ESSAYS ON INTERNATIONAL TRADE AND FINANCIAL FRICTIONS

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by
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Abstract

by

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This dissertation studies the role of firm heterogeneity in (1) explaining the impact of unilateral trade liberalization on industry labor productivity, (2) reconciling micro estimates that attribute an important effect of credit constraints on export collapse with macro findings that the impacts are minimal, and (3) interpreting the relationship between firm productivity and liquidity management when financing is costly.

The first chapter theoretically and empirically investigates the impact of trade liberalization on industry labor productivity (i.e. output per worker). Applying a two-country, two-industry, two-factor trade model with firm heterogeneity, I show that the impact of trade liberalization on industry labor productivity depends on the structure of tariff reductions. In particular, a unilateral trade liberalization in a labor-abundant country leads to declines in both industry labor productivity and the real wage. The relative wage, measured as a ratio of the real wage over return to capital, also declines when the unilateral trade liberalization takes place disproportionately in the labor-intensive sector. I find supporting evidence of these predictions from the performance of Chinese manufacturing industries and regional variations following China’s entry into the WTO.

The second chapter provides a quantitative macro-assessment on the importance of credit constraints in the collapse of export during the Great Recession. I develop
and quantify a dynamic Melitz model that incorporates a working capital constraint. Mapping the model to Chinese-firm level evidence, I find that most of the collapse in Chinese exports during the recent global financial crisis was due to a negative demand shock. Two general equilibrium effects, working through the aggregate exporting price and wage rate, reconcile micro estimates that attribute an important effect of financial constraints with macro findings that the impacts are minimal.

The third chapter explores theoretically and empirically the relationship between firm productivity and liquidity management in the presence of financial frictions. We build a dynamic investment model and show that, counter to basic economic intuition, more productive firms could demand less capital assets and hold more liquid assets compared to less productive firms when financing costs are sufficiently high. We empirically test this prediction using a comprehensive dataset of Chinese manufacturers and find that more productive firms indeed hold less capital and more cash. We do not, however, observe this for U.S. manufacturers. Our study suggests a larger capital misallocation problem in markets with significant financing frictions than previously documented.
To Xinxing Ying
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CHAPTER 1

TRADE LIBERALIZATION AND INDUSTRY LABOR PRODUCTIVITY

1.1 Introduction

The past several decades have witnessed a dramatic and persistent increase in global trade, and in particular trade from developing countries. While much of the increase in global trade has been accomplished through multilateral liberalization agreements within the GATT and the WTO, for less-developed countries, many liberalizations have effectively been unilateral. The reasons for these unilateral moves are varied, but such liberalizations continue to be policy relevant. This chapter examines the consequences of unilateral trade liberalization for industry labor productivity.

Following Bernard et al. (2007), I develop a multi-country model with industries that differ in their factor intensity, and firms differing in their productivity. I show that the impact of a trade liberalization on labor productivity measured at the industry level in a labor-abundant country depends heavily on the structure of tariff reductions. When trade liberalization is bilateral and symmetric across industries,

1 The dollar value of world merchandise trade in 1950 was $296 billion, and reached to the level of $18.95 trillion in 2014, with an annual growth rate of 6.7%. By 2009 over one-third of world exports originated from developing countries.

2 Examples include India in 1991, Colombia in the 1980s and early 1990s, etc. See Goldberg and Pavcnik (2007) for a nice review.

3 Such as ideological leadership for Chile (Edwards and Lederman, 1998), tariff complementarity between preferential and MFN tariff reductions under the ASEAN Free Trade Agreement (Calvo Pardo et al., 2009), and race-to-bottom tariff cuts favoring FDI inflows for Asian emerging economies (Vezina, 2014).
it leads to increases in industry labor productivity for all industries. However, when trade liberalization is symmetric across industries but unilateral, industry labor productivity declines in the labor-intensive sector and increases in the capital-intensive sector. When trade liberalization is unilateral and disproportionately in the labor-intensive sector, labor productivity declines in both industries. Regarding factor prices, real wage increases only if trade liberalization is bilateral and symmetrical, while relative wage declines only if trade liberalization is unilateral and disproportional to labor-intensive industry.

