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 needed for first-best production. Exporters are equally constrained on both their domestic and export sales, but more constrained than domestic firms, due to the longer time needed for export shipments. Greater default risk faced by exporters and higher fixed costs interact with this constraint to reduce exports on the extensive margin. The empirical application to Chinese firms strongly supports these theoretical results.

JEL: F1, F3, D9, G2

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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 (2009) argue that trade finance was important in the earlier Japanese financial crisis of the 1990s; in contrast, Levchenko, Lewis and Tesar (2010) find no evidence that trade credit played a role in restricting imports or exports for the recent episode in the United States; on the other hand, Chor and Manova (2010) find that financial vulnerable sectors in source countries did indeed experience a sharper drop in monthly export to the U.S.; 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 Qiu, 1999, Beck, 2002, and Matsuyama, 2005) argued that credit-market imperfections would adversely affect exporters needing more finance and hence influence trade patterns. That theme was picked up in a Melitz (2003) model by Chaney (2005), and implemented by Manova (2008), who argue that credit constraints affect exporting firms in different countries and industries differentially due to fixed costs.[1]

In view of these divergent empirical findings, 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 (2009) argue forcefully for two reasons: exporters face inherently more default risk, since it is more difficult to enforce payment across country boundaries; and there is also a longer time-lag between production and the receipt of sales revenue. They define "trade finance" (as distinct from "trade credit") to be the financial contracts that arise to offset these risks for exporters.[2] To these reasons we add the extra fixed costs faced by exporters, in a Melitz-style model, as a third reason why exporters might need more credit. The goal of this paper is to build these three reasons into a model of heterogeous 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.

[1] Other papers dealing with trade and finance include Qiu (1999), Greenaway, *et al* (2007), Muûls (2008), and Buch, *et al* (2008).

[2] Trade credit refers to an accounting convention whereby accounts receivable for *either* domestic or foreign sales are credited when a shipment takes place and before payment is received.

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. Rather, the loans being made by the bank are for "working capital," to cover the costs of current production, regardless or 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 in the absence of any working-capital needs, 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 first-best 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 first-best; 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 *total* sales revenue of a firm, regardless of whether it is from exports or domestic sales. So a firm engaged in both these activities – which we refer to as an exporting firm – will face an identical credit constaint on exports and domestic sales. But because exports take longer in shipment, exporting firms face a tighter credit constraint on both exports and domestic sales than purely 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, they are not treated differently; but when these activities occur in an exporting and purely domestic firm, they are indeed treated differently. This result come for consideration of the first reason for exports to be treated differently than domestic sales – the time-lag between production and receipt of sales revenue. In contrast, the other two reasons – greater risk or fixed costs for exporters – do not lead to any tightening of the credit constraint, i.e. they do not lead to a further deviation from first-best production by the exporter. But these factors interact with the credit constraint to reduce the extensive margin of exports, and they do so by an amount that is increasing in the tightness of the credit constraint.

These theoretical results are tested using a rich panel dataset of Chinese manufacturing firms over the period of 2000-2007, in section 3. This application is of special interest because China's exports experienced unprecedented growth over the past decades whereas 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). Using China's firm-level data to test our model, we obtain robust empirical evidence that exporting firms face more severe credit constraints than purely domestic firms. We also confirm the empirical finding of Manova, Wei and Zhang (2009) that the credit constraint is much weaker for multinational firms in China.[3]

We note that 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. Midrigan and Xu (2009) take a model of this type and apply it to plant-level data for Colombia and South Korea. Gross and Verani (2010) show how the firm revenue function used in Clementi and Hopenhayn (2006) can arise from a Melitz-style model, and drawing on Verani (2010), 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 and default risk – that we use here. We anticipate that our results would apply in some form to these dynamic models, too. Additional directions for research are discussed in section 4.

[3] That result is found for other developing countries by Harrison and McMillan (2003) and Antràs, Desai and Foley (2009).

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. Each unit of labor in this sector produces a given number of units of the homogeneous good. We assume that both countries produce in this sector and it follows that wages are thus fixed by the 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 constant elasticity of substitution. The utility function of the representative consumer is

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

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. The aggregate price index in the differentiated sector is:

$$P = \left(\int_{\omega \in \Omega} p(\omega)^{1-\sigma} d\omega \right)^{\frac{1}{1-\sigma}}, \tag{1}$$

where $p(\omega)$ is the price of each variety. Accordingly, the demand for each variety is:

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

where $Y \equiv \mu w L$ is the total expenditure on the differentiated good at home.

2.1.2 Firms and the Bank

Firms in the differentated sector need to borrow working capital to finance the fixed and variable costs of their projects. Firms borrow from a single, monopolistic bank, and the bank will charge interest payments to maximize its profits. The bank faces an opportunity cost of i – the interest rate – on its loans. We will assume that the loans for domestic (export) projects are paid back after δ_d (δ_e) periods, and further assume that $\delta_e > \delta_d$, reflecting the longer time-lags involving in the shipping of exports. So the opportunity cost to the bank for a loan extended for domestic or exports sales is $i\delta_d$ and $i\delta_e$, respectively. For convenience, think of both δ_d and δ_e lying between zero and unity, e.g. the fraction of a year that the loan is needed.

In general, only a portion of fixed and variable costs might need be borrowed since some funds could be available internally from within the firm. It will turn out a loan of the amount M for the fraction δ of a year will be equivalent to a loan of the amount δM required for the whole year. So by allowing the parameters δ_d and δ_e to differ between domestic and exports sales, and also allowing it to vary for other firms of type f with parameter δ_f, such as multinationals, we are effectively allowing for full variation in both the time needed for these loans and the amount of the loans in proportion to total costs. For these reasons, we can simplify notation initially by assuming that all firms need to cover 100% of their costs with working capital, while later introducing the parameter δ that vary over domestic sales, exports or type of firm.

2.1.3 Default Risk

We will introduce default risk by supposing that there is some probability that any project (domestic or export) receives its sales revenue, and zero otherwise. Domestic sales are successful with probability ρ_d, meaning that firms receive their revenue $p_d q_d$ with probability ρ_d, and zero otherwise. Likewise, exports are successful with probability $\rho_e < \rho_d$. The lower probability of collecting on export sales can reflect more stringent specifications of quality in foreign countries, which the exporter might not achieve; the difficulty of taking legal action to collect payment across country boundaries; or any other risks associated with exports.

To see the role played by risk, consider the decision of a domestic firm in the *absence* of any credit constraints. Denoting the firm's productivity level by x and domestic fixed cost by C_d, the firm will maximize its expected profit as follows:

$$\max_{q_d} \rho_d p_d q_d - \left(\frac{q_d w}{x} + C_d\right).$$

The firm will then produce at the optimal level and charge a fixed markup: $\rho_d p_d^o(x) = \left(\frac{\sigma}{\sigma-1}\right) \frac{w}{x}$. It is obvious that the probability ρ_d acts like a "discount" on the expected price received, which is

$\rho_d p_d^o(x)$. Using the demand function (2), the expected revenue is:

$$\rho_d r_d^o(x) = \left(\frac{\sigma}{\sigma-1}\right)\frac{wq_d^o(x)}{x} = \rho_d^\sigma \left(\frac{\sigma}{\sigma-1}\frac{w}{x}\right)^{1-\sigma}\frac{Y}{P^{1-\sigma}}. \tag{3}$$

We see that expected revenue falls as a project becomes more risky, so that ρ_d falls. Because we have assumed that $\rho_e < \rho_d$, export projects will earn correspondingly less expected revenue due to their greater risk. We will refer to these price, quantities and revenue earned from domestic sales and exports as the "first best" levels, because they are are obtained in the absence of credit constraints.

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 the annouced productivity level x'. We will assume that the principle of the loan is repaid *for sure* (say, due to some collateral that the firm puts up), but that interest is repaid if and only if the project is successful. Thus, expected interest payment are $\rho_d I_d(x')$.

By the revelation principle, the bank can do not better than to design a loan-interest payment schedule that induces firms to reveal their true productivity, $x' = x$. Adding this incentive compatibility condition condition as a constraint, a domestic firm's profit maximization problem is then:

$$\begin{aligned} \max_{x',q_d} E\left(\pi_d(x,x')\right) &= \rho_d p_d q_d - \left(\frac{q_d w}{x} + C_d\right) - \rho_d I_d(x') \\ \text{s.t.} \qquad & E\left(\pi_d(x,x)\right) \geq E\left(\pi_d(x,x')\right) \\ & E\left(\pi_d(x,x)\right) \geq 0 \\ & M_d(x') \geq \frac{q_d w}{x} + C_d, \end{aligned} \tag{4}$$

and also subject to the domestic demand function in (2). The first constraint is the incentive compatibility constraint; the second ensures that expected profits are non-negative, and the third specifies that the amount of the loan must cover the fixed and variable costs of production at the chosen production level q_d.

The third constraint will be binding in equilibrium, which implies:

$$q_d = \left(M_d(x') - C_d\right)\frac{x}{w}. \tag{5}$$

Provided that the loan and interest payment schedules are differentiable in x', then the incentive-compatibility condition implies that,

$$\left.\frac{\partial E\left(\pi_d(x,x')\right)}{\partial x'}\right|_{x'=x} = 0. \tag{6}$$

By substituting the quantity equation (5) into the demand function (2) we solve for the price. Using that we derive the firms' profits $E\left(\pi_d(x,x')\right)$, and take the derivative as in (6) to obtain:

$$\left[\Phi_d\left(x, M_d(x)\right) - 1\right] M_d'(x) = \rho_d I_d'\left(x\right), \tag{7}$$

where

$$\begin{aligned} \Phi_d\left(x, M_d(x)\right) &\equiv \left[\rho_d p_d \left(\frac{\sigma-1}{\sigma}\right)\right] / \frac{w}{x} \\ &= \rho_d \left(\frac{\sigma-1}{\sigma}\right) \left(M_d(x) - C_d\right)^{-\frac{1}{\sigma}} \left(\frac{xP}{w}\right)^{\frac{\sigma-1}{\sigma}} Y^{\frac{1}{\sigma}}. \end{aligned} \tag{8}$$

The value of Φ_d on the first line of (8) is recognized as the ratio of marginal revenue to marginal costs. Without any credit constraint, we noted above that marginal revenue equals marginal cost, $\rho_d p_d^o(x) = \left(\frac{\sigma}{\sigma-1}\right)\frac{w}{x}$, so that $\Phi_d = 1$. When firms produce quantity below the optimal level $q_d^o(x)$ then $\Phi_d > 1$. This means that Φ_d is a measure of 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 (8) is obtained by using the quantity in (5) and solving for the corresponding price from demand (2). 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 needs to impose credit constraints. Let us suppose that the bank lends more to higher productivity firms, and also collects more in interest payments: we will confirm that these monotonicity conditions hold in the optimal schedules for the bank. Then in (7), both $M_d'(x)$ and $I_d'(x)$ are positive, which necessarily implies that the firm is credit constrained, i.e. $\Phi_d > 1$. The reason this condition is needed is that a firm that is producing at the first-best would have only a *second-order loss* in profits from announcing a slightly smaller productivity x', and producing at a slightly smaller level. But the firm would have a *first-order gain* from the reduction in interest payments $I_d'(x) > 0$. So a firm at the first-best would always understate its productivity. With increasing loan and interest payment schedules, a credit constraint is therefore 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. In comparison with purely domestic firms, exporters have three differences: greater risk on their export sales ($\rho_e < \rho_d$); longer time needed for their export loans (which will affect the bank's problem analyzed in the next section); and of course, additional fixed costs of exporting, which are denoted by C_e.

Similar to the domestic market case, an exporter chooses quantities to produce at domestic market and export market and claims a productivity x' to maximize its expected profit, $E\left(\pi_e(x, x')\right)$,

$$\begin{aligned}
\max_{x', q_d, q_e} E\left(\pi_e(x, x')\right) &= \rho_d p_d q_d - \left(\frac{q_d w}{x} + C_d\right) - \rho_d I_d^e(x') \\
&\quad + \rho_e p_e q_e - \left(\frac{q_e w}{x} + C_e\right) - \rho_e I_e^e(x') \\
\text{s.t.} \quad & E\left(\pi_e(x, x)\right) \geq E\left(\pi_e(x, x')\right) \\
& E\left(\pi_e(x, x)\right) \geq 0 \\
& M_d^e(x') + M_e^e(x') \geq \frac{q_d w}{x} + C_d + \frac{q_e w}{x} + C_e,
\end{aligned} \tag{9}$$

and subject to export demand,

$$q_e = \frac{Y^*}{P^*}\left(\frac{p_e}{P^*}\right)^{-\sigma}, \tag{10}$$

where Y^* is the foreign total expenditure on the differentiated good. 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 differentated good Y^*.[4]

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. For notational convenience, we break up this total loan into the component intended to cover domestic costs, $M_d^e(x')$, and the component intended to cover export costs, $M_e^e(x')$. But from the exporting firm's perspective, these funds are fully fungible so the bank is really just making a single loan.

