dataset. We will use such a merged dataset when we examine the role of credit constraints by mode of shipment.

[19] Note that we use deflated firm's value-added to measure production and exclude intermediate inputs (materials) as one kind of factor inputs. However, we are not able to use value-added to estimate firm's TFP in 2008 since it is absent in the current trial version of the dataset. We instead use industrial output to replace value-added in that year.

4 Estimation Results

4.1 The Credit Constraint

To begin to assess the relationship between firm revenue and interest payments in (25), note that a simple plot between these variables (taking the averages within 2-digit manufacturing sectors) shows a clear positive relationship as implied by our model.[20] Next, we consider OLS estimates of (25), shown in column (1) of Table 2. Controlling for the endogeneity of the export share requires the Heckman procedure, which we report below, and controlling for the endogeneity of interest payments requires the use of $TFP2_{jt}$ as an instrument. So after briefly examining the OLS estimates in this section, we then move to the 2SLS estimates, reported in the remaining columns of Table 2. In the first two columns we restrict attention to Chinese firms, while foreign firms are examined in column (3).

The baseline OLS estimates for Chinese firms in column (1) uses the export share and share squared, rather than the predicted values of these variables. All coefficients are significant and their signs are consistent with our theoretical predictions. The coefficient of interest payment is positive ($\hat{\beta}_1 > 0$), while the interest payment's interaction with export share is negative ($\hat{\beta}_2 < 0$) and its interaction with export share squared is positive ($\hat{\beta}_3 > 0$). Their economic magnitudes lie in the predicted range suggested by our theory.[21] We obtain $\hat{\beta}_2 = -64.8$ in column (2), which is higher than its lower bound, -141.5, in expression (24). The estimated value of the credit constraint $g_1(\eta_e^m)$ is -15.7, evaluated at the mean of the export share for Chinese firms (η_e^m) of 0.49, conditional on exporting. Thus, as predicted from our theory, $\hat{\beta}_1 + g_1(\eta_e^m)$ is still positive but less than $\hat{\beta}_1$, implying that exporting firms are more credit constrained than domestic firms. Moreover, those firms with higher export shares – say, at the 90^{th} percentile of the export share, η_e^u – will face tougher credit constraints: the estimated value of $g_1(\eta_e^u)$ is -20.3, or about 30% larger in absolute value than that when calculated at the mean export share.

4.2 Bivariate Selection Model

The OLS estimates in column (1) of Table 2 uses the export share, but that share is endogenous. To control for this, we introduce a Heckman procedure, or equivalently, a Type-II Tobit model. The bivariate sample selection specification includes: (i) an export participation equation,

$$Export_{jt} = \begin{cases} 0 \, if \; x_{jt} - \underline{x}_{et} \leq 0 \\ 1 \, if \; x_{jt} - \underline{x}_{et} > 0 \end{cases}, \tag{29}$$

[20] See the Appendix, Figure A1.

[21] Recall that the coefficients should satisfy condition (24): $\hat{\beta}_2 \in (-\frac{1}{2}(\beta_1 + \sqrt{\beta_1^2 + 4\beta_1\beta_3}), 0)$.

where $\underline{x}_{et}$ is the cut-off productivity for firms to export and $(x_{jt} - \underline{x}_{et})$ denotes a latent variable faced by firm j; and (ii) an "outcome" equation whereby the firm's export share is modeled as a linear function of other variables.

We perform the Heckman two-step method to estimate such a bivariate selection model. Note that the latent variable's distribution is the distribution of firm's TFP shifted to the left by the export cutoff productivity. We have already argued that measuring firm productivity x_{jt} with $TFP1_{jt}$ in (29) will result in an endogenous variable. Accordingly, we first run a preliminary regression where the dependent variable $TFP1_{jt}$ is regressed on firm-level indicators, on $TFP2_{jt}$, and on the other variables that appear in the Heckman equations (discussed just below; see the notes to Table 3). The use of firm-level indicators allows the cross-sectional differences between firms to be preserved in the predicted value $\widehat{TFP1}_{jt}$ obtained from that regression. We use $\widehat{TFP1}_{jt}$ to replace x_{jt} in (29). Of course, the use of an estimated regressor requires that the standard errors are bootstrapped.

For the other variables to include in the Heckman equations, our theoretical model suggests that firm's export decision depends on its collateral as shown in our working paper (Feenstra, Li and Yu, 2011). We follow Manova (2012) by using the firm's tangible assets as a measure of collateral. In particular, we model this cutoff productivity as depending on the ratio of firm's tangible assets over its total assets $(Tang/Asset)_{jt}$.[22] In addition, previous studies suggest that U.S. exporters are more capital-intensive and more capital-intensive industries have more exporting firms (Bernard *et al*, 2007). This suggests that some Heckscher-Ohlin forces are at work within and across industries. Recent studies also suggest that the reverse Heckscher-Ohlin predictions may work for China, with labor-intensive firms exporting more (Lu, 2011). It is worthwhile to see whether firm's log of capital-labor ratio plays a role on firm's export decision, and we hence include such a variable in the export participation equation.

