EXPORTS AND CREDIT CONSTRAINTS UNDER INCOMPLETE INFORMATION: THEORY AND EVIDENCE FROM CHINA

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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 need for optimal production. The longer time needed for export shipments induces a tighter credit constraint on exporters than on purely domestic firms. 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.

I. 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 is 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 exports 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 (2013) argue that to the extent that financial variables affected exports, they also affected 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 (2013) in a Melitz (2003) framework and implemented by Manova (2013), 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]

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[1] Other papers dealing with trade and finance are Qiu (1999), Greenaway, Guariglia, and Kneller (2007), Harrison and McMillan (2003), Mûls (2008), Buch et al. (2008), Héricourt and Poncet (2009), Poncet, Steingress, and Vandenbussche (2010), and Egger and Keuschnigg (2011).

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 from 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*) as the financial contracts that arise to offset these risks for exporters. We 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. (2013).[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 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 too. 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.[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 II, we derive the incentive-compatible loan schedule by the bank that maximizes its own profits. Sales revenue of firms is less than

[2] In our working paper (Feenstra, Li, & Yu, 2011), we also included the risk that exporters face 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. (2013) 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.

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

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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 it 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, exporting firms face a tighter credit constraint on both markets than purely domestic firms do.

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, 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 manufacturing firms over the period 2000 to 2008 in sections III and IV. 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 & 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 (2013), who focuses on the financial vulnerability of sectoral exports by showing how production characteristics of the firm (i.e., its export share and mode of transport) and industry (i.e., information incompleteness) influence the credit constraint. But as in Manova (2013), we find that higher collateral can offset the credit constraint and expand exports. Conclusions and directions for further research are discussed in section V, and an online appendix includes additional theoretical and empirical results.[4]

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

II. Incentive-Compatible Loans

A. *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. 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).

Consumers. Consumers are endowed with 1 unit of labor and the preference over the differentiated good displays a constant elasticity of substitution. The utility function of the representative consumer is

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

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

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. They 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 the 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.

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 involved in the shipping of exports.

B. *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:

$$\begin{aligned} \max_{x',q_d} \pi_d(x,x') &= p_d q_d - (1-\delta)\left(\frac{q_d w}{x} + C_d\right) \\ &\quad - \left(M_d(x') + I_d(x')\right), \\ \text{s.t. } & \pi_d(x,x) \geq \pi_d(x,x'), \\ & \pi_d(x,x) \geq 0, \\ & M_d(x') \geq \delta\left(\frac{q_d w}{x} + C_d\right), \end{aligned} \tag{2}$$

and also subject to the domestic demand function in equation (1), where C_d is the fixed cost.[5] The first constraint is the incentive-compatibility constraint, the second ensures that profits are nonnegative, 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 will be binding in equilibrium, we take the derivative of the profit respective to announced productivity, x', to obtain the first-order condition:

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

where

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

The value of Φ_d in the first line of equation (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 the lower is the quantity produced due to this constraint. The second line of equation (4) is obtained by using the binding quantity level in the third constraint and its corresponding price from demand in equation (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 equation (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: $\Phi_d > 1$. The reason this condition is needed is that if the bank specifies loan and interest schedules such that firms are not credit constrained and all profits are paid back to the bank, a firm that is supposed to produce at the monopoly optimum with marginal revenue equal to marginal cost would have only a second-order loss in profits from announcing a slightly smaller productivity x', and producing slightly less. But the firm would have a first-order gain from the reduction in interest payments $I_d'(x) > 0$. 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.

C. *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:

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

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

[5] Notice here that 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.

[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 $Y^* = \tilde{Y}^*\tau^{-\sigma}$.

total loan received by the exporter is denoted by M_e, total interest payments are I_e, and 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 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

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

This condition states that the loan will be allocated within the firm so that marginal revenue in the domestic and export markets is 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 equation (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 equation (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,

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

where

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

and from the equality of marginal revenues in equation (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.

D. Bank's Decision

The monopolistic bank chooses the loans given to domestic firms subject to the incentive compatibility condition, equation (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, equation (10), and the equality of marginal revenue, equation (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:

$$\begin{aligned} \max_{M,I} &\int_{\underline{x}_d}^{\underline{x}_e}\left(I_d(x)-i\tau_d M_d(x)\right)f(x)\,dx \\ &+\int_{\underline{x}_e}^{\infty}\left(I_e(x)-i\tau_d M_e^d(x)-i\tau_e M_e^e(x)\right)f(x)\,dx \end{aligned} \tag{13}$$

$$s.t.\ (3) \text{ if } x\in[\underline{x}_d,\underline{x}_e), \text{ and (10) and (12) if } x\in[\underline{x}_e,\infty),$$

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 those in the Melitz (2003) model, of course, because here they are influenced by the credit conditions offered by the bank.