[4] That is, including iceberg transport costs $\tau > 1$ then export demand is $q_e = \left(\tilde{Y}^*/P^*\right)\left(\tau p_e/P^*\right)^{-\sigma}$, which equals that shown in (10) by defining $Y^* = \tilde{Y}^* \tau^{-\sigma}$.

Likewise, we distinguish the interest payments from the domestic and export loans, $I_d^e(x')$ and $I_e^e(x')$, respectively, but the bank realizes that it will receive a single interest payment, which is $\rho_d I_d^e(x') + \rho_e I_d^e(x')$ in expected value.

Setting up a Lagrangian with the objective function and the third constant, and solving this 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:

$$\rho_d p_d \left(\frac{\sigma - 1}{\sigma}\right) = \rho_e p_e \left(\frac{\sigma - 1}{\sigma}\right). \tag{11}$$

This condition states that the loan will be allocated within the firm so that marginal revenue in the domestic and export markets are equalized. This condition means that for any given loan, the bank will know exactly how production is allocated between the two market. Provided that the bank respects this allocation, we can think of it as providing loans separately to the two markets. That is, for any announcement of productivity x', and subsequent choice of quantities satifying (11), we will define the loans allocated to each market as follows,

$$\begin{aligned} M_d^e(x') &\equiv \frac{q_d w}{x} + C_d \\ M_e^e(x') &\equiv \frac{q_e w}{x} + C_e. \end{aligned} \tag{12}$$

We can readily solve for this allocation of loans by subtracting fixed costs from both sides of (12) and taking the ratio. Then using demand in (2) and (10), combined with the requirement from (11) that the expected prices $\rho_d p_d$ and $\rho_e p_e$ are equalized, it follows that the loans to the two markets are related by:

$$\frac{M_e^e(x) - C_e}{M_d^e(x) - C_d} = \frac{\eta_e}{\eta_d}, \tag{13}$$

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

$$\eta_d = \frac{\rho_d^\sigma Y P^{\sigma-1}}{\rho_d^\sigma Y P^{\sigma-1} + \rho_e^\sigma Y^* P^{*\sigma-1}} \text{ and } \eta_e = \frac{\rho_e^\sigma Y^* P^{*\sigma-1}}{\rho_d^\sigma Y P^{\sigma-1} + \rho_e^\sigma Y^* P^{*\sigma-1}}. \tag{14}$$

We see from (13) that there is a simple, linear relationship between the loans allocated to the two markets. We can now proceed analogously to the domestic firms' problem. We use (12) to determine the quantity sold in each market analogous to (5), depending on the loans $M_d^e(x')$ and $M_e^e(x')$, and substitute into demand (2) and (10) for each market to determine prices. With these we obtain the firms' profits $E\left(\pi_e(x,x')\right)$. Taking the derivative of expected profits with respect to x', and setting that equal to zero, we obtain the condition for incentive compatibility:

$$\left[\Phi_d^e\left(x, M_d^e(x)\right) - 1\right] M_d^{e\prime}(x) + \left[\Phi_e^e\left(x, M_e^e(x)\right) - 1\right] M_e^{e\prime}(x) = \rho_d I_d^{e\prime}(x) + \rho_e I_d^{e\prime}(x), \tag{15}$$

where,

$$\begin{aligned}
\Phi_d^e\left(x, M_d^e(x)\right) &\equiv \left[\rho_d p_d \left(\frac{\sigma-1}{\sigma}\right)\right] / \frac{w}{x} \qquad (16)\\
&= \rho_d \left(\frac{\sigma-1}{\sigma}\right) \left(M_d^e(x) - C_d\right)^{-\frac{1}{\sigma}} \left(\frac{xP}{w}\right)^{\frac{\sigma-1}{\sigma}} Y^{\frac{1}{\sigma}}, \\
\Phi_e^e\left(x, M_e^e(x)\right) &\equiv \left[\rho_e p_e \left(\frac{\sigma-1}{\sigma}\right)\right] / \frac{w}{x} \\
&= \rho_e \left(\frac{\sigma-1}{\sigma}\right) \left(M_d^e(x) - C_e\right)^{-\frac{1}{\sigma}} \left(\frac{xP^*}{w}\right)^{\frac{\sigma-1}{\sigma}} Y^{*\frac{1}{\sigma}},
\end{aligned}$$

and from the equality of marginal revenues in (11) we have that,

$$\Phi_d^e\left(x, M_d^e(x)\right) = \Phi_e^e\left(x, M_e^e(x)\right). \tag{17}$$

The interpretation of these conditions is analogous to what we obtained for domestic firms. The values Φ_d^e and Φ_e^e are the ratio of marginal revenue to marginal costs in the two markets served by the exporter. Credit constraints mean that $\Phi_d^e = \Phi_e^e > 1$, so the firm is 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 (7), and chooses the loans given to exporters for the domestic market $(M_d^e(x))$ and for export market $(M_e^e(x))$, subject to the equality of marginal revenue (17) and the incentive-compatibility conditions (15). A standard property of firm profits under any incentive-compatible policy is that they must be non-deceasing in the true productivity, i.e. $E\left(\pi_d(x,x)\right)$ and $E\left(\pi_e(x,x)\right)$ are nondecreasing in x.[5] This means that the cutoff domestic firm with productivity $\underline{x}_d$ is defined by the zero-cutoff-profit condition $E\left(\pi_d(\underline{x}_d,\underline{x}_d)\right) = 0$, and the cutoff exporter with productivity $\underline{x}_e$ by the condition $E\left(\pi_d(\underline{x}_e,\underline{x}_e)\right) = E\left(\pi_e(\underline{x}_e,\underline{x}_e)\right)$. We will identify addition conditions below needed to ensure that the cutoff exporter, in particular, is well defined.[6]

[5] This is established in Baron and Myerson (1982), and subsequent literature.
[6] See note ??.

The bank's problem is then to choose $M_d(x), M_d^e(x), M_e^e(x), I_d(x), I_d^e(x)$, and $I_e^e(x)$ to maximize its profits:

$$\max_{M,I} \quad \int_{\underline{x}_d}^{\underline{x}_e} (\rho_d I_d(x) - i\delta_d M_d(x)) f(x)\, dx \tag{18}$$

$$+\int_{\underline{x}_e}^{\infty} (\rho_d I_d^e(x) + \rho_e I_e^e(x) - i\delta_d M_d^e(x) - i\delta_e M_e^e(x)) f(x)\, dx$$

$$s.t. \quad (7) \text{ if } x \in [\underline{x}_d, \underline{x}_e),\ (15) \text{ and } (17) \text{ if } x \in [\underline{x}_e, \infty),$$

where i is the opportunity cost of lending the loan for one unit of period and $f(x)$ is the probability density function of firms' productivity distribution. The length of the period that the firm has to hold the loan in the domestic and export market is δ_k, $k = d, e$. We assume that $\delta_e > \delta_d$, reflecting the longer lag between production and sales for exports.

The maximization problem (18) is solved in two steps. First, we determine the loan schedule that maximizes bank's profit, which is an optimal control problem analyzed in Appendix A. The derivative of the optimal loan schedules will be related to the derivative of the interest payments through the incentive-compatibility conditions (7) and (15). 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 obtaining the implied initial interest payments.

2.4.1 The Loan Schedules

The solution for the optimal loan schedules for the bank is simplified using the fact that the credit constraints in the domestic and export market must be equal for an exporter, as in (17). In addition the loans to domestic and export production of the exporter are linearly related by (13), so we only need to analyze one of these, say M_d^e, in addition to the loans M_d provided to domestic firms. It is shown in Appendix A that the optimal loan schedules for the bank satisfies the following conditions:

$$\Phi_d(x, M_d(x)) = (1 + i\delta_d)\left[1 - \left(\frac{\sigma-1}{\sigma}\right)\frac{1-F(x)}{xf(x)}\right]^{-1}, \tag{19}$$

$$\Phi_d^e(x, M_d^e(x)) = (1 + i(\delta_d\eta_d + \delta_e\eta_e))\left[1 - \left(\frac{\sigma-1}{\sigma}\right)\frac{1-F(x)}{xf(x)}\right]^{-1}, \tag{20}$$

where η_d and η_e denotes the relative size of the domestic market and the export market respectively, as in (14), and $F(x)$ is the cumulative density function of x. Note that the second equation applies equally well to $\Phi_e^e(x, M_e^e(x))$, which is the credit constraint faced by the exporter in export market. Substituting the full expressions for $\Phi_d(x, M_d(x))$ from (8) or $\Phi_d^e(x, M_d^e(x))$ from (16) into the above conditions, we obtain nonlinear equations defining the loan schedules for domestic firms and exporters.

To simplify this solution, we consider a Pareto distribution for firms productivity, $F(x) = 1 - (1/x)^{\theta}, x \geq 1$, where θ is the shape parameter. Then the credit constraints above become constant values:

$$\Phi_d(x, M_d(x)) = \overline{\Phi}_d \equiv (1 + i\delta_d)\left(1 - \frac{\sigma - 1}{\sigma\theta}\right)^{-1}, \tag{21}$$

$$\Phi_d^e(x, M_d^e(x)) = \overline{\Phi}_e \equiv (1 + i(\delta_d\eta_d + \delta_e\eta_e))\left(1 - \frac{\sigma - 1}{\sigma\theta}\right)^{-1}. \tag{22}$$

Notice that the weak condition, $\theta > (\sigma - 1)/\sigma$, as we assume holds, is sufficient for $\overline{\Phi}_d$ and $\overline{\Phi}_e$ to be greater than unity.

Then the loan schedules are solved from from (8) and (16) as:

$$\begin{aligned} M_d(x) &= \left(\rho_d \frac{\sigma - 1}{\sigma}\left(\frac{x}{w}P\right)^{\frac{\sigma-1}{\sigma}} Y^{\frac{1}{\sigma}}\right)^{\sigma} \overline{\Phi}_d^{-\sigma} + C_d \\ M_d^e(x) &= \left(\rho_d \frac{\sigma - 1}{\sigma}\left(\frac{x}{w}P\right)^{\frac{\sigma-1}{\sigma}} Y^{\frac{1}{\sigma}}\right)^{\sigma} \overline{\Phi}_e^{-\sigma} + C_d \\ M_e^e(x) &= \left(\rho_e \frac{\sigma - 1}{\sigma}\left(\frac{x}{w}P^*\right)^{\frac{\sigma-1}{\sigma}} Y^{*\frac{1}{\sigma}}\right)^{\sigma} \overline{\Phi}_e^{-\sigma} + C_e. \end{aligned} \tag{23}$$

With these loan schedules, the firm must produce a constant fraction of its optimal quantity,

$$\begin{aligned} q_d(x) &= q_d^o(x)\overline{\Phi}_d^{-\sigma}, \\ q_d^e(x) &= q_d^o(x)\overline{\Phi}_e^{-\sigma}, \\ q_e^e(x) &= q_e^o(x)\overline{\Phi}_e^{-\sigma}. \end{aligned} \tag{24}$$

where $q_d^o(x) = \left(\frac{\sigma}{\sigma-1}\frac{w}{\rho_d x}\right)^{-\sigma}\frac{Y}{P^{1-\sigma}}$ and $q_e^o(x) = \left(\frac{\sigma}{\sigma-1}\frac{w}{\rho_e x}\right)^{-\sigma}\frac{Y^*}{P^{*1-\sigma}}$ are the first-best level of production in the domestic market and export market, respectively, in the absence of a credit constraint.

Examining these solutions, we see that credit constraints for domestic firms and exporters are composed of two terms. First is $\left(1 - \frac{\sigma-1}{\sigma\theta}\right)^{-1}$, which applies even if $i = 0$ in (21) and (22), so that the banks has no opportunity cost of making loans. In that case the credit constraint is still needed to ensure incentive compatibility, as argued above. Second, when $i > 0$ then the credit constraint is further increased and we see that loans are reduced from (23). It is intuitive that the bank will restrict loans as its opportunity cost rises, and furthermore, that the oppotunity cost is measured relative the to time required for the domestic and foreign loans, or δ_d and δ_e, respectively. We have assumed that $\delta_e > \delta_d$, from which it follows that the credit constraint $\overline{\Phi}_e$ for exporters in (22) exceeds $\overline{\Phi}_d$ for domestic firms in (21), when $i > 0$. Furthermore, an exporting firm is constrained to the same degree $\overline{\Phi}_e^{-\sigma}$ in its domestic and export markets – as seen from (24) – which follows from our assumption that the loan is fully fungible within the firm.