In this model, industry labor productivity is jointly determined by the real wage and industry total factor productivity (TFP). Industry TFP always increases regardless of the type of trade liberalization through the Melitz channel, i.e., by increasing the productivity threshold level to produce and lowering the productivity threshold level to export. When trade liberalization is symmetric and bilateral, the real wage increases, reinforcing the TFP increase, and leading to an increase in industry labor productivity. When the liberalization is unilateral but proportional across sectors, the real wage declines but not as much as the rental rate (since capital is scarce). Hence, labor productivity declines in the labor-intensive sector but increases in the capital-intensive sector. However, when unilateral trade liberalization is more disproportional to labor-intensive industry, real wage declines dramatically, more so than rental rate, and labor productivity declines in both industries. Essentially, the downward pressure on industry labor productivity through the real wage channel, i.e. the traditional Heckscher Ohlin effect, dominates the upward pressure through the endogenous industry TFP channel driven by firms’ entry-exit.

To evaluate the model’s predictions, I exploit both national and regional variations of industry labor productivity in China following China’s accession to the WTO in 2001. China provides an excellent example of a labor-abundant developing country whose trade liberalization was both unilateral and disproportionately in the labor-
intensive industries. Moreover, the limited labor mobility across provinces in China allows me to exploit geographical variation in industrial composition, and to effectively consider multiple, simultaneous liberalization episodes. To do this, I construct provincial output tariff, a combination of national output tariff and pre-liberalization industrial composition, to measure the regional trade shock induced by national trade liberalization.

Based on the empirical analysis, first I find that, consistent with the theoretical predictions in the model, a unilateral output tariff reduction leads to a statistically significant decrease in industry labor productivity regardless of whether the variation is considered at the national level or the provincial level. Second, the provincial regression reveals that the significant impact of provincial output tariff on provincial industry labor productivity becomes insignificant once provincial wage is controlled. This points to a wage channel through which tariff reductions affect industry labor productivity. Third, I find that provinces that face a larger regional trade shock, measured as larger reductions in provincial output tariff, experience larger declines in both the real wage and the relative wage.

The remainder of this chapter is structured as follows. Section 1.2 reviews the related literature. Section 1.3 develops the model, while the numerical results for simulated trade liberalization are discussed in Section 1.4. Section 1.5 presents the empirical results for China, Section 1.6 conducts sensitive analysis on alternative parameter specifications, and Section 1.7 concludes the study.

4This contradicts the findings in Trefler (2004), in which more liberalized industries have experienced larger increase in industry labor productivity based on the evidence from the Canada-U.S. Free Trade Agreement.
1.2 Related Literature

My finding in this chapter extends the current understanding of the impact of unilateral trade liberalization on industry labor productivity. This is important because most trade liberalizations in developing nations have been unilateral (Goldberg and Pavcnik 2007). Melitz (2003) develops an one-factor dynamic industry model with firms that are heterogeneous in productivities to rationalize the positive impact of symmetric trade liberalization on industry productivity. Essentially, all firms face more competition when their exposure to trade increases, so more productive firms would be able to access larger markets by profitably covering the fixed costs of entering new markets. The expansion of high productivity firms drives up the real wage and forces low productivity non-exporters to exit the market, thus raising average industry TFP. In Melitz’s model, due to the feature of single factor (labor) and single industry, industry labor productivity is equivalent to industry TFP. In other words, trade liberalization unambiguously leads to increases in industry labor productivity, but this is not always observed in practice.

Segerstrom and Sugita (2015) extend the single factor, single industry in Melitz (2003) into two industries that share the same labor market to study the impact of unilateral trade liberalization on industry labor productivity. In their model, a confluence of the wage effect and the competitiveness effect determines industry labor productivity. When the competitiveness effect dominates the wage effect, more liberalized industries will experience a smaller increase (compared to less liberalized industries), or even a decrease, in industry labor productivity. Although industry labor productivity could potentially decline under a unilateral trade liberalization, the downward pressure of wage increase on industry labor productivity contradicts

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5 The positive relationship between output tariff and industry labor productivity is shown at both the national and the provincial level of China in the empirical analysis.
the empirical evidence of the positive relationship.\footnote{In the empirical analysis based on cross-province evidence in China, I show that provincial wage positively correlates with provincial industry labor productivity.}