Finally, we also control for year fixed effects D_t and 4-digit sector fixed effects ζ_n. We hence perform the Probit model as our first-step Heckman equation:

$$\Pr(Export_{jt} = 1 \,|\, Z_{jt}) = \Phi[\alpha_0 + \alpha_1 \widehat{TFP1}_{jt} + \alpha_2 (Tang/Asset)_{jt} + \alpha_3 \ln(K/L)_{jt} + D_t + \zeta_n], \quad (30)$$

where $\Phi(.)$ is the cumulative density function of the normal distribution and Z_{jt} is the vector of the included exogenous variables. When estimating this selection equation, however, we immediately face a data limitation: about 80% of our sample does not report data on intangible assets. To

[22] As in the finance literature, the common measure for firm's access to collateral is the share of tangible assets in total assets instead of the level of tangible assets, due in large part to the fact that the latter is endogenous to the size of the firm and its revenue.

address this problem, we include an intangible asset indicator (*i.e.*, one if intangible assets are reported and zero otherwise) in the estimation.

We then carry the inverse Mills ratio obtained from the first-step Probit estimates to the second-step Heckman specification. The Heckman estimation also require a variable that is significant in the first-step but excluded from the second-step estimates. We adopt $\widehat{TFP1}_{jt}$ as such an exclusion variable for two reasons. First, firm productivity is a widely-accepted key variable that affects the firm's export decision (Melitz, 2003). Second, our theory clearly suggests that firm's export share (η_e) is not affected by firm productivity, as seen from equation (9) where the export share only depends on foreign and domestic market sizes.[23]

Table 3 reports the estimation results for the Heckman estimates for Chinese firms and foreign firms, respectively. In the first-step Probit estimates for Chinese firms, in column (1), we see that firms with higher TFP have a higher probability of exporting. In addition, firms with higher share of tangible assets in total assets are more likely to export.[24] Firms with larger capital-intensity are more likely to export, which suggests that Chinese firms' exports follow the Heckscher-Ohlin pattern.[25] The second-step Heckman estimates in column (2) result in similar findings to those in the first-step Probit estimates.

Compared to Chinese firms, the Heckman estimates for foreign firms show very different results in columns (3)-(4). Firm productivity does not have any significant impact on foreign firms' export decision. Possible reasons are that many foreign exporting firms are processing firms which usually are less productive (Yu, 2011) or such multinationals are vertically integrated and may rely much on their own sales network abroad (Feenstra and Hanson, 2005). In conjunction with 2SLS results reported below, we conclude that foreign-owned firms do not fit the same specification as Chinese firms, and for that reason we focus on the latter in subsequent estimation.

[23] If there are many foreign markets, then more productive firms will export to more markets and therefore have higher export market shares. We interpret this result as saying that the selection equation becomes more complex with many foreign markets. For this reason, there will certainly be a correlation between the firms' export share and firm-level indicators. But when we check the simple correlation between firms' export share and TFP2 in the data, it is negligible (0.03) during 2000-2008.

[24] This is consistent with our theoretical results shown in our working paper: having greater collateral will relax the cash flow constraint, especially for exporters.

[25] Such a finding is different from Lu (2011) as pure exporters are excluded from our sample. Dai, Maitra and Yu (2012) find evidence that pure exporters are mostly processing firms in China. Once processing firms are excluded, China's exports still follow the prediction of the Heckscher-Ohlin model.

4.3 2SLS Estimates

For 2SLS estimation we must control for the endogeneity of the export share and of interest payments. We use the fitted export share from the second-step Heckman estimates to replace the expected export share as shown in (25). In addition, we adopt the *ex ante* level of firm productivity, $TFP2_{jt}$, as the instrument for the firm's interest payment. Accordingly, we have three instruments used in the estimation of (25): the level of $TFP2_{jt}$; the interaction term between $TFP2_{jt}$ and the fitted export share; and the interaction term between $TFP2_{jt}$ and the fitted value of the squared export share. Standard errors are corrected for our use of estimated regressors by bootstrapping.[26]

The 2SLS estimates for Chinese firms are shown in column (2) of Table 2. The magnitude of the key coefficients ($\hat{\beta}_1$ to $\hat{\beta}_4$) in column (2) are somewhat larger than their OLS counterparts in column (1), but have the same signs. In particular, firms with higher interest payment generate larger revenue. More importantly, firms with higher export share are more credit constrained since $\hat{\beta}_2$ ($\hat{\beta}_3$) is negative (positive) and significant. All the key estimated coefficients are located in the reasonable range suggested by (24) in our theory. Once again, the estimated value of credit constaints for the firm with average of fitted export share, $g_1(\eta_e^m) = -38.6$, is smaller in absolute value than the magnitude of the coefficient on interest payment itself, $\hat{\beta}_1 = 79.9$. Similar to our findings above, if we take the 90^{th} percentile of the fitted export share (η_e^u), we still obtain $|g_1(\eta_e^u)| = 53.5 < \hat{\beta}_1$. Furthermore, we see that the measured credit constaints for firms with 90^{th} percentile export share, $|g_1(\eta_e^u)|$, are about 40% larger than that for firms with average export share, $|g_1(\eta_e^m)|$, indicating that the credit constraint becomes more stringent as a firm's export share grows.