Using these solutions for $\overline{\Phi}_d$ and $\overline{\Phi}_e$ in the quantity equations (24), we immediately obtain:

Proposition 1 *Given that productivity is private information to the firms and Pareto distributed, the optimal, incentive-compatible loan schedule set by the bank implies that each firm produces a constant fraction of its optimal quantity. Moreover, when $i > 0$ then an exporter produces a lower fraction of its optimal quantity, in both its domestic and export markets, than a purely domestic firm.*

We note that an alternative interpretation of the solutions above can be obtained by supposing at the outset that domestic projects done by domestic or exporting firms only need to cover a fraction δ_d of their costs by loans from the bank, whereas export projects need to cover a fraction δ_e of their costs by loans; the remainding costs would be covered by cash on hand within the firm. Those parameters enter the final constraints in problems (4) and (9). In this case, we suppose that the time needed for loans to each type of firm is one period, so the opportunity cost to the bank is simply the interest rate i. Then the solutions for the credit constraints are identical to those shown in (21) and (22), and so are the solutions for quantities in (24). More generally, if firms of type f need to cover δ_f of their costs from local loans, then that parameter will multiply i in the credit constraint. Firms affiliated with multinationals, for example, may require less credit from local banks, and so δ_f is lower and so is the credit constraint.

Returning to the case where export sales require loans for longer time than domestic sales, $\delta_e > \delta_d$, we can also investigate the role played by the greater risk faced in export sales, $\rho_e > \rho_d$. While these risk parameters do not impact the domestic credit constraint in (21), they do affect the exporters' constraint in (22) when $i > 0$,, but in a surprising direction. In particular, a rise in ρ_e

will increase the weight η_d and reduce the weight η_e in (14), so that with $\delta_e > \delta_d$ then the exporters' credit constraint $\overline{\Phi}_e$ in (22) is also *reduced*. This result occurs because the bank correctly assumes that exporting firm will apply the same deviation from first-best production to both domestic and export sales, but with increased risk of exporting, export sales are correspondingly lower. Hence, the bank gives greater weight to domestic sales, so that the exporting firm looks more like a domestic firm and its credit constraint is actually loosened.

This surprising result runs contrary to the idea that increased default risk faced by exports – as may have occurred during the financial crisis of 2008 – would result in tighter credit constraints and reduced exports. But there are three reasons to take this result with a grain of salt: (i) it depends on the specification of risk in the repayments to the bank;[7] (ii) it still that case that the level of exports falls with greater risk, as we show now; (iii) it is also the case the greater risk reduces the extensive margin of exports, as we show in the next section.

To show why exports fall with increased risk, it is helpful to consider the *first-best* level of exported export revenue, which equals:

$$\rho_e r_e^o(x) = \left(\frac{\sigma}{\sigma-1}\right)\frac{wq_e^o(x)}{x} = \rho_e^{\sigma}\left(\frac{\sigma}{\sigma-1}\frac{w}{x}\right)^{1-\sigma}\frac{Y^*}{P^{*1-\sigma}}.$$

This first-best export revenue clearly declines as ρ_e falls. Expected export revenue when constrained by credit equals a constant fraction of this first-best expected revenue: $\rho_e r_e^e(x) = \rho_e r_e^o(x)/\overline{\Phi}_e$. Increased risk therefore has two opposing effects on export revenue: reducing it directly in the first-best exports; but raising it indirectly due to the softer credit constraint (reduced $\overline{\Phi}_e$). It can be shown that the first effect dominates the second, so that taking the derivative of (**??**) we obtain,

$$\frac{d\left[\rho_e r_e^e(x)\right]}{d\rho_e} = \sigma r_e^e(x)\left[1-\left(\frac{\overline{\Phi}_e-\overline{\Phi}_d}{\overline{\Phi}_e}\right)\eta_d\right] > 0.$$

Thus, increased risk (lower ρ_e) clearly lowers expected export revenue, in both the first-best and credit-constrained cases, despite the fact that it does not tighten the credit constraint.

[7] We have assumed that the principal of the loans is repaid for sure (due to the firm putting up some collateral, for example), but the interest payment occur if and only if the project is successful so revenue is collected. Instead, suppose that we specify that *both* the principal and interest are repaid if and only if the project is successful. Then we find that the credit constaints for domestic firms instead become: $\Phi_d\left(x, M_d(x)\right) = \left[1+\frac{(1+i-\rho_d)\delta_d}{\rho_d}\right]\left(1-\frac{\sigma-1}{\sigma\theta}\right)^{-1}$. Notice that this constraint is now increasing in ρ_d.Likewise, the credit constaint for exporters in increasing in ρ_e, though there is not a tractable solution for $\Phi_e\left(x, M_e(x)\right)$ because it now depends on x.

2.4.2 The Cutoff Productivity Levels

The solutions for the loan schedules and credit constraints, combined with the incentive-compatibility constraints, immediately imply the slope for the interest payment schedules. But the entire schedules are not pinned down until we also determine their initial values. As discussed above, the initial interest payment for a domestic firm will determine $\underline{x}_d$ via the zero-cutoff-profit condition $E\left(\pi_d(\underline{x}_d, \underline{x}_d)\right) = 0$, and likewise the initial interest payment for the marginal exporter will determine $\underline{x}_e$ via the condition $E\left(\pi_d(\underline{x}_e, \underline{x}_e)\right) = E\left(\pi_e(\underline{x}_e, \underline{x}_e)\right)$. So we can solve for the initial interest payments by differentiating (18) with respect to $\underline{x}_d$ and $\underline{x}_e$, and using these first-order conditions to determine the initial interest payments, as discussed in Appendix A.

By taking the first derivative of (18) respect to $\underline{x}_d$ and $\underline{x}_e$, we can get the loan and the interest payment for the cutoff domestic firm,

$$M_d(\underline{x}_d) = \sigma C_d, \tag{25}$$

$$\rho_d I_d(\underline{x}_d) = \left(\overline{\Phi}_d - 1\right) M_d(\underline{x}_d). \tag{26}$$

Notice that even though the loan σC_d is the same as needed to finance first-best production in Melitz (2003), the cutoff productivity $\underline{x}_d$ is *higher* than the first-best cutoff productivity, because the interest payment for the cutoff producer is greater than zero. That is, for firms with productivity slightly lower than $\underline{x}_d$, they would be able to enter the domestic market and earn profits in the absence of credit constraints. However, due to the private information, the bank has to impose credit constraint in order to induce firms to reveal their true productivity. Consequently, such firms are prevented from entering the market.

The solution for the initial loan and interest payment to the cutoff exporter are slightly more complicated:

$$M_d^e(\underline{x}_e) + M_e^e(\underline{x}_e) = \left(\Delta\left(\sigma - 1\right) + 1\right) C_e + C_d, \tag{27}$$

$$\rho_d I_d^e(\underline{x}_e) + \rho_e I_e^e(\underline{x}_e) = \left(\overline{\Phi}_e - 1\right)\left(M_d^e(\underline{x}_e) + M_e^e(\underline{x}_e)\right) + \Theta, \tag{28}$$

where the parameters in the above equations are:

$$\begin{aligned}
\Delta &\equiv \frac{(1+i\delta_e)}{(1+i\delta_d\eta_d + i\delta_e\eta_e)}\left(1 - \left(\frac{1+i\delta_d\eta_d + i\delta_e\eta_e}{1+i\delta_d}\right)^{\sigma-1}\eta_d\right)^{-1}, \\
\Theta &= \frac{i\left(\delta_e - \delta_d\right)}{\left(1 - \frac{\sigma-1}{\sigma\theta}\right)}\left(\eta_d C_e - \eta_e C_d\right).
\end{aligned}$$

To interpret these parameters, consider first the case where $i = 0$. Then we see that $\Delta = 1/(1-\eta_d) = 1/\eta_e$, or the inverse of the relative size of the export market. It can be confirmed that this level of loans in (27) leads to a loan level for the export market, $M_e^e(\underline{x}_e) = \sigma C_e$, and consequently an expected profit from the export market before paying back the interest payment, $\sigma\overline{\Phi}_e C_e$. This export loan for the cutoff exporter is precisely equal to the export costs of first-best production for the cutoff exporter in the Melitz (2003) model. Turning to the parameter Θ,it is the "extra" amount of interest payment charged to the cutoff exporter, over and above the first term on the right of (28). When $i = 0$ then $\Theta = 0$.

Now consider $i > 0$. It is readily confirmed that Δ is increasing in i under our maintained assumption that $\delta_e > \delta_d$.[8] This implies that $\Delta > 1/\eta_e$ for $i > 0$, so the level of loans given to the marginal exporter in (27) will *rise*. That result may sound counter-intuitive since the bank is facing a higher opportunity cost of funds. But it is explained by the fact that rising loans indicates from the loan schedules in (23) that the marginal exporter $\underline{x}_e$ *must be rising*. In other words, with a positive opportunity cost of funds, even more exporters are excluded from that market. Interest payments depend on Θ, and for $i > 0$ we see that $\Theta > 0$ if and only if $\eta_d/C_d > \eta_e/C_e$, i.e. the domestic market size relative to fixed costs exceeds that for the export market. That condition is a standard assumption in the Melitz model, and we also make it here. Then as the interest rate i rises, the interest payments for the cutoff exporter are also rising, for several reasons: because loans increase; because $\overline{\Phi}_e$ increases; and because Θ also increases. So the cutoff exporter is receiving higher loans but also making higher interest payments.

Formally, combining (25) and (27) with the loan schedules in (23) we can explicitly solve for the cutoff productivities as follows,

$$\underline{x}_d = w\left(\left(\frac{\sigma}{\sigma-1}\right)\left(\frac{(\sigma-1)\,C_d}{\rho_d^{\sigma}YP^{\sigma-1}}\right)^{\frac{1}{\sigma}}\overline{\Phi}_d\right)^{\frac{\sigma}{\sigma-1}}, \tag{29}$$

$$\underline{x}_e = w\left(\left(\frac{\sigma}{\sigma-1}\right)\left(\frac{\Delta\,(\sigma-1)\,C_e}{\rho_d^{\sigma}YP^{\sigma-1}+\rho_e^{\sigma}Y^{*}P^{*\sigma-1}}\right)^{\frac{1}{\sigma}}\overline{\Phi}_e\right)^{\frac{\sigma}{\sigma-1}}. \tag{30}$$

It is obvious that when there are credit constraints such that $\overline{\Phi}_d > 1$, the cutoff productivity $\underline{x}_d$

[8] There is an upper bound in i, since we argue in Appendix A that $\left(\frac{(1+(\delta_d\eta_d+\delta_e\eta_e)i)}{(1+i\delta_d)}\right)^{\sigma-1}\eta_d < 1$ is needed to ensure that $E\left(\pi_e(x,x)\right)$ has a larger slope than $E\left(\pi_d(x,x)\right)$. This slope condition holds automatically in the Melitz model, but here we need to add it an extra assumption in order to get a well-defined solution for the marginal exporter.

is *higher* than the first-best cutoff productivity which is achieved when $\overline{\Phi}_d = 1$. Similarly, when interest rate $i = 0$ and $\overline{\Phi}_e = 1$, the cutoff exporter, $\underline{x}_e$, exactly equals that in the Melitz (2003) model. Thus, when interest rate increases above zero so that $\Delta > 1/\eta_e$ and credit constraints are present so that $\overline{\Phi}_e > 1$, then the cutoff exporter $\underline{x}_e$ must also rise.

The cutoff productivities indicate that a rise in interest rates has a greater impact on exporters than on domestic producers, for two reasons. First, the credit constraint on exporters, $\overline{\Phi}_e$, increases faster in interest rate than the credit constraints on pure domestic firms, $\overline{\Phi}_d$. Second, increasing interest rates also increases Δ, which affects the cutoff exporter in (30) but not the domestic firm in (30).