One of the key assumptions in Segerstrom and Sugita (2015) that leads to the negative relationship between wage and industry labor productivity is that labor is the unique production input. \citeauthor{bernard2007} (2007) extend \citeauthor{melitz2003} into a model with two countries, two industries, and two factors to study the impact of trade liberalization on industry TFP and welfare gains.\footnote{Essentially, \citeauthor{bernard2007} combines \citeauthor{helpman1985} with \citeauthor{melitz2003}. \citeauthor{helpman1985} propose a trade model to allow both inter- and intra-industry trade, and it is widely used to explain trade flow or regional trade agreements, such as \citeauthor{baier2004}. \citeauthor{liu2010} applies \citeauthor{bernard2007} to rationalize the exceptional firm export performance in China.} In their model, trade cost reductions strengthen the original comparative advantage through the channel of inter-firm reallocations within an industry, as emphasized in \citeauthor{melitz2003}. Due to the feature of a two-factor production function, this theoretical framework provides a way to reconcile the wage channel in Segerstrom and Sugita (2015) with empirical findings when firm heterogeneity is considered. Nevertheless, their analysis focuses on a symmetric bilateral trade liberalization, is silent on industry labor productivity, and is theoretical. In this chapter, following Bernard et al. (2007), I theoretically investigate the impact of unilateral trade liberalization on industry labor productivity and empirically test the model’s predictions based on evidence of China’s accession to the WTO.

In addition, the empirical analysis in this chapter contributes to two other streams of literatures. First, the empirical findings in this chapter confirm one of the channels through which trade liberalization could worsen income inequality. Researchers have looked into the impact of unilateral trade liberalization on the skill premium in certain countries, such as Mexico \cite{hanson1999}, \cite{robertson2000}, \cite{robertson2004}, Morocco \cite{currie1997}, and Colombia \cite{attanasio2004}.
They find that unilateral trade liberalization leads to an increase in skill-premium since most of the tariff cuts occur in the unskilled-labor-intensive sectors, which are comparative advantage sectors in those countries. This finding is consistent with predictions delivered by the standard Stolper-Samuelson model. My finding of positive correlation between tariff reductions and relative factor prices (wage over rental rate) under a unilateral trade liberalization supports the negative impact of trade liberalization on income inequality in developing nations. Second, the empirical regressions relying on variations across provinces in China enrich the literature of studying the impact of national trade liberalization on subnational outcomes, including output, poverty, wage, employment, and inequality, covering a variety of countries, such as India (Hasan et al. 2007; Topalova 2007; Edmonds et al. 2010), Vietnam (McCaig 2011), the United States (David et al. 2013), Brazil (Kovak 2013), and China (Cheng 2015). However, few of them have studied the impact of regional trade shock on regional industry labor productivity, relative factor prices, and industry TFP, which are covered in this chapter.

1.3 Model

This section presents a two-country, two-industry, and two-factor trade model with heterogeneous firms based on Bernard et al. (2007). In the model, there are two types of industries, labor-intensive and capital-intensive, that both use labor and capital as inputs in both home and foreign countries, but in different proportions. Within in each type of industry, there is a continuum of firms that choose to enter the domestic/foreign market, as structured in Melitz (2003). Based on the model, the impact of tariff reductions on the industry labor productivity would highly rely on the structure of tariff reductions.
1.3.1 Demand

Preferences are identical across home and foreign countries. The representative consumer in each country obtains utility from composite goods of each industry as follows:

$$U = C_1^\alpha C_2^{1-\alpha}$$ \hspace{1cm} (1.1)

in which $\alpha$ represents the expenditure share on the industry 1 (labor-intensive) good. I choose the composite final consumption good as the numeraire to ensure all the variables in the model are in real terms. The choice of numeraire implies

$$P^H = \left( \frac{P^H_1}{\alpha} \right)^\alpha \left( \frac{P^H_2}{1-\alpha} \right)^{1-\alpha} = 1$$ \hspace{1cm} (1.2)

$P^H_1$ and $P^H_2$ denotes the industry price index for labor-intensive and capital-intensive industry, respectively.

The composite consumption good for industry $i$ at home is given by a C.E.S. aggregation over both home and foreign varieties:

$$C^H_i = \left[ \int_{\omega \in \Omega^H} q^H_i(\omega)^{\frac{\sigma-1}{\sigma}} d\omega + \int_{\omega \in \Omega^F} q^F_i(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}}, \hspace{0.5cm} i = 1, 2$$ \hspace{1cm} (1.3)

$\Omega^H$ and $\Omega^F$ denote the sets of variety $\omega$ available in home and foreign markets. For simplicity, I assume the elasticity of substitution $\sigma$ among varieties is the same in both home and foreign markets. Perfect competition at the industry composite goods level implies the industry price index as:

$$P^H_i = \left[ \int_{\omega \in \Omega^H} p^H_i(\omega)^{1-\sigma} d\omega + \int_{\omega \in \Omega^F} (\tau^F_i p^F_i(\omega))^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}}, \hspace{0.5cm} i = 1, 2 \hspace{1cm} (1.4)$$

$\tau^F_i$, in the form of iceberg cost, represents the tariff foreign variety producer in
industry $i$ needs to pay to enter the home market. Analogously, we can derive the composite consumption good for industry $i$ at foreign market, $C_i^F$, and the industry price index at foreign market, $P_i^F$, similar to the ones at the home market. For the home variety producer in industry $i$, the tariff needs to pay to enter the foreign market would be $\tau_i^H$.