In column (3), we perform the 2SLS estimates by including foreign firms only. The estimation results are quite different from those in columns (1)-(2). Although higher interest payments still lead to larger revenue ($\hat{\beta}_1 > 0$), the coefficient $\hat{\beta}_2$ on the interactions of the interest payments with fitted export shares are too large in absolute value, with the result that the implied value of $\hat{\beta}_1 + g_1(\eta_e^m)$ becomes negative. In other words, there is no longer a positive relationship between bank payments and revenue for foreign exporters. This finding may be due to the argument of Manova, Wei and

[26] There are in fact five steps to our estimation: i) the preliminary regression of $TFP1_{jt}$ on firm-level indicators, interactions between 4-digit industry indicators and $TFP2_{jt}$, and other variables that appear on the right of (30); ii) the selection equation (30) using $\widehat{TFP1}_{jt}$; iii) the second-step Heckman equation excluding $\widehat{TFP1}_{jt}$, used to obtain predicted export shares $\widehat{\eta}_{ejt}$ and $\widehat{\eta^2_{ejt}}$; iv) the first-step of 2SLS where I_{jt}, $I_{jt}\widehat{\eta}_{ejt}$ and $I_{jt}\widehat{\eta^2_{ejt}}$ are regressed on $TFP2_{jt}$, $TFP2_{jt}\widehat{\eta}_{ejt}$ and $TFP2_{jt}\widehat{\eta^2_{ejt}}$, along with other variables on the right of (25); v) the final estimation of (25). Panel bootstrapping by randomly drawing firms is done over all five steps, which thereby corrects for clustering by firms.

Zhang (2011) that foreign subsidiaries in China have alternative sources of credit, i.e. from their parent firms, so that the relationship between bank credit and revenue is confounded. Since we find that foreign firms exhibit a different pattern of credit constraints in our estimates, and because they are not examined in our theory, we henceforth omit foreign firms from our estimation.[27]

4.4 Collateral of Firms

We consider two extensions of the estimating equation (25). The first allows for the role of tangible assets as collateral for firms. Manova (2012) has shown that this variable is important in explaining the sensitivity of sectoral exports to financial variables. In our model, the role of collateral can be easily introduced by supposing that there is a constant probability ρ that the firm is successful in its production, thereby repaying the loan to the bank. If it is not successful, then with probability $(1-\rho)$ it defaults on the loan and instead the bank receives its collateral A_{jt}, which we measure with tangible assets. Under this formulation, the expected payments to the bank are $[\rho I(x_{jt})+(1-\rho)A_{jt}]$, and the expected revenue of the firm is $\rho r(x_{jt})$. Using these to replace the respective variables in (17), dividing the equation through by ρ, and substituting the above specifications for g_i, we obtain the alternative estimating equation:

$$\begin{aligned} R_{jt} &= \beta_0 + [\beta_1 + \beta_2 E(\eta_{ejt}|Z_{jt}) + \beta_3 E(\eta_{ejt}^2|Z_{jt})]I_{jt} + \beta_4 E(\eta_{ejt}|Z_{jt}) + \beta_5 \mathbf{1}_{\{x_{jt}\geq \underline{x}_e\}} \\ &\quad + [\beta_6 + \beta_7 E(\eta_{ejt}|Z_{jt}) + \beta_8 E(\eta_{ejt}^2|Z_{jt})]A_{jt} + w_{jt}. \end{aligned} \tag{31}$$

where $\beta_{i+5} \equiv \beta_i (1-\rho)/\rho,\ i = 1,2,3.$[28] We see that in this alternative estimating equation we include a measure for the firms' collateral and interact this variable with the fitted values of the export share and share squared, in much the same way as the interest payments appear.

As seen from (31), collateral enters the estimating equation as a substitute for interest payments. Since $\beta_1 > 0$ and the probability of a project's success is non-negative, $\rho \in (0,1]$, collateral is positively associated with revenue (i.e., $\beta_6 > 0$). Analogously, we expect that effect of collateral on revenue is smaller for exporters and decreases with export share: $\beta_7 < 0$.

When we estimate (31) over the entire 2000-2008 sample (not reported), we lose significance of the key coefficient $\hat{\beta}_2$ on the interaction of the interest payments and the fitted export share.

[27] Also reported in Table 2 are several tests to check the validity of our instruments. We report the Kleibergen-Paap LM χ^2 statistic to test the null hypothesis that the model is under-identified, and the Anderson-Rubin Wald F statistic to test the null hypothesis of weak identification. Both hypotheses are strongly rejected at the 1% significance level. But since we have not attempted to correct the significant level of these tests for the use of estimated regressors, we interpret these results with caution.

[28] The introduction of the success rate of projects ρ, and the default rate $(1-\rho)$, leads to a slightly different definition of the credit constraints $\overline{\Phi}_d$ and $\overline{\Phi}_e$. But the definitions of the coefficients in (18) and (19) still hold: see Feenstra, Li and Yu (2011) for details.

Likewise, the coefficients $\hat{\beta}_7$ and $\hat{\beta}_8$ on the interactions of collateral with fitted export shares are also insignificant. One reason for this may be that the last year of our sample (2008) has preliminary data.[29] Accordingly, for the remainder of the paper we focus for the the earlier years 2000-2006, during which time we can conveniently merge with Chinese firm-level trade data as needed in the rest of Table 4.