The maximization problem, equation (13), is solved in two steps. First, we determine the loan schedule that maximizes the 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] We show in the appendix that the optimal loan schedules for the bank are such that

$$\Phi_d\left(x, M_d(x)\right) = \overline{\Phi}_d \equiv (1 + i\delta\tau_d)\left(1 - \frac{\sigma - 1}{\sigma\theta}\right)^{-1},$$
$$\Phi_e^d\left(x, M_e^d(x)\right) = \Phi_e^e\left(x, M_e^e(x)\right) = \overline{\Phi}_e \equiv \left[1 + i\delta\left(\tau_d\eta_d + \tau_e\eta_e\right)\right]\left(1 - \frac{\sigma - 1}{\sigma\theta}\right)^{-1}. \tag{14}$$

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 equation (14). Thus, even when the bank has no opportunity cost of making loans, a credit constraint is still needed to ensure incentive compatibility. When $i > 0$, the credit constraint is further increased, and it is intuitive that the bank will restrict credit more as its opportunity cost rises. 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 equation (14), when $i > 0$. The extra constraint that exporters face will be the key testable implication in our empirical application.

While the solution for the credit constraints implies the slope for the interest payment schedules, from equations (3) and (10), we still need to determine the initial interest payments. Considering first domestic firms, by taking the first derivative of equation (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 equations (3) and (14), the interest payment for domestic firms is

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

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

We show 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 equation (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

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

We also show in the appendix that the lowest-productivity exporting firm, $\underline{x}_e$, is above the cutoff productivity for exporters in the Melitz model.

III. Estimating Equation and Data

A. *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 is linear in these variables, as we show below, but the coefficient on interest payments is a nonlinear function of the credit constraints that domestic firms and exporters face. The credit constraint in turn depends on the firms' share of exports, as shown by η_e and $\eta_d = 1 - \eta_e$ in equation (14). We will end up with an estimating equation that is nonlinear in the export share, which we treat as an endogenous variable: both of 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 equation (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

$$I(x) \equiv \begin{cases} I_d\,(x) & \text{if x} \in \left[\underline{\mathrm{x}}_d, \underline{\mathrm{x}}_e\right] \\ I_e\,(x) & \text{if x} \in \left[\underline{\mathrm{x}}_e, \infty\right] \end{cases},$$

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

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

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

where the coefficients are obtained from above as

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

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

and

$$g_{1jt} = g_1(\eta_{ejt}) = \frac{\sigma}{\sigma - 1}\left(\frac{\overline{\Phi}_e}{\overline{\Phi}_e - 1} - \frac{\overline{\Phi}_d}{\overline{\Phi}_d - 1}\right) \leq 0, \quad (19)$$

$$g_{2jt} = g_2(\eta_{ejt}) = -\frac{\sigma}{\sigma - 1}\left(\overline{\Phi}_e - \overline{\Phi}_d\right) \leq 0,$$

$$g_{3jt} = g_3(\eta_{ejt}) = -\frac{\sigma}{\sigma - 1}\left[\left(\frac{\overline{\Phi}_e}{\overline{\Phi}_e - 1}\right)\Theta i_t + \overline{\Phi}_e C_e\right] \times \mathbf{1}_{\{x_{jt} \geq \underline{\mathrm{x}}_e\}}.$$

We define $\mathbf{1}_{\{x \geq \underline{\mathrm{x}}_e\}}$ as an indicator variable that takes 1 for $x \geq \underline{\mathrm{x}}_e$ and 0 otherwise, and the term $\overline{\Phi}_e$ appearing above depends on the export share η_{ejt} from equation (14).

The coefficient 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 equation (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 equation (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 equation (17) apply only to exporters and indicate additional credit constraints on those firms.

To interpret these extra terms, consider first the function $g_1(\eta_{ejt})$, 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 $\beta_1 + g_1(\eta_{ejt})$, 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 $\beta_0 + g_2(\eta_{ejt})$ for exporters but by only β_0 for domestic firms. So exporters are constrained in what they can earn due to the extra credit constraint that they face through 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 $g_3(\eta_{ejt})$ appearing in equation (17), which also incorporates the extra fixed costs C_e that exporters face. The presence of this term can be traced back to Θ in equation (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 equation (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, and others. So we denote by R_{jt} the actual revenue earned by 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 equation (17).