### 1.3.2 Production

Home and foreign countries are endowed with both labor and capital, while home country is relatively more labor abundant (consider China) and foreign country is relatively more capital abundant.

\[
\frac{L^H}{K^H} > \frac{L^F}{K^F} \tag{1.5}
\]

In each industry, there is a continuum of variety producers choosing labor and capital as inputs based on a constant returns to scale Cobb-Douglas production function. The production technology for each variety in industry $i$:

\[
q_i = \varphi_i k_i^{\beta_i} \ell_i^{1-\beta_i}, \quad i = 1, 2 \tag{1.6}
\]

Industry 1 uses labor relatively more intensively than industry 2, i.e. $\beta_1 < \beta_2$. Productivity $\varphi_i$ represents the source of firm/variety heterogeneity, which is drawn from a Pareto distribution with probability density function:

\[
g(\varphi) = ck^c \varphi^{-(c+1)}, \text{ where } k > 0, \ c > 0, \text{ and } \varphi \geq k \tag{1.7}
\]

Cumulative density function:

\[
G(\varphi) = 1 - \left(\frac{k}{\varphi}\right)^c \tag{1.8}
\]
$c > \sigma - 1$ is assumed to guarantee finite profit for each variety producer. To get a draw from the productivity distribution, each variety producer needs to pay the entry cost $f_e$.

The marginal cost of producing one unit of output $q_i$ is:

$$mc_i = \frac{1}{\varphi_i} \left( \frac{1}{\beta_i} \right)^{\beta_i} \left( \frac{1}{1 - \beta_i} \right)^{1-\beta_i} r^{\beta_i} w^{1-\beta_i} = \frac{B_i}{\varphi_i} r^{\beta_i} w^{1-\beta_i}$$

where $B_i = \left( \frac{1}{\beta_i} \right)^{\beta_i} \left( \frac{1}{1 - \beta_i} \right)^{1-\beta_i}$ is a constant. $r$ and $w$ denote rental rate and wage rate, respectively. Follow Melitz (2003), the total cost function for each variety producer would be:

$$tc_i = \left( f_i + \frac{q_i}{\varphi_i} \right) B_i r^{\beta_i} w^{1-\beta_i}$$

in which $f_i$ represents the fixed production cost faced by each variety producer.

Monopolistic competition among variety producers implies that the pricing rule for home producers at the home and foreign markets would be the same:

$$p_{id}^H = p_{ix}^H = \frac{\sigma}{\sigma - 1} mc_i^H$$

while tariff $\tau_i^H$ is required to pay for home producers to enter the foreign market.

1.3.3 Factor Market Equilibrium

To close up the model, we need factor market clearing conditions:

$$r^H K^H = \beta_1 R_1^H + \beta_2 R_2^H$$

$$w^H L^H = (1 - \beta_1) R_1^H + (1 - \beta_2) R_2^H$$

$$r^F K^F = \beta_1 R_1^F + \beta_2 R_2^F$$

$$w^F L^F = (1 - \beta_1) R_1^F + (1 - \beta_2) R_2^F$$
and the total revenue meets total factor income in each country:

\[ R_H^{H} = r^H K^H + w^H L^H \]  \hspace{1cm} (1.16)  
\[ R_F^{F} = r^F K^F + w^F L^F \]  \hspace{1cm} (1.17)

### 1.3.4 Relationship between Productivity Cutoffs

There are two productivity cutoffs, the production cutoff and the export cutoff, in each industry, and these are essential for determining industry level TFP. At the production cutoff, the profit from selling at the home market for the home producers is zero. Likewise, at the export cutoff, the zero export profit condition holds for the home exporters sells at the foreign market. Using these two zero profit conditions, we can derive the relationship between the production cutoff and the export cutoff. For instance, at the home market, the productivity cutoff premium for industry \( i \):

\[ \Lambda_i^H = \frac{\varphi_i^{x^H}}{\varphi_i^{x^H}} = \tau_i^F \left( \frac{P_i^H}{P_i^F} \right) \left( \frac{R_H f_i x_i}{R_F f_i} \right)^{\frac{1}{\sigma-1}} \]  \hspace{1cm} (1.18)

depends on the relative industry price index \( \frac{P_i^H}{P_i^F} \), relative total revenue \( \frac{R_H}{R_F} \), relative fixed cost \( \frac{f_i x_i}{f_i} \), and tariff \( \tau_i^F \).