Thus, column (1) of Table 4 reports the 2SLS estimates with collateral over the 2000-2006 sample, using the sample of matched firms in our earlier dataset and the firm-level trade data. The sample is reduced to $536,064$ observations due to the omitted years 2007-2008 and this matching of firms.[30] We find that all of the results in column (1) are consistent with our theoretical predictions. Firms with more collateral, as measured by tangible assets ratio, have higher revenue, $\hat{\beta}_6 > 0$. When interacting the tangible asset ratio with export share, the tangible assets ratio raises revenue less for firms with greater export share, $\hat{\beta}_7 < 0$. The economic magnitudes for the key coefficients (β_1 to β_3) are also consistent with our theoretical predictions, though we now find that $|g_1(\eta_e^m)| = 75.1$ is only slightly below $\hat{\beta}_1 = 77.8$.

4.5 Exports by Mode of Transport

As a second extension, we consider breaking up exports into their mode of transport, as done by Amiti and Weinstein (2011). Our theory suggests that exporters are more constrained than domestic firms due to the longer time needed for export shipments. In reality, firms would have many types of shipments: by air, sea, truck, and their combination. Usually sea shipments are the slowest and have the longest time-lag to receive payment. It is reasonable to expect that if a firm relies more on sea shipments, then it would face more stringent credit constraints.

To examine whether the credit constraint is more stringent as the time to ship for exporters is lengthened, we generate an indicator, Sea, which is defined as one if the share of firm's exports directly by sea relative to its total exports are higher than 50% and zero otherwise. Analogously, we introduce another indicator, Non-sea, which equals (1 – Sea).[31] We then run a single regression, reported in columns (2)-(3), in which we interact interest payments times the fitted export share and share squared with the Sea and Non-sea indicators, respectively. It turns out all the key

[29] As explained in note 19, the data for 2008 is a trial version, so that TFP cannot be computed in the same mannner as for earlier years.

[30] In addition, in Table 4 we exclude the Hong Kong/Maco/Taiwan-invested firms, since shipping by sea for those firms may involve only very short distances. Those firms are included again in Table 5.

[31] Our estimation results are essentially unchanged if we take other proportion of sea shipment such as 75%, 90% or 95%, to form the Sea indicator. We have found, however, that if we try to distinguish air shipments as a separate category, then those results are not robust.

coefficients are statistically significant and of desirable signs as predicted by our model.

Turning to the economic magnitudes for each key variable, the estimated coefficients $\hat{\beta}_2$ and $\hat{\beta}_3$ for Sea estimates in column (2) are much higher than their counterparts for Non-sea estimates in column (3). Accordingly, the estimated credit constraint for firms that heavily rely on sea shipment is $g_1(\eta_e^m) = -99.5$, which is *70% larger than* that obtained for non-sea transport mode, $g_1(\eta_e^m) = -58.7$. These findings are strongly consistent with our hypothesis that exporters are more credit constrained due to the longer time needed for sea shipments.

4.6 Incomplete Information

So far we have seen evidence that the credit constraint is more stringent as a firm's export share grows and as the time to ship for exports is lengthened. Still, it is possible that the extent of incomplete information could be worse in some sectors than in others. In our theory, a reduction in the Pareto parameter θ leads to an increase in the dispersion of firms' productivity, and corresponds to *tighter* credit constraints in (14). To test this prediction, we make use of TFP2 which governs productivity levels that are known by the firms, but not observed by the bank. We compute its variance across firms within an industry, and then rank all the sectors by this variance, obtaining different percentiles to split the sample for estimation.[32]

Table 5 reports the 2SLS estimates with different percentiles of the variance of productivity. The dispersion of measured variance lies in the range between .376 to 4.77. We then present estimation results using four different ranges (*all*, $>10^{th}$, and $>25^{th}$ percentile) to examine the role of credit constraints on firm revenue in successively higher variance industries. We find that, again, all the structural coefficients have the anticipated signs and magnitudes. By taking the mean of fitted export share in each column, we see that the measured credit constraint $|g_1(\eta_e^m)|$ increases monotonically with the rise of sectoral variance of firm productivity, consistent with the idea that more incomplete information leads to tighter credit constraints. Moreover, all the estimated credit constraints obtained in each regression are less in absolute value than the coefficients of interest payment themselves, showing that our estimates fit with our model predictions.

5 Conclusions

In this paper, we have asked why firms will face credit constraints on their domestic sales and exports. We rely on the idea that firms must obtain working capital prior to production and that their productivity is private information. From the revelation principle, the bank can do no better

[32] See the last column of Appendix Table A1.

than to offer loan and interest schedule that lead the firms to truthfully reveal this information. We argue that such incentive-compatible schedules will lead to credit constraints on the firms. The reason for this is that a firm that is not credit constrained would suffer only a second-order loss in profits by producing slightly less and borrowing less, but would have a first-order reduction in interest payments. Thus, such a firm would never truthfully reveal its productivity.