We summarize these results with:

Proposition 2 *The credit constraint imposed by the bank decreases firm's production both in the extensive margin and the intensive margin, even when interest rate $i = 0$. Moreover, as i increases, the impact of the credit constraint on the extensive margin of exports is more severe than on the extensive margin of domestic production.*

This proposition comes from consideration of the first reason for exports to be treated differently than domestic sales: the time-lag between production and receipt of sales revenue. The other two reasons – default risk and fixed costs of exporting – also have an impact on the extensive margin of exports, as seen from (30). An increase in the risk of exporting, which is a fall in ρ_e, directly increases $\underline{x}_e$. But there is an offsetting indirect effect via the credit constraint $\overline{\Phi}_e$, which we argued above is reduced when ρ_e falls. Combining these two effects, we obtain the derivative:

$$\frac{d\underline{x}_e}{d\rho_e} = -\left(\frac{\sigma}{\sigma-1}\right)\frac{\underline{x}_e \Delta \eta_e}{\rho_e}\left[1 - \frac{\sigma i(\delta_e - \delta_d)\eta_d}{1 + i\delta_e}\right].$$

Provided that the weak condition $\sigma i(\delta_e - \delta_d)\eta_d < 1 + i\delta_e$ holds, then this derivative is negative, so the increased risk of reduces the extensive margin of exporters. Furthermore, as the credit constraint tightens due to a rising interest rate, then this derivative becomes more negative, at least in the neighborhood of $i = 0$:

$$\left.\frac{d^2\underline{x}_e}{d\rho_e di}\right|_{i=0} < 0.$$

Thus, there is an interaction between a tightened credit constraint due to rising i and the impact of risk on the extensive margin of exports.

The same interaction holds for the impact of fixed costs of exporting on the extensive margin. It is immediate from (30) that the extensive margin $\underline{\mathrm{x}}_e$ is rising in the fixed costs C_e, just as occurs in the Melitz (2003) model.What is new here is that the derivative of $\underline{\mathrm{x}}_e$ with respect to fixed costs is increasing in the interest rate i, which raises both $\overline{\Phi}_e$ and Δ in (30). That is, when the credit constraint is tighter than higher fixed costs will have a greater impact on reducing the extensive margin of exports.

3 Data, Empirics, and Results

3.1 Empirical Specification

We can use our results above to derive a linear relationship between (expected) interest payments and (expected) revenue of the firm, where the coefficients of this linear relationship depend on the credit constraints faced by domestic firms and exporters. This equation will be tested using data on Chinese firms.

To derive this relationship, start with domestic firms. The loans $M_d(x)$ are needed to finance total costs, so $M_d(x) - C_d$ are needed for variable costs. The ratio of (expected) marginal revenue to marginal costs is $\overline{\Phi}_d$, and the ratio of (expected) price to (expected) marginal revenue for CES demand is $\sigma/(\sigma - 1)$. Therefore, the total expected sales revenue $\rho_d r_d(x)$ obtained from the working-capital loans of $M_d(x)$ are $\rho_d r_d(x) = (M_d(x) - C_d)\,\overline{\Phi}_d\sigma/(\sigma - 1)$.

In our data we will not observe total loans to firms, but rather, total interest payments. From the incentive-compatibility condition (7) combined with the initial interest payments (26), it is immediate that,

$$\rho_d I_d(x) = \left(\overline{\Phi}_d - 1\right) M_d(x), \text{ for } x \in [\underline{\mathrm{x}}_d, \underline{\mathrm{x}}_e).$$

Substituting for the expression for expected revenue, we immediately obtain:

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

A similiar line of argument will show that the relationship between expected revenue and loans for an exporting firm is,

$$\begin{aligned}
&\rho_d r_d^e(x) + \rho_d r_e^e(x) \\
= &\frac{\sigma\overline{\Phi}_e}{(\sigma-1)}\left(M_d^e(x) + M_e^e(x) - C_d - C_e\right) \\
= &\frac{\sigma\overline{\Phi}_e}{(\sigma-1)}\left(\frac{\rho_d I_d^e(x) + \rho_e I_e^e(x)}{\overline{\Phi}_e - 1} - \frac{\Theta}{\overline{\Phi}_e - 1} - C_d - C_e\right) \\
= &\frac{\sigma}{(\sigma-1)}\left(\left(\rho_d I_d^e(x) + \rho_e I_e^e(x)\right)\frac{\overline{\Phi}_e}{(\overline{\Phi}_e - 1)} - \left(\frac{\Theta}{(\overline{\Phi}_e - 1)} + C_d + C_e\right)\overline{\Phi}_e\right),
\end{aligned}$$

where the first line follows from the fact that the exporter faces the credit constraint (ratio of marginal revenue to marginal costs) of $\overline{\Phi}_e$ on all its sales; and the second equality from (15) with (28).

To summarize the above relations into our estimating equation, denote the expected interest payments and firm revenue as,

$$E\left(I(x)\right) = \begin{cases} \rho_d I_d(x) & \text{if x} \in [\underline{\mathrm{x}}_d, \underline{\mathrm{x}}_e] \\ \rho_d I_d^e(x) + \rho_e I_e^e(x) & \text{if x} \in [\underline{\mathrm{x}}_e, \infty] \end{cases}$$

and,

$$E\left(r(x)\right) = \begin{cases} \rho_d r_d(x) & \text{if x} \in [\underline{\mathrm{x}}_d, \underline{\mathrm{x}}_e] \\ \rho_d r_d^e(x) + \rho_e r_e^e(x) & \text{if x} \in [\underline{\mathrm{x}}_e, \infty] \end{cases}$$

In addition, define $\mathbf{1}_{\{x \geq \underline{\mathrm{x}}_e\}}$ is an indicator variable which takes one for $x \geq \underline{\mathrm{x}}_e$ and zero otherwise. In our estimation reported here, we will measure this variable by an indicator variable for *exporting* by the firm. In future work we will estimate the probability of exporting with a selection equation, and use the predicted cutoff value of firm productivity $\underline{\mathrm{x}}_e$ from that equation to measure $\mathbf{1}_{\{x \geq \underline{\mathrm{x}}_e\}}$.

Using these various definitions, we obtain a linera relation between expected firm revenue and interest payments,

$$E\left(r(x)\right) = \beta_0 + \beta_1 E\left(I(x)\right) + \beta_2 E\left(I(x)\right)\mathbf{1}_{\{x \geq \underline{\mathrm{x}}_e\}} + \beta_3 \mathbf{1}_{\{x \geq \underline{\mathrm{x}}_e\}} + \gamma_i + \gamma_t + \epsilon_{it}, \tag{31}$$

where the coefficients are obtained from above as:

$$\begin{aligned}
\beta_0 &= -\frac{\sigma}{(\sigma-1)}\overline{\Phi}_d C_d < 0, \qquad (32) \\
\beta_1 &= \frac{\sigma}{(\sigma-1)}\frac{\overline{\Phi}_d}{(\overline{\Phi}_d - 1)} > 0, \\
\beta_2 &= \frac{\sigma}{(\sigma-1)}\left(\frac{1}{\overline{\Phi}_e - 1} - \frac{1}{\overline{\Phi}_d - 1}\right) < 0, \\
\beta_3 &= -\frac{\sigma}{(\sigma-1)}\left(\left(\overline{\Phi}_e - \overline{\Phi}_d\right)C_d + \overline{\Phi}_e\left(\frac{\Theta}{\overline{\Phi}_e - 1} + C_e\right)\right) < 0.
\end{aligned}$$

This pattern of signs is obtained from our findings above that the exporter faces more stringent credit constraints for $i > 0$ ($\overline{\Phi}_e > \overline{\Phi}_d$), and our argument that $\Theta > 0$. We see in particular that the coefficient β_2 on the interaction between expected interest and the export indicator is negative, and the coefficient β_3 on the export indicator itself is also negative, reflecting the tighter credit constraints for exporting and also the extra fixed costs. Thus, the fixed costs of exporting enter the estimating equation through the (negative) coefficient on the export indicator variable, but not through the (negative) coefficient on the interaction between interest payments and the export indicator

We include the error term in (31), which can be decomposed into the three following components: (i) firm-specific fixed effects γ_i to control for time-invariant factors; (ii) year-specific fixed effects γ_t to control for firm-invariant factors; and (iii) an idiosyncratic effect ϵ_{it} with normal distribution $\epsilon_{it} \sim N(0, \sigma_i^2)$ to control for other unspecified factors. Since the last term in the right includes firm's fixed cost for export market, later we shall introduce an interaction term between export dummy and industry-specific fixed effects into the estimation as a robustness check. In addition, when estimating (31) we will interact all right-hand side variables with an indicator variable for multinational firms operating in China. Including that indicator and its interactions will allow the credit constraints to be weaker for multinationals, as we expect from the results of Manova, Wei and Zhang (2009).

3.2 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 2000-2007. The number of firms doubled from 162,885 in 2000 to 336,768 in 2007. The data are collected and maintained by China's National Bureau of Statistics in an annual survey of manufacturing enterprises.[9] 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 $735,000 under current exchange rate). 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 contains rich information, a few samples in the data set are noisy and

[9] Indeed, aggregated data on the industrial sector in the annual *China's Statistical Yearbook* by the Natural Bureau of Statistics (NBS) are compiled from this dataset.

misleading due, in large part, to the mis-reporting by some firms.[10] Following Jefferson *et al.*(2008), we clean the sample and rule out outliers by using the following criteria: first, observations whose key financial variables (such as total assets, net value of fixed assets, sales, gross value of industrial output) cannot be missing; otherwise, they will be dropped. Secondly, the number of employees hired for a firm must not be less than 10 people.[11] 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: (1) the total assets must be higher than the liquid assets; (2) the total assets must be larger than the total fixed assets; (3) the total assets must be larger than the net value of the fixed assets; (4) a firm's identification number cannot be missing and must be unique; and (5) the established time must be valid. In particular, observations in which the opening year is after 2007 or the opening month is later than December or earlier than January are dropped as well.

Since multinationals as well as SOEs potentially stand out in the data, it is an advantageous to take a careful look at these firms. We first construct a dummy for multinationals to distinguish foreign from non-foreign firms.[12] In a robustness check, we consider a broader classification of multinationals by including the Hong Kong/Macao/Taiwan (H/M/T)-invested firms.[13] Turning to the indicator for SOEs,[14] to keep the estimation results compatible across firm's type, we use large SOEs as a default sample by dropping SOE observations whose operation scales are smaller than the threshold for large firms. In particular, the observations are dropped if any of following indicators is lower than \$735,000 under current exchange rate level: (1) the value of the firm's sales; or (2) the value of the total assets; or (3) the value of the fixed assets.

After this rigorous filter, we obtain a sample of $998,223$ observations from the original sample

[10] 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*. Holz (2004) offers careful scrunity on possible measurement problems in Chinese data, especially on the aggregated level.

[11] Levinsohn and Petrin (2003) suggest covering all Chilean plants with at least 10 workers. Here, we follow their cretirion.

[12] Specifically, multinationals include the following: foreign-invested joint-stock corporations (code: 310), foreign-invested joint venture enterprises (320), fully foreign-invested enterprise (330), and foreign-invested limited corporations (340).

[13] Specifically, the H/M/T-owned firms includes the following firms: H/M/T/ joint-stock corporations (code: 210), H/M/T joint venture enterprises (220), fully H/M/T-invested enterprises (230), and H/M/T-invested limited corporations (340).

[14] By definition, SOEs include firms such as domestic SOEs (code: 110); state-owned joint venture enterprises (141); state-owned and collective joint venture enterprises (143); and state-owned limited corporations.

of $1,898,958$, which accounts for around a half of the original data set. As shown in Table 1, during years 2000-2007, the fraction of SOEs is only 3.8% on average. In contrast, multinationals accounts for 10.5% of total firms but increases to 21.5% if including investment from H/M/T. On average, foreign firms have higher revenue and more interest payment than domestic firms. Similarly, exporting firms, which account for around 30% in the sample, also have higher revenue and more interest payment than firms which sell products domestically only.

[Insert Table 1 Here]

3.3 Measure of TFP

TFP is usually measured as the Solow residual, defined as the difference between the observed output and its fitted value calculated via OLS. However, this method suffers from two biases: a simultaneity bias and a selection bias. The first bias comes from the fact that a profit-maximizing firm would readjust its input decision as a response to productivity shocks that are observed by firms but not by econometricians. Second, all firms covered in the samples are those that have relatively high productivity and survived during the period of investigation. Those firms that had low productivity, shut down, and left the market were not observed nor included in the sample. Put another way, the sample covered in the regressions is not randomly selected. Hence, all related estimates would suffer from a selection bias.