The free-entry condition is further required to solve for the two cutoffs. To get a draw from the productivity distribution, each variety producer needs to pay entry cost \( f_e \). Assume \( \delta \) is the exogenous death rate, we can express the free-entry condition for industry as:

\[ V_i^H = \frac{f_i}{\delta} \int_{\varphi_i^{x^H}}^{\infty} \left[ \left( \frac{\varphi}{\varphi_i^{x^H}} \right)^{\sigma-1} - 1 \right] g(\varphi) \, d\varphi + \frac{f_i x_i}{\delta} \int_{\varphi_i^{x^H}}^{\infty} \left[ \left( \frac{\varphi}{\varphi_i^{x^H}} \right)^{\sigma-1} - 1 \right] g(\varphi) \, d\varphi = f_e \]  \hspace{1cm} (1.19)

Essentially, the sum of present discounted profit on both markets will be equal to the entry cost, otherwise the market will either encourage or discourage the entry of
firms. We can further express the relationship between the production cutoff and the productivity cutoff premium:

$$\varphi^*_{iH} = \left( f_i + f_{xi} \left( \Lambda_i^H \right)^{-c} \right)^{\frac{1}{c}} \left[ \frac{1}{\delta} \left( \frac{c}{\gamma} - 1 \right) k^c \right]^{\frac{1}{c}} \left( \frac{1}{f_{xi}} \right)^{\frac{1}{c}}$$

(1.20)

in which $\gamma = c - \sigma + 1$. If we define the probability of exporting conditional on production as $\chi^H_i = \frac{1 - G(\varphi^*_{ix})}{1 - G(\varphi^*_{ih})}$, and the mass of variety as $M^H_i$, we can further rewrite the industry price index as:

$$P^H_i = \left[ M^H_i \left( p^H_{id} \left( \bar{\varphi}^H_i \right) \right)^{1-\sigma} + \chi^F_i M^F_i \left( \tau^F_i \bar{\varphi}^F_i \left( \bar{\varphi}^F_i \right) \right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$$

(1.21)

in which $\bar{\varphi}^H_i = \left[ \int_{\varphi^*_{ix}}^{\infty} \varphi^{\sigma-1} \mu(\varphi) d\varphi \right]^{\frac{1}{\sigma-1}}$ is the weighted average industry productivity.

1.3.5 Industry Labor Productivity and Industry TFP

In this model, a firm’s productivity is exogenously given. Thus changes to industry TFP are driven by the resource reallocation between firms. We can define the industry TFP as the weighted average productivity within an industry and show that the industry TFP is entirely dependent on the production cutoff in that industry. In particular, the weighted average productivity for industry 1 at home is defined as:

$$\bar{\varphi}^H_1 = \left[ \int_{\varphi^*_{ix}}^{\infty} \varphi^{\sigma-1} \mu(\varphi) d\varphi \right]^{\frac{1}{\sigma-1}} = \left( \frac{c}{c - \sigma + 1} \right)^{\frac{1}{\sigma-1}} \varphi^*_1$$

(1.22)

in which $\varphi^*_1$ denotes the production cutoff for industry 1 at home. It is quite clear that any factors that will have a negative impact on the production cutoff would also impose a negative impact on industry TFP.

Nevertheless, industry labor productivity would be affected by more than one factor. According to Segerstrom and Sugita (2015), there are two main measures of
industry labor productivity, i.e., the real industrial output per unit of labor. The difference between the two measures is the industry price index used to deflate the nominal output. One the factory gate industry price index, another one is the model implied industry price index based on both home and foreign varieties. Based on the industry price index used in the empirical analysis, I focus on the later one:

\[ \Phi_1^H = \frac{R_1^H}{P_1^H L_1^H} \]  

(1.23)

in which \( R_1^H \) denotes the total revenue for industry 1 at home, including both domestic sales and export sales. \( L_1^H \) is the amount of labor force used in industry 1 at home. \( P_1^H \) is the model-implied industry price index as derived in equation (21). It is not clear what the driving forces of industry labor productivity are until we have the solution for the system of equations.