We rely on a key reason why export sales differ from domestic sales: a longer time-lag in exports between production and sales (Berman, et al, 2012). This time-lag leads the bank to impose a more stringent credit constraint on exporters, for both their exports and domestic sales, than on purely domestic firms. The credit constraint reduces both the intensive margin and the extensive margin of exports. In our estimation we find that the credit constraint becomes tighter as a firm's export share grows, as the time to ship for exports is lengthened, and as there is greater dispersion of firms' productivities reflecting more incomplete information.

Our theoretical result that the exports and domestic sales of an exporting firm should face the same credit constraint corresponds most closely to the empirical finding of Behrens, Corcos and Mion (2010) for Belgium, who show that financial variables impact both types of sales equally within a firm. This contrasts to the empirical findings of Amiti and Weinstein (2011) for Japan, however, who show that the health of the main bank has a five-times greater impact on firm-level exports than domestic sales. One reason for this difference is that Amiti and Weinstein (2011) are arguably capturing the "trade finance" activities of these banks, targeted specifically at exports, whereas our model and empirical work deals with working-capital loans in general.

One limitation of our model is that it is static, whereas other theoretical literature focuses on the dynamic characteristics of credit constraints. Clementi and Hopenhayn (2006) characterize incentive-compatible credit constraints in a dynamic model, and show how such constraints affect firm's growth and survival. In this setting, a firm's credit constraint is relaxed when it increases its cash flow. Gross and Verani (2012) show how the firm revenue function used in Clementi and Hopenhayn (2006) can arise from a Melitz-style model, and drawing on Verani (2011), solve for the dynamics of domestic and exporting firms. None of these papers, however, introduce the distinctions between domestic firms and exporters – in the time-lag of shipments – that we use here. We anticipate that our results would apply in some form to these dynamic models, too, but that is beyond the scope of this paper.

References

[1] Ahn Jaebin (2011), "A Theory of Domestic and International Trade Finance," International Monetary Fund WP/11/262.

[2] Amiti, Mary, and David Weinstein (2011), "Exports and Financial Shocks," *Quarterly Journal of Economics,* 126 (4), 1841-1877.

[3] Beck, Thorsten (2002), "Financial development and international trade: is there a link?" *Journal of International Economics* 57, pp. 107-131.

[4] Behrens, Kristian, Gregory Corcos and Giordano Mion (2010), "Trade Crisis? What Trade Crisis?" NBB Working Paper No. 195.

[5] Berman, Nicolas, José De Sousa, Philippe Martin and Thierry Mayer (2012) "Time to Ship during Financial Crises," NBER working paper no. 18274.

[6] Bernard, Andrew, Bradford Jensen, Stephen Redding, and Peter Schott (2007), "Firms in International Trade," *Journal of Economic Perspectives* 21(3), pp. 105-130.

[7] Bolton, Partrick and David S. Scharfstein (1990), "A Theory of Predation Based on Agency Problems in Financial Contracting," *American Economic Review* 80 (1), pp. 93-106.

[8] Brandt, Loren, Johannes van Biesebroeck, and Yifan Zhang (2012), "Creative Accounting or Creative Destruction? Firm-Level Productivity Growth in Chinese Manufacturing," *Journal of Development Economics* 97(2), pp. 339-351.

[9] Buch, Claudia, Iris Kesternich, Alexander Lipponer, and Monika Schnitzer (2008), "Real versus Financial Barriers to Multinational Activity," mimeo, University of Tuebingen.

[10] Cai, Hongbin and Qiao Liu (2009),"Competition and Corporate Tax Avoidance: Evidence from Chinese Industrial Firms," *Economic Journal* 119, pp.764-795.

[11] Chaney, Thomas (2005), "Liquidity Constrained Exporters", University of Chicago.

[12] Chor, Davin and Kalina Manova (2012) "Off the Cliff and Back? Credit Conditions and International Trade during the Global Financial Crisis," *Journal of International Economics* 87(1), pp. 117-133.

[13] Claessens, Stijn and Tzioumis, Konstantinos (2006), "Measuring Firms' Access to Finance," mimeo, World Bank and Brooking conference paper.

[14] Clementi, Gian Luca and Hugo A. Hopenhayn (2006), "A Theory of Financing Constraints and Firm Dynamics," *Quarterly Journal of Economics* 121(1), pp. 229-265.

[15] Dai Mi, Madhura Maitra, and Miaojie Yu (2012), "Unexceptional Exporter Performance in China? The Role of Processing Trade," mimeo, Peking University.

[16] Egger, Peter and Christian Keuschnigg (2011), "Access to Credit and Comparative Advantage," ETH Zuerich and University of St. Gallen.

[17] Ellison Glenn, Edward Glaeser, and William Kerr (2010), "What Causes Industry Agglomeration? Evidence from Coagglomeration Patterns," *American Economic Review* 100(3), pp. 1195-1213.

[18] Feenstra, Robert and Gordon Hanson (2005), "Ownership and Control in Outsourcing to China: Estimating the Property-Rights Theory of the Firm," *Quarterly Journal of Economics* 120(2), pp. 729-762.

[19] Feenstra, Robert, Zhiyuan Li and Miaojie Yu (2011), "Exports and Credit Constraints under Incomplete Information: Theory and Evidence from China," NBER Working Paper 16940.