To overcome these two empirical challenges, we use the augmented Olley-Pakes (1996) approach to estimate and calculate the firms' TFP. The technical details of the Olley-Pakes (1996) approach is described in Appendix B. Here we only stress several novel modification. First, given that the measure of TFP requires real terms of firm's inputs (labor and capital) and output, we first adopt different price deflators for inputs and outputs. Data on input deflators and output deflators are directly from Brandt *et al.* (2009) in which the output deflators are constructed using "reference price" information from *China's Statistical Yearbooks* whereas input deflators are constructed based on output deflators and China's national input-output table (2002).[15] Second, we use deflated firm's value-added to measure production since we do not include intermediate input (materials) as one kind of input factors. The reason is that processing trade in China accounts for more than a half of its total trade since 1995. The prices of imported intermediate inputs are different from

[15] Such data can be accessed from http://www.econ.kuleuven.be/public/N07057/CHINA/appendix/.

those of domestic intermediate inputs. Using China's domestic deflator to measure its imported intermediate input would raise another unnecessary estimation bias.

Third, it is essential to construct the real investment variable when using the Olley-Pakes (1996) approach. As usual, we adopt the perpetual inventory method to investigate the law of motion for real capital and real investment. Different from assigning an arbitrary number for the depreciation ratio, we use the exact firm's real depreciation provided by the Chinese firm-level data set. Last but not least, given China's WTO accession in 2001, which was a positive demand shock for China's exports, we also include a WTO dummy in the Olley-Pakes estimations to capture the effect of the WTO accession.

Columns (1)-(2) of Table 2 reports the estimated elasticity coefficient of labor and capital for the thirty China's manufacturing sectors coded from 13 to 42, according to China's adjusted industrial classifications (GB/T4754), which were adopted in 2002.[16] On average, the estimated elasticity for labor is .399 and for capital is .278. Accordingly, the average (natural) logarithm of China's TFP is 4.214, as presented in Table 1. We then separate all firms in the sample to two groups: domestic firms which only sell their products at home, and export firms which sell their products both at home and abroad. Overall, the log of TFP for domestic firms (4.486) is smaller than its counterpart for exporting firms (4.521). Columns (3)-(4) of Table 2 presents the estimated TFP for domestic firms and exporting firms by manufacturing sectors.

[Insert Table 2 Here]

3.4 Preliminary Estimates

Before running regressions, it is worthwhile to have a glance of the data pattern for key variables. Figure 1 clearly demonstrates that firm's revenue is positively associated with its interest payment, by taking the average over the years 2000-2007 and summing up to 2-digit manufacturing sectors. This suggests that the more the interest payment, the higher revenue that the firm generates.

[Insert Figure 1 Here]

The main message gleaned from Figure 1 can be ascertained by performing benchmark OLS estimations. As shown in Column (1) of Table 3, the coefficient of firm's interest payment is

[16] Firm data before 2002 were clustered into industrial data by adopting the old industrial classification. We concord such data so that they are consistent with data after 2002.

significantly positive. Such a finding is preserved in Column (2) by using the industry-specific and year-specific fixed effects and even in Column (3) by considering the product of expect dummy and industry-specific fixed effects. In Column (4) with the firm-specific and year-specific fixed effects, the total effect of firm's interest payment on its revenue is still positive, though its economic magnitude becomes smaller.

However, the coefficient of interest payments interacted with the export indicator is positive in Table 3, and marginally significant. That finding contradicts our theoretical prediction. We believe the reason is due to the endogeneity of firms' interest payment, which shall be addressed now.

[Insert Table 3 Here]

3.5 Endogeneity Issues

Firms' interest payments are not exogenously given, but affected by its size. A firm with higher revenue would in turn has stronger demand on external finance to do business. To obtain the accurate estimation results, we need to control for the endogeneity of interest payment by choosing an appropriate instrumental variable (IV).[17] As seen from (23), the loan schedules are the function of firm's productivity. Thus our theory clearly suggests that the level of firm's TFP is a good candidate of IV. The intuition is straightforward. Under the incentive compatible conditions set by the bank, firms with higher productivity are easier to access to bank's loans, which in turn generates more interest payment.

Table 4 reports the 2SLS estimates using the export dummy to measure the indicator variable $\mathbf{1}_{\{x \geq \mathrm{x}_e\}}$. There are four endogenous variables in the estimations: (1) interest payment itself; (2) an interaction term between interest payments and the export indicator; (3) an interaction term between interest payments and the foreign firm indicator;; and (4) and the triple interaction between the interest payments, export indicator and foreign firm indicator. Accordingly, we adopt four instruments here: the level of firm's TFP (x_{it}) itself, the interaction terms between firm's level of TFP and the export indicator, the export indicator itself, and the interaction term between firm's level of TFP, export indicator, and foreign firm indicator.

The first-stage regression results shown in the lower module of Table 4 offer strong evidence to justify the validity of such instruments. In particular, in Columns (1)-(4), the t-values of the four

[17] The IV approach is a good way to control for endogeneity issues. Wooldridge (2002, Chapter 5) provided a careful scrutiny of this topic.

endogenous regressors are highly statistically significant. In addition, the excluded F statistics in the first stage are also significant. These tests give sufficient evidence that the instruments perform well, and therefore, the specification is well justified both theoretically and statistically.[18]

Column (1) of Table 4 reports the 2SLS estimation results with year-specific fixed effects. Similar to the OLS firm-specific and year-specific fixed-effect estimates in last column of Table 3, the coefficient of interest payment itself is positive. More importantly, the coefficient of truncated interest payment now turns to be significantly negative. Thus, after controlling for the endogeneity of interest payment, our estimation result confirms with the theory that exporting firms face more stringent credit constraint: $\overline{\Phi}_e > \overline{\Phi}_d$.

The capability of accessing to bank's loans differ across sectors. As observed from Figure 1, state-owned monopolistic industries such as tobacco (code in Figure 1: 16) and processing of petroleum (code: 25) would be much easier to get bank's loans than others such as apparel (code:17) and footwear (code: 18) in China. To control for such industrial heterogeneity, the 2SLS estimate in column (2) of Table 4 includes both industry-specific fixed effects and year-specific fixed effects and still finds similar results as in column (1). Moreover, as shown in (31), exporting firms have to pay more fixed cost than the domestic firms due to the presence of its up-front exporting fixed cost: these are the terms making up $\beta_3 < 0$, including $C_e\overline{\Phi}_e$. To control for such an issue, in addition to the inclusion of the export indicator, column (3) includes the interaction of export dummy and industrial fixed effects, as well as industrial fixed effects and year-specific fixed effects, and still finds results as before. In column (4) provide the 2SLS estimation results by controlling for both firm-specific and year-specific fixed effects and still find robust results as above.

[Insert Table 4 Here]

[18] In addition, we also perform several additional tests to check for the validity of instruments: First, we use the Kleibergen-Paap (2006) Wald statistic to check whether or not the two excluded instruments are correlated with the endogenous regressors. The null hypothesis that the model is under-identified is rejected at the 1% significance level. Second, The Kleibergen-Paap (2006) F-statistics provide strong evidence to reject the null hypothesis that the first stage is weakly identified at a highly significant level. Third, the Anderson and Rubin (1949) χ^2 statistics reject the null hypothesis that the coefficients of the endogenous regressor equal zero. We do not report results of such tests in the text though available upon request.

4 Concluding Remarks

In this paper, we first constructed a model to why firm's will face credit constraints on their domestic sales and exports. We rely on the idea that firm's must obtain working capital prior to production, but that their productivity is private information. From the revelation principle, the bank can do no better than offer loan and interest schedule that lead the firms to truthfully reveal this information. We argue that such incentive-compatible schedules will involve 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 and produce at the first-best.

We have built into the model three reasons why export sales differ from domestic sales: due to longer time-lag in exports between production and sales; due to higher default risk in exports; and due to additional fixed costs of exports. Our results show that the first of these reasons – the time needed for the loan – is most important in determined credit constraints. This reason will lead banks to impose a more stringent credit constraint on exporters, for both their exports and domestic sales, than on purely domestic firms. Having a great default risk on export payment may or may not lead to strong credit constraints, depending on the specification of loans repaid in the event of default from the buyer. Finally, the additional fixed costs of exporter also restricts the sales of exporters, but by an amount that is equal across exporters (i.e. this additional constraints does not interact with the amount of interest payments).

Our theoretical result that the exports and domestic sales of a firm should face the same credit constraint corresponds most closely to the empirical finding of Behrens, Corcos and Mion (2010) for Belguim, who show that financial variables impact both types of sales equally within a firm. This contrasts to the empirical findings of Amiti and Weinstein (2009) for Japan, 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 are arguably capturing the "trade finance" activities of these banks, targetted specifically at exports, whereas our model and empirical work deals with working-capital loans in general, as noted above.

Several extensions and possible generalizations merit special consideration. One of them is to endogenize the internal finance via multinational corporation *a là* Antràs *et al.* (2009). Another possible extension is to consider outward foreign direct investment (FDI) into the model in the sense that firms with higher productivity would perform outward FDI in addition to exports. A third is to introduce dynamics into the model, along the lines of Clementi and Hopenhayn (2006) and Gross and Verani (2010). These are all interesting topics to explore in the future.

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Table 1: Basic Statistics for Key Variables (2000-2007)

Variables	Mean	Std.Dev.
Firm's Revenue ($1,000)	11,426	101,780
Domestic Firm's Revenue ($1,000)	7,380	45,003
Export Firm's Revenue ($1,000)	21,239	174,456
Foreign Firm's Revenue ($1,000)	20,372	164,025
Firm's Interest Payment ($1,000)	125.7	1,264
Domestic Firm's Interest Payment ($1,000)	76.4	517.7
Export Firm's Interest Payment ($1,000)	245.2	2159
Foreign Firm's Interest Payment ($1,000)	94.95	915.0
Log of TFP (Olley-Pakes)	4.214	1.150
Truncated Interest Payment using Exports	99.79	994.5
Export Value ($1,000)	2,197	45,002
Export Indicator	.298	.457
Firm's Value-Added ($1,000)	2,702	19,944
Firm's Capital Stock ($1,000)	390.9	4,350
State-owned firm indicator	.038	.192
Foreign Dummy (exclusive H/M/T)	.105	.307
Foreign Dummy (inclusive H/M/T)	.215	.411

Notes: There are 998,223 observations in the sample. Firms revenue and interest payment are converted to dollar using exchange rate (1 dollar=8.05 Renminbi on average). SOEs dummy equals one for pure state-owned enterprises, stated-owned joint venture enterprises, state-owned and collective joint venture enterprises, and state-own limited corporation firms, and zero otherwise. All foreign (i.e. multinational) firms are defined exclusive of those originating in Hong Kong, Macau, or Taiwan (H/M/T), except in the final row of the table,

Table 2: Total Factor Productivity of Chinese Plants in Log Level

Chinese Industrial Classfication (2-digit)	Labor (OP)	Capital (OP)	Domestic Log of TFP	Export Log of TFP
Processing of Foods (13)	.447	.286	4.419	4.394
Manufacturing of Beverages (14)	.444	.309	3.980	4.027
Manufacture of Beverages (15)	.474	.422	2.942	3.072
Manufacture of Tobacco (16)	.416	.669	.667	1.315
Manufacture of Textile (17)	.437	.203	4.760	4.863
Manufacture of Apparel, Footware & Caps (18)	.508	.184	4.527	4.448
Manufacture of Leather, Fur, & Feather (19)	.474	.350	3.569	3.408
Processing of Timber, Manufacture of Wood, Bamboo, Rattan, Palm & Straw Products (20)	.446	.130	5.333	5.421
Manufacture of Furniture (21)	.563	.231	4.051	3.951
Manufacture of Paper & Paper Products (22)	.473	.276	4.005	4.260
Printing, Reproduction of Recording Media (23)	.413	.195	4.874	5.091
Manufacture of Articles For Culture, Education & Sport Activities (24)	.490	.168	4.813	4.773
Processing of Petroleum, Coking, &Fuel (25)	.252	.282	5.213	6.188
Manufacture of Raw Chemical Materials (26)	.313	.346	4.356	4.575
Manufacture of Medicines (27)	.411	.208	5.265	5.548
Manufacture of Chemical Fibers (28)	.382	.304	4.391	4.700
Manufacture of Rubber (29)	.377	.308	4.242	4.303
Manufacture of Plastics (30)	.421	.239	4.600	4.595
Manufacture of Non-metallic Mineral goods (31)	.321	.422	3.577	3.778
Smelting & Pressing of Ferrous Metals (32)	.464	.308	4.140	4.504
Smelting & Pressing of Non-ferrous Metals (33)	.362	.260	4.975	5.210
Manufacture of Metal Products (34)	.420	.277	4.370	4.314
Manufacture of General Purpose Machinery (35)	.404	.282	4.386	4.459
Manufacture of Special Purpose Machinery (36)	.406	.404	3.443	3.434
Manufacture of Transport Equipment (37)	.466	.396	3.214	3.248
Electrical Machinery & Equipment (39)	.453	.405	3.141	4.902
Computers & Other Electronic Equipment (40)	.495	.192	5.074	3.658
Manufacture of Measuring Instruments & Machinery for Cultural Activity & Office Work (41)	.408	.411	3.426	3.597
Manufacture of Artwork (42)	.460	.347	3.597	3.492
All industries	.399	.278	4.486	4.521

Notes: We do not report standard errors for each coefficient to save space, which are available upon request.