1.4 Numerical Experiments

To solve the system of equations, I follow the parameterization in Bernard et al. (2007) as shown in Table A.8. I conduct three different tariff reduction schemes to show the model’s implications on real wage, relative factor prices (wage over rental rate), industry labor productivity, and industry TFP. In the first case, I consider a bilateral trade liberalization on labor-intensive industry, which is the comparative advantage industry at home country. In the second case, I consider a proportional unilateral trade liberalization on both labor-intensive and capital-intensive industries at home country. To make the unilateral trade liberalization more disproportional, I only impose tariff reduction in labor-intensive industry at home market in the third case. The details of this three cases are illustrated as follows:
• Case 1: symmetric bilateral trade liberalization on labor intensive industry

\[
\begin{bmatrix}
\tau^F_1 & \tau^F_2 \\
\tau^H_1 & \tau^H_2
\end{bmatrix}
= \begin{bmatrix}
1.3 & 1.0 \\
1.3 & 1.0
\end{bmatrix}
\Rightarrow \begin{bmatrix}
1.0 & 1.0 \\
1.0 & 1.0
\end{bmatrix}
\]

• Case 2: proportional unilateral trade liberalization on both industries

\[
\begin{bmatrix}
\tau^F_1 & \tau^F_2 \\
\tau^H_1 & \tau^H_2
\end{bmatrix}
= \begin{bmatrix}
1.3 & 1.3 \\
1.0 & 1.0
\end{bmatrix}
\Rightarrow \begin{bmatrix}
1.0 & 1.0 \\
1.0 & 1.0
\end{bmatrix}
\]

• Case 3: disproportional unilateral trade liberalization on labor intensive industry

\[
\begin{bmatrix}
\tau^F_1 & \tau^F_2 \\
\tau^H_1 & \tau^H_2
\end{bmatrix}
= \begin{bmatrix}
1.3 & 1.0 \\
1.0 & 1.0
\end{bmatrix}
\Rightarrow \begin{bmatrix}
1.0 & 1.0 \\
1.0 & 1.0
\end{bmatrix}
\]

The results of comparative statics at Home are shown in both Figure A.1 and Figure A.2. In Figure A.1 when both countries lower their tariffs on labor-intensive industry proportionally, real wage increases at home country. Relative wage (wage rate over rental rate) also increases at home country. In the second case, if home country unilaterally lowers tariffs on both labor- and capital-intensive industries in a proportional way, real wage declines at home country. However, we still see the relative wage increases at home country. This is driven by a larger drop in rental rate than that in wage rate at home country. In the third case, if home country unilaterally lowers only tariffs on labor-intensive industry (in a disproportional way) and keeps tariffs on capital-intensive industry unchanged, real wage drops much more than that in the second case at home country. As a result, relative wage declines at home country. Therefore, under unilateral tariff liberalization, the more disproportional tariff reductions on the labor-intensive industry at home, the more likely real wage and relative wage is to decline. All predictions on factor prices are consistent with
the standard Stolper-Samuelson effect.

Figure A.1 also displays the responses of both industry labor productivity and industry TFP at home under different types of trade liberalizations. Industry labor productivity for both industries increases when trade liberalization is symmetrical bilateral. When the trade liberalization is unilateral and proportional on both industries, industry labor productivity declines in labor-intensive industry, while increases in capital-intensive industries. When the unilateral trade liberalization is more disproportional on labor-intensive industry, industry labor productivity declines in both industries.

For industry TFP, labor-intensive industry always has an increase in TFP regardless of the type of trade liberalization scheme. The increase in TFP for labor-intensive industry is the highest in the third case. According to the model, industry TFP is entirely captured by the production cutoff. A much larger decline in real wage leads to a larger drop in the marginal cost \( (r^H)^{\beta_1} (w^H)^{1-\beta_1} \) in the labor-intensive industry. The drop in the marginal cost would push down the export cutoff and push up the production cutoff, thus increase the industry TFP. Capital-intensive industry experiences an increase in TFP for the second and third cases, and a minor decline when liberalization is bilateral.

As a matter of fact, under a multi-industry Melitz model with both production and export cutoffs, in both a single factor or a multi-factor model, the tension between production cutoff and export cutoff induces these two cutoffs to always move in opposite directions. This is confirmed in Figure A.2. In Figure A.2, these two cutoffs always move in opposite directions in all three types of liberalization schemes. As a result, both production cutoff and industry TFP at home will increase. Surprisingly, the marginal cost in capital-intensive industry at home increases when trade liberalization is bilateral. This is confirmed by the drop in production cutoff and the rise in export cutoff.
In sum, the model yields three main testable implications that we will pursue in the empirical section that follows: result (1), industry labor productivity declines when unilateral trade liberalization is disproportionately in the labor-intensive industry; result (2), The real wage declines when unilateral trade liberalization is disproportionately in the labor-intensive industry; result (3), the relative wage, defined as the ratio of wage over rental rate, declines when unilateral trade liberalization is disproportionately in the labor-intensive industry.