[20] Greenaway, David, Alessandra Guariglia, and Richard Kneller (2007), "Financial Factors and Exporting Decisions," *Journal of International Economics* 73, pp. 377-395.

[21] Gross, Till and Stéphane Verani (2012), "Financing Constraints, Firm Dynamics, and International Trade," Finance and Economics Discussion Series 2012-68. Board of Governors of the Federal Reserve System.

[22] Harrison, Ann E. and Margaret S. McMillan (2003), "Does Direct Foreign Investment Affect Domestic Credit Constraints?" *Journal of International Economics* 61, pp.73-100.

[23] Heckman, James and Edward Vytlacil (1998) "Instrumental Variables Methods for the Correlated Random Coefficient Model: Estimating the Average Rates of Return to Schooling when the Return is Correlated with Schooling," *The Journal of Human Resources,* 33(4), Autumn, 974-987.

[24] Héricourt, Jérôme and Sandra Poncet (2009), "FDI and Credit Constraints: Firm Level Evidence in China", *Economic Systems* 33 (1), pp. 1-21.

[25] Kletzer, Kenneth and Pranab Bardhan (1987), "Credit Markets and Patterns of International Trade", *Journal of Development Economics* 27 (1-2), pp. 57-70.

[26] Levchenko, Andrei A., Logan T. Lewis and Linda L. Tesar (2010), "The Collapse of International Trade During the 2008-2009 Crisis: In Search of the Smoking Gun," NBER Working Papers 16006.

[27] Levinsohn, James and Amil Petrin (2003), "Estimating Production Functions Using Inputs to Control for Unobservable," *Review of Economic Studies* 70(2), pp. 317-341.

[28] Lu, Dan (2011), "Exceptional Exporter Performance? Evidence from Chinese Manufacturing Firms," mimeo, University of Chicago.

[29] Manova, Kalina (2012), "Credit Constraints, Heterogeneous Firms and International Trade," *Review of Economic Studies,* forthcoming.

[30] Manova, Kalina, Shang-Jin Wei, and Zhiwei Zhang (2011), "Firm Exports and Multinational Activity under Credit Constraints," NBER working paper no. 16905.

[31] Matsuyama, Kiminori (2005), "Credit Market Imperfections and Patterns of International Trade and Capital Flows," *Journal of the European Economic Association*, 3(2–3), 714–723.

[32] Melitz, Marc (2003), "The Impact of Trade on Intra-industry Reallocations and Aggregate Industry Productivity," *Econometrica* 71(6), pp. 1695-1725.

[33] Muûls, Mirabelle (2008), "Exporters and Credit Constraints: A Firm-level Approach," National Bank of Belgium working paper number 139.

[34] Olley, Steven and Ariel Pakes (1996), "The Dynamics of Productivity in the Telecommunications Equipment Industry," *Econometrica* 64(6), pp. 1263-1297.

[35] Poncet, Sandra, Walter Steingress and Hylke Vandenbussche (2009), "Credit Allocation in China: Firm-Level Evidence", MET 17(2), pp. 3-7.

[36] Qiu, Larry D. (1999), "Credit Rationing and Patterns of New Product Trade," *Journal of Economic Integration*, 14(1), pp. 75-95.

[37] Verani, Stéphane (2011), "Aggregate Consequences of Firm-Level Financing Constraints," Board of Governors of the Federal Reserve System.

[38] Yu, Miaojie (2011), "Processing Trade, Firm Productivity, and Tariff Reductions: Evidence from Chinese Products," CCER Working Paper, No. E201006, Peking University.

Table 1: Basic Statistics for Key Variables (2000-2008)

Variables	Mean	Std.Dev.
Pure Exporters		
Firm's Revenue ($1,000)	6,297	53,514
Firm's Interest Payment ($1,000)	26.80	154.6
Other Chinese Firms		
Firm's Revenue ($1,000)	10,687	129,178
Firm's Interest Payment ($1,000)	115.1	1,525
Export Indicator	.198	.398
Export Share	.096	.249
Export Share Conditional on Exporting	.487	.352
Fitted Export Share	.114	.086
Firm's Log of Capital-Labor Ratio	3.60	1.20
Firm's Tangible Assets Ratio	.985	.050
Intangible Assets Indicator	.183	.386
Foreign Firms		
Firm's Revenue ($1,000)	22,686	168,831
Firm's Interest Payment ($1,000)	205.1	1,688
Export Indicator	.574	.494
Export Share	.325	.383
Export Share Conditional on Exporting	.567	.345
Fitted Export Share	.326	.161
Firm's Log of Capital-Labor Ratio	4.01	1.47
Firm's Tangible Assets Ratio	.984	.043
Intangible Assets Indicator	.301	.458

Notes: Excluding the 36,637 observations for pure exporters, there are 926,543 Chinese firm observations, and 99,742 foreign observations in the sample. Firms revenue and interest payment are converted to dollar using the exchange rate (1 dollar=8.05 Renminbi on average). All foreign (*i.e.,*multinational) firms are defined exclusive of those originating in Hong Kong, Macao, or Taiwan.