Table 3: OLS Estimates

Regressand: Firm's Revenue	(1)	(2)	(3)	(4)
Interest Payment	50.34**	43.20**	43.62**	37.11**
	(24.82)	(-15.39)	(15.55)	(9.02)
Interest Payment×Foreign Indicator	-21.08**	-16,69**	-17.04**	-9.982
	(-3.45)	(-2.73)	(-2.77)	(-1.03)
Interest Payment×Export Indicator	12.66**	9.12*	8.57*	9.27*
	(3.48)	(-1.94)	(1.79)	(1.69)
Interest Payment×Export Indicator	4.672**	.075	.520	-10.21
×Foreign Indicator	(.49)	(0.01)	(0.05)	(-0.96)
Export Indicator	1360**	2,023**	-1,342**	-881.7
	(2.74)	(2.83)	(-3.11)	(-1.11)
Export Indicator×Foreign Indicator	2,769**	1,822	1,316	2,699
	(2.19)	(1.09)	(0.79)	(1.43)
Foreign Indicator	7,119**	6,436**	6,549**	2,569**
	(10.96)	(10.79)	(10.80)	(1.96)
Industry-Specific Fixed Effects	No	Yes	Yes	No
Export Dummy*Ind. Fixed Effects	No	No	Yes	No
Firm-Specific Fixed Effects	No	No	No	Yes
Year-Specific Fixed Effects	No	Yes	Yes	Yes
Observations	963,442	963,442	963,442	963,442

Notes: Robust t-values corrected for clustering at the firm level in parentheses. *(**) indicates significance at the 10(5) percent level.

Table 4: 2SLS Estimates

Regressand: Firm's Revenue	(1)	(2)	(3)	(4)
Interest Payment	195.4**	199.5**	202.1**	342.2**
	(16.92)	(16.60)	(16.72)	(20.44)
Interest Payment×Foreign Indicator	-32.94	-34.18	-36.03	-4.72
	(-.97)	(-0.99)	(-1.04)	(-0.20)
Interest Payment×Export Indicator	-53.57**	-55.26**	-58.69**	-140.4**
	(-3.64)	(-3.64)	(-3.85)	(-11.45)
Interest Payment×Export Indicator	88.52**	88.28**	88.89**	212.6**
×Foreign Indicator	(2.10)	(2.08)	(2.09)	(9.06)
Export Indicator	-3,993**	-8,405**	-314.9	9,523**
	(-2.29)	(-4.28)	(-0.29)	(6.30)
Export Indicator×Foreign Indicator	-2,209	-790.9	-2,463	-31,311**
	(-.39)	(-0.14)	(-0.43)	(-8.08)
Foreign Indicator	-2,363	-4,014	-3,113	-8,424**
	(-.62)	(-1.03)	(-0.80)	(-2.08)
Industry-Specific Fixed Effects	No	Yes	Yes	No
Export Dummy*Ind. Fixed Effects	No	No	Yes	No
Firm-Specific Fixed Effects	No	No	No	Yes
Year-Specific Fixed Effects	Yes	Yes	Yes	Yes
First-Stage Regressions				
IV1: TFP_{it}^{OP}	.177**	.203**	.182**	.036**
	(11.57)	(11.52)	(11.02)	(6.66)
	[85.69]	[75.49]	[77.27]	[497.0]
IV2: TFP_{it}^{OP}×Foreign Indicator	.302**	.300**	.302**	.145**
	(4.66)	(4.61)	(4.65)	(21.89)
	[25.04]	[35.28]	[21.38]	[493.1]
IV3: TFP_{it}^{OP}×Export Indicator	1.323**	1.320**	1.343**	.5692**
	(11.62)	(11.51)	(10.95)	(59.52)
	[65.55]	[49.12]	[56.98]	[1,015]
IV4: TFP_{it}^{OP}×Foreign Indicator	.781**	.782**	.782**	.262**
×Export Indicator	(7.50)	(7.52)	(7.52)	(31.33)
	[20.35]	[29.27]	[18.35]	[577.5]
Observations	959,835	959,835	959,835	864,188

Notes: Robust t-values corrected for clustering at the firm level in parentheses. *(**) indicates significance at the 10(5) percent level. Excluded F statistic in the first stage are reported in square brackets. 95, 647 observations are not used in Column (4) due to singleton groups in the fixed effects estimation.

In the first-stage regressions, IV1 reports the coefficient of TFP (Olley-Pakes) level in the estimation using interest payment as the regressand. Similarly, IV2 reports the coefficient of the product between TFP level and foreign firm (FOR)'s dummy in the estimation using the product of interest payment and FOR as the regressand. IV3 reports the coefficient of the product between TFP level and export dummy in the estimation using the product of interest payment and export dummy as the regressand. Finally, IV4 reports the coefficient of the product among TFP level, export dummy, foreign firm's dummy in the estimation using the product of truncated interest payment and export dummy as the regressand.

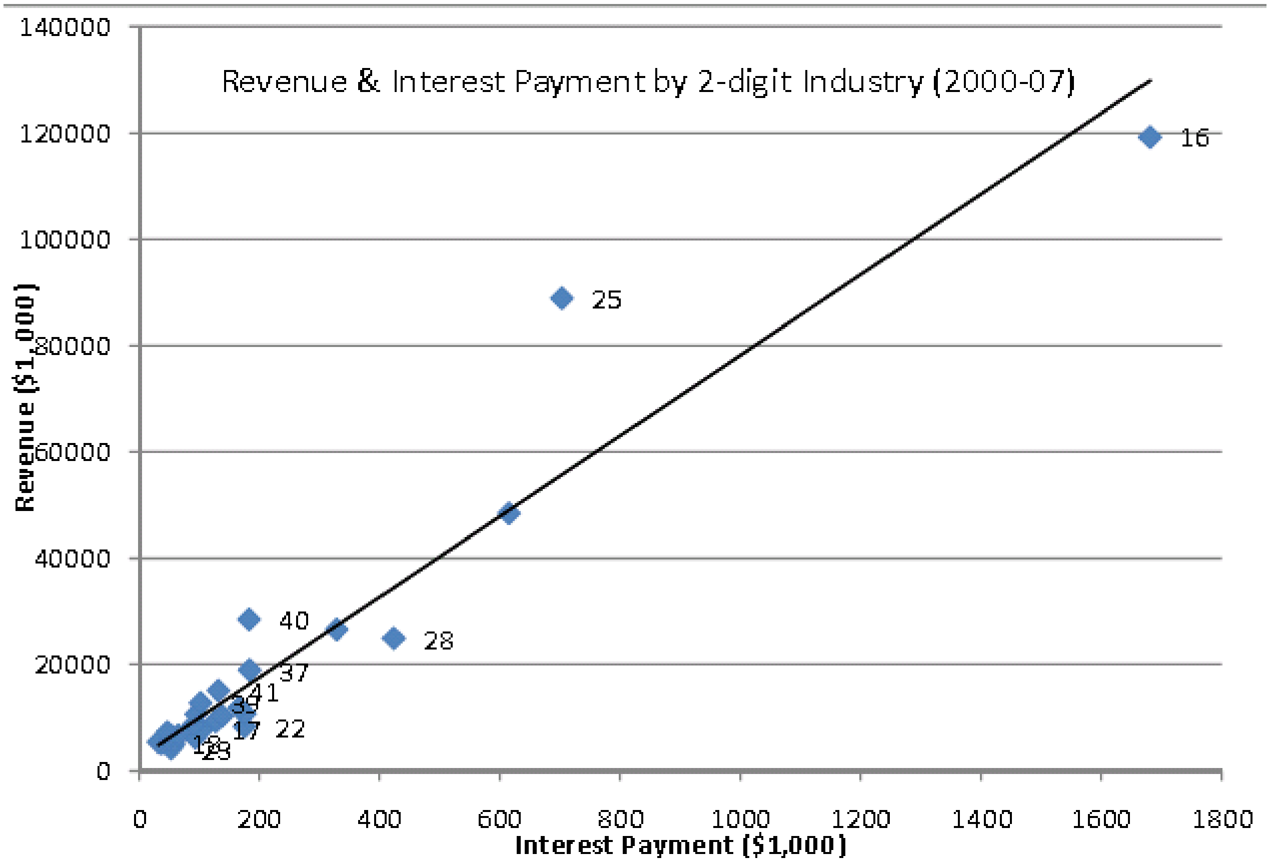

Figure 1: Chinese Firm's Revenue and Interest Payment by 2-digit Industry

Appendix

A Solving the Bank's Problem

A.1 The Loan Schedules

The constraints to the banks's problem involve these control variables as well as their derivatives $M_d^{e\prime}(x)$ and $M_d^{\prime}(x)$. Incorporating constraints in the control variables and their derivatives is relatively straighforward using the Euler-Lagrange equation of the calculus of variations (Chiang, 2000, p. 137). Without causing any confusion, we simplify the exposition by denote $\Phi_d\left(x, M_d(x)\right)$ as Φ_d, $\Phi_d^e\left(x, M_d^e(x)\right)$ as Φ_d^e and $\Phi_e^e\left(x, M_e^e(x)\right)$ as Φ_e^e. We define the Lagrangian function using the integrand of the bank's objective and the incentive-compatibility constraint, for $x \in [\underline{x}_d, \underline{x}_e]$ as:

$$\pounds = \left[\rho_d I_d(x) - i\delta_d M_d\left(x\right)\right] f\left(x\right) + \lambda\left(x\right)\left[\left(\Phi_d - 1\right) M_d^{\prime}(x) - \rho_d I_d^{\prime}(x)\right]. \tag{33}$$

Likewise, for exporting firms the Lagrangian function is defined for $x \in [\underline{x}_e, \infty)$ as,

$$\begin{aligned} \pounds \;=\; & \left[\rho_d I_d^e(x) + \rho_e I_e^e(x) - i\delta_d M_d^e\left(x\right) - i\delta_e M_e^e\left(x\right)\right] f\left(x\right) \\ & + \lambda\left(x\right)\left[\left(\Phi_d^e - 1\right) M_d^{e\prime}(x) + \left(\Phi_e^e - 1\right) M_e^{e\prime}(x) - \left(\rho_d I_d^{e^{\prime}}(x) + \rho_e I_e^{e\prime}(x)\right)\right]. \end{aligned} \tag{34}$$

We can simplify the bank's problem for the exporting firms by explicitly solving for the relationship between the loans $M_d^e\left(x\right)$ and $M_e^e\left(x\right)$, using the equality of marginal revenues in (11). As explained in the text, this solution is:

$$\frac{M_e^e(x) - C_e}{M_d^e(x) - C_d} = \frac{\eta_e}{\eta_d}. \tag{35}$$

Substituting this relation and (17) into (34), the Lagrangian function for the bank for $x \in [\underline{x}_e, \infty)$ becomes,

$$\begin{aligned} \pounds \;=\; & \left[\rho_d I_d^e(x) + \rho_e I_e^e(x) - i\delta_d M_d^e\left(x\right) - i\delta_e\left(\frac{\eta_e}{\eta_d}\left(M_d^e(x) - C_d\right) + C_e\right)\right] f\left(x\right) \\ & + \lambda\left(x\right)\left[\left(\Phi_d^e - 1\right) M_d^{e\prime}(x)\left(1 + \frac{\eta_e}{\eta_d}\right) - \left(\rho_d I_d^{e\prime}(x) + \rho_e I_e^{e\prime}(x)\right)\right]. \end{aligned} \tag{36}$$