1.5 Empirical Evidence

This section documents the empirical evidence concerning the relationship between trade liberalization and industry labor productivity at both national and provincial levels in China. Measures of trade liberalization, based either on industry- or province-level, have a robust negative impact on industry labor productivity.

1.5.1 Data

To study the impact of trade liberalization on industry labor productivity and industry TFP, requires two pieces of data information: one is the measure of trade policy changes, and the other one is industry level output and employment. First, to capture the changes in China’s trade policy pre- and post-2001, I utilize both the two-digit (medium size) and three-digit (small size) industry tariff data in Lu and Yu (2015). Most of the graphical displays will be based on the two-digit industry tariff data, while three-digit industry tariff data are used in the regression analysis to exploit as many variations as possible. Second, I use the Annual Survey of Industrial Production conducted by the National Bureau of Statistics of China (NBS) from 1998 to 2005 to compute industry labor productivity and industry TFP. The dataset includes all state-owned firms as well as non-state-owned firms whose sales exceed five million yuan (about $700,000) per year, spanning 37 two-digit manufacturing indus-
tries and 31 provinces or province-equivalent municipal cities. On average, it contains over 300,000 firms per year, and it is the most representative and comprehensive firm-level dataset available in China. This dataset reports firms’ information related to both production and balance sheet. The key variables of interest for this chapter are value-added output, gross output, intermediate input, fixed assets, revenue, number of workers, export, ownership, wage payment, non-wage benefits, industry classification, location, and open year. According to Cai and Liu (2009b), strict double checking procedures have been applied to guarantee the quality of the dataset.

1.5.2 Why China?

Beyond the significant economic importance of China in the world economy, China’s accession to the WTO in 2001 provides us an excellent case to study the effect of trade liberalization. First, the large disparity of tariff reductions across different industries provides enough cross-sectional variations to study the effect of trade liberalization between 1998 and 2005, the time period studied in this project. As we can see in Figure A.8, the import tariffs for several industries were still above 20% in 1998.\footnote{In Figure A.8, tariffs are calculated as log(1+tariff), which will be smaller than the levels of tariffs. In other words, the levels of tariffs could still be slightly above 20% even though the log(1+tariff) is slightly less than 20%. Source: Author’s calculations based on tariff data from Lu and Yu (2015).} As a requirement to enter the WTO, all tariffs are required to be reduced to certain uniform bounding rates. As a result, we can see that sectors that levied relatively higher tariff rates in 1998 experienced relatively larger tariff cuts during 1998 and 2005. This is confirmed by the significantly negative correlation coefficient, -0.87, between the level of tariff rates in 1998 and tariff reductions between 1998 and 2005.

Second, the large variations in employment distribution of industries across different subnational regions in China enable us to identify the general equilibrium effect...
across different industries. Following the literature, provincial output tariff, defined as the weighted sum of national industry output tariffs within provinces as shown in equation (1.24), are constructed to capture the variations in employment distribution. \( \tau_{ort} \) denotes the provincial output tariff for province \( r \) at year \( t \), while \( \tau_{ojt} \) represents the national output tariff for industry \( j \) at year \( t \). \( s_{jr,1998} \) is the employment share of industry \( j \) in province \( r \) in prior to China’s WTO accession (here I use the year 1998). Likewise, I construct provincial input tariff based on national industry input tariffs.

\[
\tau_{ort} = \sum_{j=1}^{J} (s_{jr,1998}) \tau_{ojt} = \sum_{j=1}^{J} \left( \frac{L_{j,1998}}{\sum_{j} L_{j,r,1998}} \right) \tau_{ojt}
\]  

(1.24)

Figure A.9 plots the levels (left panel) of provincial tariffs in 1998 versus the changes (absolute changes, right panel) of the provincial tariffs between 1998 and 2005 among 31 provinces or province-equivalent municipal cities in China.\(^9\) Intuitively, the variations among provincial tariffs are mainly driven by the variations in employment distribution prior to the trade liberalization. For example, compared to Liaoning province, Zhejiang province has larger employment shares in industries that experience larger tariff cuts. The variations in provincial tariffs offer us an exogenous measure of local trade shock (induced by national shock) to study the factor reallocation across industries.