Table 2: Benchmark Estimates for Chinese and Foreign Firms (2000-2008)

Data Sample:	Chinese-owned firms		Foreign firms
Regressand: Firm's Revenue	OLS	2SLS	2SLS
	(1)	(2)	(3)
Interest Payment (β_1)	64.83***	79.97***	173.4***
	(31.36)	(55.92)	(10.49)
Interest Payment	-69.72***	-143.5***	-1,714***
$\times$ Fitted Export Share (β_2)	(-2.51)	(-2.10)	(-6.31)
Interest Payment	167.5***	238.7***	2,193***
$\times$ Fitted Square of Export Share (β_3)	(4.49)	(2.53)	(6.22)
Fitted Export Share (β_4)	-12,469***	-6,756***	-25,103***
	(-8.91)	(-6.12)	(-5.10)
Export Indicator (β_5)	7,206***	12.00	2,238*
	(7.02)	(0.04)	(1.95)
Lower Bound $-\frac{1}{2}(\beta_1 + \sqrt{\beta_1^2 + 4\beta_1\beta_3})$	-141.5	-183.7	-708.5
Mean of (positive) Export Share (η_e^m)	0.49	0.49	0.57
Estimated Value of $g_1(\eta_e^m)$	-15.69	-38.59	-564.9
90^{th}% of (positive) Export Share (η_e^u)	0.97	0.99	0.99
Estimated Value of $g_1(\eta_e^u)$	-20.31	-53.47	-748.6
Kleibergen-Paap rk LM χ^2 statistic	–	$27.95^\dagger$	$89.09^\dagger$
Anderson-Rubin Wald F statistic	–	$31.82^\dagger$	$35.61^\dagger$
Industry Fixed Effects	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes
Observations	926,543	909,173	99,814

Notes: T-values shown in parentheses are corrected for clustering at the firm level, using bootstrapped standard errors for 2SLS. *,**(***) indicates significance at the 10, 5 and 1 percent level, respectively. † indicates significance of p-value at the 1 percent level. The OLS estimates in columns (1) use the actual export share rather than the fitted export share. The instruments used in the 2SLS estimation are TFP2, the interaction of TFP2 with the fitted export share from the Heckman estimates in Table 3, and the interaction with the fitted square of the export share. Industry fixed effects at the 1-digit Chinese Industry Classification (CIC) level are included. The estimated values of $g_1(\eta_e^m)$and $g_1(\eta_e^u)$ are obtained by inserting the mean $(\eta_e^m)$and 90th percentile (η_e^u) of the fitted export share into (23), respectively.

Table 3: **The Heckman Two-Step Estimates of Bivariate Selection Model (2000-2008)**

Type of Firms:	Chinese Firms		Foreign Firms	
Heckman Two-step:	1^{st} Step:	2^{nd} Step	1^{st} Step:	2^{nd} Step
	Probit	OLS	Probit	OLS
	(1)	(2)	(3)	(4)
Log of Fitted TFP1	0.035***	–	0.003	–
	(17.50)		(0.60)	
Tangible Assets Ratio	0.939***	0.553***	1.151***	0.644***
	(24.08)	(61.44)	(9.59)	(13.14)
Intangible Assets Indicator	0.497***	0.282***	0.389***	0.209***
	(99.40)	(72.30)	(28.89)	(16.08)
Log of Capital-Labor Ratio	0.010	-0.003***	-0.056***	-0.056***
	(1.11)	(-3.00)	(-2.55)	(-9.33)
Inverse Mills Ratio		0.573***		0.581***
		(57.30)		(10.02)
Log of Capital-Labor Ratio×Year Indicator	Yes	Yes	Yes	Yes
Log of Capital-Labor Ratio×Industry Indicator	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes	Yes
Observations	909,173		99,814	

Notes: T-values shown in parentheses are obtained using bootstrapped standard errors, corrected for clustering at the firm level. *,**(***) indicates significance at the 10,5 and 1 percent level, respectively. A Type-II Tobit model is estimated, with the first step shown by (30). The regressand in the first-step is the firm's export indicator whereas that in the second step is the firm's export share. Columns (1) and (3) are Probit estimates. The inverse Mills ratio in the second-step estimates are obtained from the Probit estimates in the first step. The fitted value of TFP1 is used as an exclusion variable that appears in the first step but not the second step. It is obtained by a preliminary regression of TFP1 on firm-level indicators, on TFP2, on interactions between firms' log of capital-labor ratio with 2-digit industry indicators and year indicators, and on the other explanatory variables in the first step equation. The firm's tangible assets ratio is measured in percentage by using its tangible assets over its total assets. Because about 80% of the sample does not report data for intangible assets, we include an indicator variable equal to unity when that variable is available, and zero otherwise. Industry fixed effects at the 4-digit CIC level, and log of capital-labor Ratio and 2-digit industry indicators are included.