The presence of this error term 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 affect 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 technique of Olley and Pakes (1996) to make a distinction between the total factor productivity (TFP) of the firm inclusive of the unanticipated, random productivity shocks (what we call TFP1) and the 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 equation (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 equation (17) to obtain

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

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 2 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 equation (20) and simplify to obtain

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

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 equation (14). Estimating equation (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 equation (14), we express g_1 as

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

[9] Note that the troublesome term $v_{1jt}u_{jt}$ appears twice in w_{jt} after the substitutions are made, but with an opposite sign so it cancels out. That occurs because, unlike Heckman and Vytlacil (1998), we start with a exact theoretical relation in equation (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.

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 $\eta_{ejt} = 0$,

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

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 equation (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 equation (23), so that exporters face an additional 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 equation (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 equation (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

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

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, equation (24) together with $\beta_3 > 0$ give us sufficient conditions, expressed in terms 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] Finally, 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 2 tobit model, described below. We use this estimated share to replace $E(\eta_{ejt}|Z_{jt})$ in the estimation. In the appendix, we show 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 equation (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 equation (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 equation (25), as we shall implement by bootstrapping.

To summarize, we interpret equation (25) as an equilibrium relation that holds in our model and aim to test whether this relation with the sign patterns indicated in equations (18) and (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 equation (24).

[10] Like β_2 and β_3, there is still an approximation involved in β_4 by treating it as constant across firms. All of 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 nonsea exports in our later estimation.

[11] In our working paper (Feenstra et al., 2011) we allowed the coefficient β_5 to vary over time as suggested by i_t, but because the results were not that robust, we omit them here. Also, in principle, 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.

[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.

B. *Firm-Level Data*

The sample used in this paper comes from a rich Chinese firm-level panel data set that covers more than 160,000 manufacturing firms per year for the years 2000 to 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: all state-owned enterprises (SOEs) and non-SOEs whose annual sales are more than 5 million renminbi (equivalent to around \$770,000 under the current exchange rate).[14] The non-SOEs can be 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 misreporting by some firms.[15] We clean the sample for mismeasurement 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. Second, the number of employees hired for a firm must not be fewer than ten people.[16] In addition, following Cai and Liu (2009) and guided by General Accepted Accounting Principles, we delete observations if any of the following rules are violated: (a) the total assets must be higher than the liquid assets, (b) the total assets must be larger than the total fixed assets, (c) the total assets must be larger than the net value of the fixed assets, and (d) the established time must be valid.[17] More important, (e) a firm's identification number cannot be missing and must be unique, (f) a firm's sales must be no lower than RMB 5 million, and (g) a firm's interest payment must be nonnegative.

After this rigorous filter, we obtain 963,180 observations, or roughly 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

[13] Data in 2008, which are still not formally released and are available only 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. This is almost identical to the number of observations in 2007 (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 that Chinese firms face. We thank a referee for pointing this out.

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

[16] Levinsohn and Petrin (2003) suggest including all Chilean plants with at least ten workers, and we follow their criterion. Brandt, Van Biesebroeck, and Zhang (2012) suggest dropping firms with fewer than eight employees as such firms "fall in a different regime" in China. We also experimented with such a looser criterion 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.

TABLE 1.—BASIC STATISTICS FOR KEY VARIABLES, 2000–2008

Variables	Mean	SD
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

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

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 SOEs, 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 dropped them.

Multinationals do not appear to apply directly to our theory since they may have additional channels to finance their working capital (Harrison & McMillan, 2003; Manova, Wei, & Zhang, forthcoming). 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, are more likely to be exporters, and have larger export shares than Chinese-owned firms.

One other variable, not reported in table 1, is also used in the estimation. 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 and $K_{jt}(L_{jt})$ is firm j's capital (labor) in 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} depends on the anticipated productivity $TFP2_{jt}$ of the firm according to a functional relation: $V_{jt} = h_1(TFP2_{jt}, \ln K_{jt})$. 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 equation (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 data set. We will use such a merged data set when we examine the role of credit constraints by mode of shipment.

IV. Estimation Results

A. *The Credit Constraint*

To begin to assess the relationship between firm revenue and interest payments in equation (25), note that a simple plot between these variables (taking the averages within two-digit manufacturing sectors) shows a clear, positive relationship as implied by our model.[20] Next, we consider OLS estimates of equation (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 move to the 2SLS estimates, reported in the remaining columns of table 2. In the first two columns, we restrict

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

[19] Note that we use a 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 a firm's TFP in 2008 since it is absent in the current trial version of the data set. We instead use industrial output to replace value-added in that year.