According to the Euler-Lagrange equation, the solution to (18) must satisfy the conditions $\frac{\partial \pounds}{\partial I} - \frac{d}{dx}\frac{\partial \pounds}{\partial I^{\prime}} = 0$ and $\frac{\partial \pounds}{\partial M} - \frac{\partial}{\partial x}\frac{\partial \pounds}{\partial M^{\prime}} = 0$. For x$\in [\underline{x}_d, \underline{x}_e]$ these conditions are

$$f\left(x\right) + \lambda^{\prime}\left(x\right) = 0 \tag{37}$$

$$i\delta_d f\left(x\right) + \left(\Phi_d - 1\right)\lambda^{\prime}\left(x\right) + \lambda\left(x\right)\frac{\partial \Phi_d}{\partial x} = 0, \tag{38}$$

and for $x \in [\underline{x}_e, \infty)$,

$$f\left(x\right) + \lambda^{\prime}\left(x\right) = 0 \tag{39}$$

$$i\left(\delta_d + \delta_e\frac{\eta_e}{\eta_d}\right) f\left(x\right) + \left(1 + \frac{\eta_e}{\eta_d}\right)\left(\left(\Phi_d^e - 1\right)\lambda^{\prime}\left(x\right) + \lambda\left(x\right)\frac{\partial \Phi_d^e}{\partial x}\right) = 0. \tag{40}$$

We impose a tranversality condition on the bank's problem such that $\lambda\left(\infty\right) = 0$. Then the optimality condition for exporting firms (39) indicates that $\lambda\left(x\right) = \lambda\left(\underline{x}_e\right) - \int_{\underline{x}_e}^{x} f\left(x\right)dx = \lambda\left(\underline{x}_e\right) - \left(F\left(x\right) - F\left(\underline{x}_e\right)\right)$, where $F\left(x\right)$ is the cumulative density function of $f(x)$. Combined with the transversality condition, it readily follows that $\lambda\left(\underline{x}_e\right) = 1 - F\left(\underline{x}_e\right)$ and consequently $\lambda\left(x\right) = 1 - F\left(x\right)$

for $x \in [\underline{x}_e, \infty)$. Using $\lambda(\underline{x}_e) = 1 - F(\underline{x}_e)$ and the optimality condition for domestic firms (37), we also obtain $\lambda(x) = 1 - F(x)$ for $x \in [\underline{x}_d, \underline{x}_e]$.[19]

Substituting this solution for $\lambda(x)$ into (38) and (40), and noticing that $\partial \Phi_d / \partial x = \left(\frac{\sigma - 1}{\sigma}\right) \Phi_d / x$ and $\partial \Phi_d^e / \partial x = \left(\frac{\sigma-1}{\sigma}\right) \Phi_d^e / x$, it follows that the solution for the credit constraints are,

$$\begin{aligned} \Phi_d &= (1 + i\delta_d) \left(1 - \frac{\sigma - 1}{\sigma} \frac{1 - F(x)}{x f(x)}\right)^{-1} - 1, \\ \Phi_d^e &= (1 + i(\delta_d \eta_d + \delta_e \eta_e)) \left(1 - \frac{\sigma - 1}{\sigma} \frac{1 - F(x)}{x f(x)}\right)^{-1} - 1. \end{aligned}$$

A.2 The Cutoff Productivity Levels

Using the solutions for the domestic credit constraints $\overline{\Phi}_d$ together with the incentive-compatibility condition (7), we can re-write the expected interest payments as:

$$\rho_d I_d(x) = \rho_d I_d(\underline{x}_d) + \left(\overline{\Phi}_d - 1\right) (M_d(x) - M_d(\underline{x}_d)). \tag{41}$$

Similar expression can be obtained for $\rho_d I_d^e(x) + \rho_e I_e^e(x)$. Substituting these into the banks problem (18), it becomes,

$$\max_{\underline{x}_d, \underline{x}_e} \int_{\underline{x}_d}^{\underline{x}_e} \left[\rho_d I_d(\underline{x}_d) + (\overline{\Phi}_d - 1)(M_d(x) - M_d(\underline{x}_d)) - i\delta_d M_d(x)\right] f(x)\, dx \tag{42}$$

$$+ \int_{\underline{x}_e}^{\infty} \left[\begin{array}{c} \rho_d I_d^e(\underline{x}_e) + \rho_e I_e^e(\underline{x}_e) + \left(\overline{\Phi}_e - 1\right) (M_d^e(x) + M_e^e(x) - M_d^e(\underline{x}_e) - M_e^e(\underline{x}_e)) \\ -i\delta_d M_d^e(x) - i\delta_e M_e^e(x) \end{array} \right] f(x)\, dx.$$

Solving this maximization problem requires taking first order derivative respect to $\underline{x}_d$ and $\underline{x}_e$. In order to do this, we shall first show some property of the expected interest payments for marginal firms, $\rho_d I_d(\underline{x}_d)$ and $\rho_d I_d^e(\underline{x}_e) + \rho_e I_e^e(\underline{x}_e)$. From (4) and (5), the domestic firm's expected profit is,

$$\begin{aligned} E(\pi_d(x, x)) &= \rho_d \left((M_d(x) - C_d) \frac{x}{w} P\right)^{\frac{\sigma-1}{\sigma}} Y^{\frac{1}{\sigma}} - M_d(x) - \rho_d I_d(x) \\ &= \frac{\sigma}{\sigma - 1} (M_d(x) - C_d) \overline{\Phi}_d - M_d(x) - \rho_d I_d(x), \end{aligned}$$

where the second equality follows because $\left(\frac{x}{w} P\right)^{\frac{\sigma-1}{\sigma}} Y^{\frac{1}{\sigma}} = (M_d(x) - C_d)^{\frac{1}{\sigma}} \overline{\Phi}_d \frac{\sigma}{\rho_d(\sigma - 1)}$ according to the optimal loan schedule (23). Since $E(\pi_d(x, x))$ is an increasing function in x, it follows that the zero-cutoff-profit condition for the domestic producer is:

$$\rho_d I_d(\underline{x}_d) = \frac{\sigma}{\sigma - 1} (M_d(\underline{x}_d) - C_d) \overline{\Phi}_d - M_d(\underline{x}_d). \tag{43}$$

[19] Notice that the continuity of the Lagrange multiplier in the neighborhood of $x = \underline{x}_e$ is because of the fact that $E(\pi_d(\underline{x}_e, \underline{x}_e)) = E(\pi_e(\underline{x}_e, \underline{x}_e))$ and consequently the equality between the shadow value of $\left(\rho_d I_d^{e'}(x) + \rho_e I_e^{e\prime}(x)\right)$ and the shadow value of $\rho_d I_d^{'}(x)$ at $\underline{x}_e$.

For the exporter, a similar argument shows that expected profits are:

$$\begin{aligned} E\left(\pi_e(x,x)\right) &= \rho_d\left(\left(M_d^e(x)-C_d\right)\frac{x}{w}P\right)^{\frac{\sigma-1}{\sigma}}Y^{\frac{1}{\sigma}}-M_d^e(x)-\rho_d I_d^e(x) \\ &\quad+\rho_e\left(\left(M_e^e(x)-C_e\right)\frac{x}{w}P^*\right)^{\frac{\sigma-1}{\sigma}}Y^{*\frac{1}{\sigma}}-M_e^e(x)-\rho_e I_e^e(x) \\ &= \frac{\sigma}{\sigma-1}\left(M_d^e(x)-C_d\right)\overline{\Phi}_e-M_d^e(x)-\rho_d I_d^e(x) \\ &\quad+\frac{\sigma}{\sigma-1}\left(M_e^e(x)-C_e\right)\overline{\Phi}_e-M_e^e(x)-\rho_e I_e^e(x). \end{aligned} \tag{44}$$

The zero-cutoff-profit condition for the exporter is $E\left(\pi_e(\underline{x}_e,\underline{x}_e)\right)=E\left(\pi_d(\underline{x}_e,\underline{x}_e)\right)$. By substituting (41) evaluted at $x=\underline{x}_e$ into (44), we obtain,

$$\begin{aligned} &\rho_d I_d^e(\underline{x}_e)+\rho_e I_e^e(\underline{x}_e) \\ = \ &\frac{\sigma}{\sigma-1}\overline{\Phi}_e\left(M_d^e(\underline{x}_e)-C_d+M_e^e(\underline{x}_e)-C_e\right)-M_d^e(\underline{x}_e)-M_e^e(\underline{x}_e)+\rho_d I_d(\underline{x}_d) \\ &-\frac{\sigma}{\sigma-1}\overline{\Phi}_d\left(M_d(\underline{x}_e)-C_d\right)+\overline{\Phi}_d M_d(\underline{x}_e)-\left(\overline{\Phi}_d-1\right)M_d(\underline{x}_d) \end{aligned} \tag{45}$$

The two equations (43) and (45) imply that the bank can freely choose the cutoff productivity, $\underline{x}_d$ and $\underline{x}_e$, independently. Once the bank selects the the cutoff productivities, it can then set the associated interest payments for the cutoff firms according to (43) and (45). But from the latter equation, the interest payments $\rho_d I_d^e(\underline{x}_e)+\rho_e I_e^e(\underline{x}_e)$ will depend on the value of $\underline{x}_d$, which appears on the right.

The first-order condition of (42) respect to $\underline{x}_d$ is, taking into account that (45) includes terms related to $\underline{x}_d$, is

$$\int_{\underline{x}_d}^{\infty}\left(\rho_d\frac{dI_d(\underline{x}_d)}{d\underline{x}_d}-(\overline{\Phi}_d-1)\frac{dM_d(\underline{x}_d)}{d\underline{x}_d}\right)f(x)\,dx=\left[\rho_d I_d(\underline{x}_d)-i\delta_d M_d(\underline{x}_d)\right]f(\underline{x}_d). \tag{46}$$

Notice that:

$$\int_{\underline{x}_d}^{\infty}\left(\rho_d\frac{dI_d(\underline{x}_d)}{d\underline{x}_d}-(\overline{\Phi}_d-1)\frac{dM_d(\underline{x}_d)}{d\underline{x}_d}\right)f(x)\,dx=\left(M_d(\underline{x}_d)-C_d\right)\frac{\overline{\Phi}_d}{\theta}f(\underline{x}_d),$$

where the equality holds since $\rho_d\frac{dI_d(\underline{x}_d)}{d\underline{x}_d}=\left(\frac{\sigma}{\sigma-1}\overline{\Phi}_d-1\right)\frac{dM_d(\underline{x}_d)}{d\underline{x}_d}$ from (43) and $\frac{dM_d(\underline{x}_d)}{d\underline{x}_d}=\frac{\sigma-1}{\underline{x}_d}\left(M_d(\underline{x}_d)-C_d\right)$ from (23), with $\frac{1-F(\underline{x}_d)}{\underline{x}_d f(\underline{x}_d)}=\frac{1}{\theta}$ under Pareto distribution. Also notice from (43) that:

$$\begin{aligned} &\left[\rho_d I_d(\underline{x}_d)-i\delta_d M_d(\underline{x}_d)\right]f(\underline{x}_d) \\ = \ &\left[\frac{\sigma}{\sigma-1}\left(M_d(\underline{x}_d)-C_d\right)\overline{\Phi}_d-(1+i\delta_d)M_d(\underline{x}_d)\right]f(\underline{x}_d). \end{aligned}$$

The first-order condition with respect to $\underline{x}_d$ is then solved as,

$$\begin{aligned} M_d(\underline{x}_d)-C_d &= \left[\frac{\left(\frac{\theta\sigma}{\sigma-1}-1\right)\overline{\Phi}_d}{\theta\left(1+i\delta_d\right)}-1\right]^{-1}C_d \\ &= (\sigma-1)\,C_d, \end{aligned} \tag{47}$$

where the second equality hold by substituting in $\overline{\Phi}_d$. We then have the loan for the cutoff producer as,

$$M_d(\underline{x}_d) = \sigma C_d,$$

Substitue this loan for the cutoff producer into (43), and we obtain the expected interest payment for the cutoff producer as,

$$\rho_d I_d(\underline{x}_d) = (\overline{\Phi}_d - 1) M_d(\underline{x}_d).$$

The interest payment schedule for firms with x$\in [\underline{x}_d, \underline{x}_e]$ is then

$$\rho_d I_d(x) = (\overline{\Phi}_d - 1) M_d(x) \ \forall x \in [\underline{x}_d, \underline{x}_e]\,. \tag{48}$$