Table 4: 2SLS Estimates by Sea and Non-sea Shipments for Chinese Firms (2000-2006)

Type of Firms:	Matched Chinese Firms		
	All Matched Firms	Interact with Sea Dummy	Interact with Non-sea Dummy
Regressand: Firm's Revenue	(1)	(2)	(3)
Interest Payment (β_1)	77.78***	78.12***	
	(52.20)	(49.44)	
Interest Payment	-252.1***	-335.0***	-166.0**
$\times$ Fitted Export Share (β_2)	(-6.78)	(-2.52)	(-4.51)
Interest Payment	281.8***	432.9***	93.76*
$\times$ Fitted Square of Export Share (β_3)	(6.74)	(2.11)	(2.08)
Fitted Export Share (β_4)	38,538***	55,279***	58,972***
	(5.95)	(7.34)	(7.96)
Export Indicator (β_5)	859.9***	899.1***	
	(2.77)	(2.63)	
Tangible Asset Ratio (β_6)	16,551***	17,380***	
	(9.69)	(9.61)	
Tangible Asset Ratio	-44,435***	-61,889***	
$\times$ Fitted Export Share (β_7)	(-6.39)	(-7.81)	
Tangible Asset Ratio	2,723	1,909	
$\times$ Fitted Square of Export Share (β_8)	(1.56)	(0.99)	
Intangible Asset Indicator	-207.9	-286.2***	
	(-0.73)	(-0.97)	
Mean of (positive) Export Share (η_e^m)	0.446	0.481	0.441
Estimated Value of $g_1(\eta_e^m)$	-75.06	-99.45	-58.70
Year Fixed Effects	Yes	Yes	
Industry Fixed Effects	Yes	Yes	
Number of Observations	536,064	536,064	

Notes: T-values shown in parentheses are obtained using bootstrapped standard errors, corrected for clustering at the firm level. *(**) indicates significance at the 10(5) percent level. We use firm-level data during 2000-2006 and match with customs transaction-level trade data. The regression reported in columns (2)-(3) includes interest payment $\times$ fitted export share $\times$ Sea indicator (and Non-sea indicator); interest payment $\times$ fitted square of export share $\times$ Sea indicator (and Non-sea indicator); and export share $\times$ Sea indicator (and Non-sea indicator) interactions. The Sea indicator is defined as one if the share of firm's exports directly by sea relative to its total exports are higher than 50% and zero otherwise. The Non-sea dummy is defined as (1 – Sea). The instruments used extend those described in Table 2 by interacting with Sea and Non-sea. Industry fixed effects at the 1-digit level are included in all estimates while Hong Kong/Taiwan/Macao firms are excluded. The estimated values of $g_1(\eta_e^m)$are obtained by inserting the mean (η_e^m) of the fitted export share into (23). In columns (2)-(3), the interactions of fitted export share and 1-digit industry indicators and the interactions of fitted export share and year indicators are included.

Table 5: 2SLS Estimates with Measures of Sectoral Productivity Dispersion (2000-2006)

Regressand: Firm's Revenue	(1)	(2)	(3)
Percentile of Sectoral Variance of TFP2	*all*	$>10^{th}$	$>25^{th}$
Interest Payment (β_1)	82.60***	85.55***	87.89***
	(31.41)	(32.90)	(33.29)
Interest Payment	-144.8*	-200.1***	-293.8***
$\times$ Fitted Export Share (β_2)	(-1.85)	(-2.79)	(-4.06)
Interest Payment	151.4	219.7***	399.9***
$\times$ Fitted Square of Export Share(β_3)	(1.37)	(2.09)	(3.66)
Fitted Export Share (β_4)	22,309***	17,517*	7,126
	(2.76)	(1.83)	(0.68)
Export Indicator (β_5)	574.9**	732.7**	878.4**
	(2.00)	(2.03)	(2.22)
Tangible Asset Ratio (β_6)	13,540***	14,166***	13,452***
	(8.09)	(7.71)	(6.97)
Tangible Asset Ratio	-22,877***	-18,396**	-11,968
$\times$ Fitted Export Share (β_7)	(-2.94)	(-2.00)	(-1.20)
Tangible Asset Ratio	-362.0	132.8	302.8
$\times$ Fitted Square of Export Share (β_8)	(-0.17)	(0.06)	(0.13)
Intangible Asset Indicator	1,083***	-879.8***	-961.8***
	(3.08)	(-2.26)	(-2.33)
Cutoffs of Sectoral Variance of TFP2	>0.367	>0.567	>0.670
Mean of (positive) Export Share (η_e^m)	0.487	0.399	0.466
Estimated Value of $g_1(\eta_e^m)$	-18.73	-61.71	-80.62
Year Fixed Effects	Yes	Yes	Yes
Industry Fixed Effects	Yes	Yes	Yes
Observations	604,154	542,893	450,599

Notes: T-values shown in parentheses are obtained using bootstrapped standard errors, corrected for clustering at the firm level. *,**(***) indicates significance at the 10,5 and 1 percent level, respectively. The sample is the same as in Table 4, but now including Hong Kong/Taiwan/Macao firms. To measure the extent of incomplete information in each sector, we take the variance of log TFP2 across firms within an industry, then rank the CIC 2-digit industries by the variance of productivity, while choosing those percentage as cutoffs to run the regressions. The estimated values of $g_1(\eta_e^m)$are obtained by inserting the mean $(\eta_e^u)$of the fitted export share into (23). Industry fixed effects at the 2-digit CIC level are included.