[20] See the appendix, figure A1.

TABLE 2.—BENCHMARK ESTIMATES FOR CHINESE AND FOREIGN FIRMS, 2000–2008

Data Sample	Chinese-Owned Firms		Foreign Firms
Regressand: Firm's Revenue	OLS (1)	2SLS (2)	2SLS (3)
Interest payment (β_1)	64.83***	79.97***	173.4***
	(31.36)	(55.92)	(10.49)
Interest payment × Fitted Export Share (β_2)	−69.72***	−143.5***	−1,714***
	(−2.51)	(−2.10)	(−6.31)
Interest payment × Fitted Square of Export Share (β_3)	167.5***	238.7***	2,193***
	(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 $-\frac{1}{2}\left(\beta_1+\sqrt{\beta_1^2+4\beta_1\beta_3}\right)$	−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
90th% 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†	89.09†
Anderson-Rubin Wald F-statistic	–	31.82†	35.61†
Industry fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	926,543	909,173	99,814

T-values shown in parentheses are corrected for clustering at the firm level, using bootstrapped standard errors for 2SLS. Significant at *10%, **5%, and ***1%. †indicates significance of p-value at the 1% level. The OLS estimates in column 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 one-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 (η_e^m) and 90th percentile (η_e^u) of the fitted export share into equation (23), respectively.

attention to Chinese firms; foreign firms are examined in column 3.

The baseline OLS estimates for Chinese firms in column 1 use 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, firms with higher export shares—say, at the 90th 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.

B. 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 2 tobit model. The bivariate sample selection specification includes an export participation equation,

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

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 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 the 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 equation (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). 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 equation (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 the firm's export decision depends on its collateral, as shown in our working paper (Feenstra, Li, & Yu, 2011). We follow Manova (2013) by using the firm's tangible assets as a measure of collateral. In particular, we model this cutoff productivity as depending

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

on the ratio of the 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 in 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 four-digit sector fixed effects ζ_n. We hence perform the probit model as our first-step Heckman equation:

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

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 address this problem, we include an intangible asset indicator—1 if intangible assets are reported and 0 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 requires 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 the firm's export share (η_e) is not affected by firm productivity, as seen from equation (9), where the export share depends on only 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 a 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 and 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, forthcoming) or such multinationals are vertically integrated and may rely much on their own sales network abroad (Feenstra & 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.

C. *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 equation (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 equation (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 magnitudes 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 important, 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 equation (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

[22] As in the finance literature, the common measure for a 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.

[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) over 2000 to 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.

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

TABLE 3.—THE HECKMAN TWO-STEP ESTIMATES OF BIVARIATE SELECTION MODEL, 2000–2008

Type of Firms:	Chinese Firms		Foreign Firms	
Heckman Two Step:	First Step:	Second Step	First Step:	Second Step
	Probit (1)	OLS (2)	Probit (3)	OLS (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, log(K/L)	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)
Year fixed effects and interacted with log(K/L)	Yes	Yes	Yes	Yes
Industry fixed effects and interacted with log(K/L)	Yes	Yes	Yes	Yes
Observations	909,173		99,814	

T-values shown in parentheses are obtained using bootstrapped standard errors, corrected for clustering at the firm level. Significant at *10%, **5%, and ***1%. A type 2 tobit model is estimated, with the first step shown by equation (30). The regressand in the first step is the firm's export indicator, and 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, and on the other exogenous 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 0 otherwise. Industry fixed effects at the four-digit CIC level are included, along with year fixed effects and the interactions of the log capital-labor ratio with two-digit CIC fixed effects and year fixed effects.

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 90th 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 90th 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 and 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 is 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 Zhang (forthcoming) that foreign subsidiaries in China have alternative sources of credit (i.e., from their parent firms), so 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]

[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 underidentified, 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 significance level of these tests for the use of estimated regressors, we interpret these results with caution.

D. *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 (2013) 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 equation (17), dividing the equation through by ρ, and substituting the above specifications for g_i, we obtain the alternative estimating equation:

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

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.

[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 equations (18) and (19) still hold: see Feenstra et al. (2011) for details.