The first-order condition with respect to $\underline{x}_e$ is slightly more complicated,

$$\begin{aligned} & \int_{\underline{x}_e}^{\infty} \left(\frac{d\left(\rho_d I_d^e(\underline{x}_e) + \rho_e I_e^e(\underline{x}_e)\right)}{d\underline{x}_e} - (\overline{\Phi}_e - 1) \frac{d\left(M_d^e(\underline{x}_e) + M_e^e(\underline{x}_e)\right)}{d\underline{x}_e} \right) f(x)\, dx \qquad (49) \\ = \ & \left[\rho_d I_d^e(\underline{x}_e) + \rho_e I_e^e(\underline{x}_e) - i\delta_d M_d^e(\underline{x}_e) - i\delta_e M_e^e(\underline{x}_e)\right] f(\underline{x}_e) - \left[\rho_d I_d(\underline{x}_e) - i\delta_d M_d(\underline{x}_e)\right] f(\underline{x}_e)\,. \end{aligned}$$

Similar to the solution of $\underline{x}_d$, we notice that,

$$\begin{aligned} & \int_{\underline{x}_e}^{\infty} \left(\frac{d\left(\rho_d I_d^e(\underline{x}_e) + \rho_e I_e^e(\underline{x}_e)\right)}{d\underline{x}_e} - (\overline{\Phi}_e - 1) \frac{d\left(M_d^e(\underline{x}_e) + M_e^e(\underline{x}_e)\right)}{d\underline{x}_e} \right) f(x)\, dx \\ = \ & \left(\frac{\overline{\Phi}_e}{\theta} \left(M_d^e(\underline{x}_e) + M_e^e(\underline{x}_e) - C_d - C_e\right) - \frac{\overline{\Phi}_d}{\theta} \left(M_d(\underline{x}_e) - C_d\right) \right) f(\underline{x}_e) \\ = \ & \left(\frac{\overline{\Phi}_e}{\theta} - \frac{\overline{\Phi}_d}{\theta} \left(\frac{\overline{\Phi}_d}{\overline{\Phi}_e} \right)^{-\sigma} \eta_d \right) \left(M_d^e(\underline{x}_e) + M_e^e(\underline{x}_e) - C_d - C_e\right) f(\underline{x}_e) \end{aligned}$$

where the first equality holds since,

$$\frac{d\left(\rho_d I_d^e(\underline{x}_e) + \rho_e I_e^e(\underline{x}_e)\right)}{d\underline{x}_e} = \left(\frac{\sigma}{\sigma - 1} \overline{\Phi}_e - 1 \right) \frac{d\left(M_d^e(\underline{x}_e) + M_e^e(\underline{x}_e)\right)}{d\underline{x}_e} - \frac{\overline{\Phi}_d}{\sigma - 1} \frac{dM_d(\underline{x}_e)}{d\underline{x}_e},$$

and $\frac{d\left(M_d^e(\underline{x}_e) + M_e^e(\underline{x}_e)\right)}{d\underline{x}_e} = \frac{(\sigma-1)}{\underline{x}_e} \left(M_d^e(\underline{x}_e) + M_e^e(\underline{x}_e) - C_d - C_e\right)$. The second equality holds since

$$\frac{M_d(\underline{x}_e) - C_d}{M_d^e(\underline{x}_e) - C_d} = \left(\frac{\overline{\Phi}_d}{\overline{\Phi}_e} \right)^{-\sigma},$$

due to (23), and $(M_d^e(\underline{x}_e) - C_d) = \eta_d \left(M_d^e(\underline{x}_e) - C_d + M_e^e(\underline{x}_e) - C_e\right)$ due to (13). The right hand side of (49) can be rewriten as, ignoring $f(\underline{x}_e)$,

$$\begin{aligned} & \rho_d I_d^e(\underline{x}_e) + \rho_e I_e^e(\underline{x}_e) - i\delta_d M_d^e(\underline{x}_e) - i\delta_e M_e^e(\underline{x}_e) - \left(\rho_d I_d(\underline{x}_e) - i\delta_d M_d(\underline{x}_e)\right) \\ = \ & \left(\frac{\sigma}{\sigma - 1} \overline{\Phi}_e - 1 \right) \left(M_d^e(\underline{x}_e) - C_d + M_e^e(\underline{x}_e) - C_e\right) - C_d - C_e - i\delta_d M_d^e(\underline{x}_e) - i\delta_e M_e^e(\underline{x}_e) \\ & - \left(\frac{\sigma}{\sigma - 1} \overline{\Phi}_d - 1 \right) \left(M_d(\underline{x}_e) - C_d\right) + C_d + i\delta_d M_d(\underline{x}_e) \\ = \ & \left(\frac{\sigma}{\sigma - 1} \overline{\Phi}_e - 1 - i\delta_d \eta_d - i\delta_e \eta_e \right) \left(M_d^e(\underline{x}_e) - C_d + M_e^e(\underline{x}_e) - C_e\right) - (1 + i\delta_e) C_e \\ & - \left(\frac{\sigma}{\sigma - 1} \overline{\Phi}_d - 1 - i\delta_d \right) \left(\frac{\overline{\Phi}_d}{\overline{\Phi}_e} \right)^{-\sigma} \eta_d \left(M_d^e(\underline{x}_e) - C_d + M_e^e(\underline{x}_e) - C_e\right). \end{aligned}$$

Putting these together, we can solve out the loans for the cutoff exporter as, using the same trick as in (47),

$$
\begin{aligned}
& M_d^e(\underline{x}_e) - C_d + M_e^e(\underline{x}_e) - C_e \\
= \; & \frac{(1+i\delta_e)\, C_e}{\left(\frac{\sigma}{\sigma-1}\overline{\Phi}_e - 1 - \frac{\overline{\Phi}_e}{\theta} - i\delta_d\eta_d - i\delta_e\eta_e\right) - \left(\frac{\sigma}{\sigma-1}\overline{\Phi}_d - 1 - \frac{\overline{\Phi}_d}{\theta} - i\delta_d\right)\left(\frac{\overline{\Phi}_d}{\overline{\Phi}_e}\right)^{-\sigma}\eta_d} \\
= \; & \frac{(\sigma-1)(1+i\delta_e)\, C_e}{(1+i\delta_d\eta_d + i\delta_e\eta_e) - (1+i\delta_d)\left(\frac{\overline{\Phi}_d}{\overline{\Phi}_e}\right)^{-\sigma}\eta_d} \\
= \; & \frac{1+i\delta_e}{(1+i\delta_d\eta_d + i\delta_e\eta_e)\left(1 - \left(\frac{(1+(\delta_d\eta_d+\delta_e\eta_e)i)}{(1+i\delta_d)}\right)^{\sigma-1}\eta_d\right)}(\sigma-1)\, C_e \\
= \; & \Delta\,(\sigma-1)\, C_e,
\end{aligned}
$$

where Δ is defined as in the text. Substituting the solution of the loan for the cutoff exporter into (45), and with rather extensive simplification, we can solve for the interest payment for the cutoff exporter as shown in (28).

A.3 Monotonicity of Profits

It is readily shown that profits are increasing in x:

$$
\begin{aligned}
\frac{dE\left(\pi_d(x,x)\right)}{dx} &= \frac{\sigma}{\sigma-1}\overline{\Phi}_d M_d'(x) - M_d'(x) - \rho_d I_d'(x) \\
&= \left(\frac{\sigma}{\sigma-1}\overline{\Phi}_d - 1\right) M_d'(x) - \left(\overline{\Phi}_d - 1\right) M_d'(x) \\
&= \frac{\overline{\Phi}_d}{\sigma-1} M_d'(x) > 0.
\end{aligned}
$$

where the second line follows from the incentive-compatibility condition (7). Similarly, we can establish that the profits of the exporter are also increasing: $\frac{dE(\pi_e(x,x))}{dx} = \frac{\overline{\Phi}_e}{\sigma-1}\left(M_d^{e\prime}(x) + M_e^{e\prime}(x)\right) > 0$. Substituting from the loans schedules in (23), it can be shown that $\left(\frac{(1+(\delta_d\eta_d+\delta_e\eta_e)i)}{(1+i\delta_d)}\right)^{\sigma-1}\eta_d < 1$ is needed to ensure that $E\left(\pi_e(x,x)\right)$ has a larger slope than $E\left(\pi_d(x,x)\right)$.

B TFP Calculation by the Olley-Pakes (1996) Approach

Econometricians have tried hard to address these empirical challenges, but were unsuccessful until the pioneering work by Olley and Pakes (1996). In the beginning, researchers used two-way (*i.e.*, firm-specific and year-specific) fixed effects estimations to mitigate simultaneity bias. Although the fixed effect approach controls for some unobserved productivity shocks, it does not offer much help in dealing with reverse endogeneity and remains unsatisfactory. Similarly, to mitigate selection bias, one might estimate a balanced panel by dropping those observations that disappeared during the period of investigation. The problem is that a substantial part of information contained in the data set is wasted, and the firm's dynamic behavior is completely unknown.

Fortunately, the Olley–Pakes methodology makes a significant contribution in addressing these two empirical challenges. Consider a standard Cobb-Douglus production function:

$$Y_{it} = A_{it} K_{it}^{\beta_k} L_{it}^{\beta_l},$$

where Y_{it} if the value-added production of firm i at year t. By assuming that the expectation of future realization of the unobserved productivity shock, υ_{it}, relies on its contemporaneous value, the firm i's investment I_{it} (not to be confused with interest payments as denoted in the main text) is modeled as an increasing function of both unobserved productivity and log capital, $\ln K_{it}$. Following previous works, such as van Biesebroeck (2005) and Amiti and Konings (2007), the Olley–Pakes approach was revised by adding the firm's export decision as an extra argument of the investment function since most firms' export decisions are determined in the previous period (Tybout, 2003):

$$I_{it} = \tilde{I}(\ln K_{it}, \upsilon_{it}, X_{it}), \tag{50}$$

where X_{it} is an indicator to measure whether firm i exports in year t. Therefore, the inverse function of (50) is $\upsilon_{it} = \tilde{I}^{-1}(\ln K_{it}, I_{it}, X_{it})$.[20] The unobserved productivity also depends on log capital and the firm's export decisions. Accordingly, the estimation specification can be written as:

$$\ln Y_{it} = \beta_0 + \beta_l \ln L_{it} + g(\ln K_{it}, I_{it}, X_{it}) + \epsilon_{it}, \tag{51}$$

where $g(\ln K_{it}, I_{it}, X_{it})$ is defined as $\beta_k \ln K_{it} + \tilde{I}^{-1}(\ln K_{it}, I_{it}, X_{it})$. Following Olley and Pakes (1996) and Amiti and Konings (2007), fourth-order polynomials are used in log-capital, log-investment, and the firm's export dummy to approximate $g(\cdot)$.[21] In addition, since our firm data set is from 2000 to 2007, we include a WTO dummy (*i.e.*, one for a year after 2001 and zero for before) to characterize the function $g(\cdot)$ as follows:

$$g(k_{it}, I_{it}, X_{it}, WTO_t) = (1 + WTO_t + X_{it}) \sum_{h=0}^{4} \sum_{q=0}^{4} \delta_{hq} k_{it}^h I_{it}^q. \tag{52}$$

After finding the estimated coefficients $\hat{\beta}_l$, we calculate the first-stage residual R_{it} which is defined as $R_{it} \equiv \ln Y_{it} - \hat{\beta}_l \ln L_{it}$.

The second step is to obtain an unbiased estimated coefficient of β_k. To correct the selection bias as mentioned above, Amiti and Konings (2007) suggested estimating the probability of a survival indicator on a high-order polynomial in log-capital and log-investment. One can then accurately estimate the following specification:

$$R_{it} = \beta_k \ln K_{it} + \tilde{I}^{-1}(g_{i,t-1} - \beta_k \ln K_{i,t-1}, \hat{pr}_{i,t-1}) + \epsilon_{it}, \tag{53}$$

where $\hat{pr}_i$ denotes the fitted value for the probability of the firm 's exit in the next year. Since the specific "true" functional form of the inverse function $\tilde{I}^{-1}(\cdot)$ is unknown, it is appropriate to use fourth-order polynomials in $g_{i,t-1}$ and $\ln K_{i,t-1}$ to approximate that. In addition, (53) also requires the estimated coefficients of the log-capital in the first and second term to be identical. Therefore, non-linear least squares seem to be the most desirable econometric technique (Pavcnik, 2002). Finally, the Olley–Pakes type of TFP for firm i is obtained once the estimated coefficient $\hat{\beta}_k$ is obtained:

$$TFP_{it}^{OP} = \ln Y_{it} - \hat{\beta}_k \ln K_{it} - \hat{\beta}_l \ln L_{it}. \tag{54}$$

[20] Olley and Pakes (1996) show that the investment demand function is monotonically increasing in the productivity shock υ_{ik}, by making some mild assumptions about the firm's production technology.

[21] Using higher order polynomials to approximate $g(\cdot)$ does not change the estimation results.