TABLE 4.—2SLS ESTIMATES BY SEA AND NON-SEA SHIPMENTS FOR CHINESE FIRMS, 2000–2006

Type of Firm	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 × Fitted Export Share (β_2)	−252.1***	−335.0***	−166.0**
	(−6.78)	(−2.52)	(−4.51)
Interest Payment × Fitted Square of Export Share (β_3)	281.8***	432.9***	93.76*
	(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 × Fitted Export Share (β_7)	−44,435***	−61,889***	
	(−6.39)	(−7.81)	
Tangible Asset Ratio × Fitted Square of Export Share (β_8)	2,723	1,909	
	(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	

T-values shown in parentheses are obtained using bootstrapped standard errors, corrected for clustering at the firm level. Significant at *10%, **5%, and ***1%. We use firm-level data for 2000–2006 and match with customs transaction-level trade data. The regression reported in columns 2 and 3 includes Interest Payment × Fitted Export Share × Sea Indicator (and Non-Sea Indicator); Interest Payment × Fitted Square of Export Share × Sea Indicator (and Non-Sea Indicator); and Export Share × Sea Indicator (and Non-Sea Indicator) interactions. The Sea Indicator is defined as 1 if the share of the firm's exports directly by sea relative to its total exports are higher than 50% and 0 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 one-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 equation (23). In columns 2 and 3, the interactions of fitted export share and one-digit industry indicators and the interactions of fitted export share and year indicators are included.

As seen from equation (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 nonnegative, $\rho \in (0, 1]$, collateral is positively associated with revenue (i.e., $\beta_6 > 0$). Analogously, we expect that the effect of collateral on revenue is smaller for exporters and decreases with export share: $\beta_7 < 0$.

When we estimate equation (31) over the entire 2000–2008 sample (not reported), we lose the significance of the key coefficient $\hat{\beta}_2$ on the interaction of the interest payments and the fitted export share. 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 on the earlier years, 2000 to 2006, so that 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 to 2006 sample, using the sample of matched firms in our earlier data set 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 the 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 $\hat{\beta}_1 = 77.8$.

E. Exports by Mode of Transport

As a second extension, we consider breaking up exports into their mode of transport, as Amiti and Weinstein (2011) did. 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 1 if the share of firm's exports directly by sea relative to its total exports is higher than 50% and 0 otherwise. Analogously, we introduce

[29] As explained in note 19, the data for 2008 are 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/Macao/Taiwan-invested firms, since shipping by sea for those firms may involve only very short distances. Those firms are included again in table 5.

TABLE 5.—2SLS ESTIMATES WITH MEASURES OF SECTORAL PRODUCTIVITY DISPERSION, 2000–2006

Regressand: Firm's Revenue Percentile of Sectoral Variance of TFP2	(1) All	(2) >10th	(3) >25th
Interest payment (β_1)	82.60***	85.55***	87.89***
	(31.41)	(32.90)	(33.29)
Interest Payment × Fitted Export Share (β_2)	−144.8*	−200.1***	−293.8***
	(−1.85)	(−2.79)	(−4.06)
Interest Payment × Fitted Square of Export Share(β_3)	151.4	219.7***	399.9***
	(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 × Fitted Export Share (β_7)	−22,877***	−18,396**	−11,968
	(−2.94)	(−2.00)	(−1.20)
Tangible Asset Ratio × Fitted Square of Export Share (β_8)	−362.0	132.8	302.8
	(−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

T-values shown in parentheses are obtained using bootstrapped standard errors, corrected for clustering at the firm level. Significant at *10%, **5%, and ***1%. 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 two-digit industries by the variance of productivity, while choosing those percentages as cutoffs to run the regressions. The estimated values of $g_1(\eta_e^m)$ are obtained by inserting the mean (η_e^m) of the fitted export share into equation (23). Industry fixed effects at the two-digit CIC level are included.

another indicator, Non-Sea, which equals (1 – Sea).[31] We then run a single regression, reported in columns 2 and 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 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.

F. 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 equation (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 and 4.77. We then present estimation results using four different ranges (all, > 10th, and > 25th 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.

V. Conclusion

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

[31] Our estimation results are essentially unchanged if we take other proportions 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.

[32] See the last column of appendix table A1.

and that their productivity is private information. From the revelation principle, the bank can do no better than to offer a loan and interest schedules that lead firms to truthfully reveal this information. We argue that such incentive-compatible schedules will lead to credit constraints on the firms. The reason 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 as to why export sales differ from domestic sales: a longer time lag in exports between production and sales (Berman et al., 2013). 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 (2014) for Belgium, who show that financial variables affect 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 deal 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 a 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.

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