Finally, yet importantly, the migration costs between provinces in China remain high during the period from 1998 to 2005. According to Tombe et al. (2015), before 1978, the Hukou registration system in China restricted not only the location (rural vs. urban) where a Chinese citizen could legally work but also the possible occupation (agriculture vs. nonagriculture). Since the 1980s, the Hukou system has been relaxed, especially after 2003, when the application of a temporary residence permit was no

\(^9\)Source: Author’s calculations based on tariff data from Lu and Yu (2015).
longer required for migrant workers. However, due to limited access to local public services, such as health care and children’s education, the costs of migration remain high enough to prohibit workers from moving freely from one province to another. As we can see from Table A.3 even though China has witnessed the migration of 22.5 million inhabitants between 2000 and 2005, the share of migrant workers in the total employment is still quite low, especially in the case of inter-provincial migration. This evidence supports the choice of a province as a subnational region, rather than a prefecture (a smaller administrative unit under a province) as a focus of this study. The regression analysis on provincial industry productivity guarantees a much more mobile labor market.

1.5.3 Main Results

I provide regression analysis of the relationship between trade liberalization and industry labor productivity, with a focus on three-digit manufacturing industries in China. I regress measures of trade liberalization, both output and input tariffs, against industry labor productivity. Industry labor productivity is simply defined as value added per worker in each industry. For control variables, I follow Lu and Yu (2015), which studies the impact of trade liberalization on industry markup dispersion, to include the number of firms, fraction of exporters, and output share of firms with different ownerships. In addition, industry and year fixed effects are also included, and standard errors are clustered at industry level. As an alternative, I also provide regression analysis of the relationship between trade liberalization and

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10 China’s accession to the WTO occurred at the end of 2001, while the migration policy change occurred in 2003. Robustness check implies that the impact of trade liberalization on industry labor productivity was mainly driven by the tariff reductions between 2001 and 2002.

11 Cheng (2015) uses prefecture as a unit of subnational region to study the impact of trade liberalization.

12 Industry output is deflated using industry deflator in Brandt et al. (2012b).
industry total factor productivity (TFP). Industry TFP is a output weighted average of firm-level TFP based on a value-added production. To calculate firm-level TFP, I borrow input elasticity estimates for each industry from Lu and Yu (2015) to calculate the “Solow residual” for each firm.

Table A.4 reports the OLS regressions of log of industry labor productivity and industry TFP against levels of tariffs with different sets of controls. The coefficients on output tariff in all regressions are positive and significant, both statistically and economically. For instance, a one standard deviation (8%) decrease in output tariff leads on average a 8% decrease in industry labor productivity (based on column (3)), which is fairly substantial given that the average annual growth of industry labor productivity is around 14% (based on the average five-year window change of 57%). Surprisingly, the impact of input tariff, which could potentially lower the cost of production, on industry labor productivity is not statistically significant in all regressions. For industry TFP, the effect of output tariff is not quite consistent, but we do see a less positive and less significant effect. Again, the effect of input tariff is not significant.

The regression based on the level of tariff above is not straightforward on the direction of tariff changes, even though all industries in China have faced tariff cuts during the WTO accession (See Figure A.8). Table A.5 reports the OLS regressions of five-year window growth rates of industry labor productivity and industry TFP against changes of tariffs. Similar sets of control variables, also in five-year window changes, are controlled in each corresponding regression. The average five-year changes of output tariff in my sample is -5% with a standard deviation of 4%. Just as

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13 Lu and Yu (2015) use the methodology based on Ackerberg et al. (2006) to estimate firm-level total factor productivity and markup. Firms within in an industry are assumed to use the same production function, and the only difference is the their “Solow residual”.

14 I follow the long-differences model in Cheng (2015), who studies the impact of changes of tariffs on the real output growth in China.
we see from the results in levels, the coefficients on output tariff changes in all regressions are positive and significant. Under a five-year window, a one standard deviation (4 percentage points) decrease in output tariff growth leads to a 4 percentage points decrease in industry labor productivity. The impact of changes in import tariff is reported as insignificant as well. The impact of tariff reductions, either output tariff or input tariff, on industry TFP is not significant.

As a robustness check, based on the model, a disproportional unilateral trade liberalization on labor-intensive industry in China would imply a drop in wage rate and relative wage (wage rate over rental rate). Table A.6 reports the OLS regressions of log of provincial wage and provincial relative wage against levels of provincial tariffs with different sets of controls. To calculate provincial rental rate, I follow Bai et al. (2006a) and apply the Hall-Jorgenson rental price equation. As we see in Table A.6 there is a significant positive correlation between both provincial wage and provincial relative wage and provincial output tariff. This implies that provinces that face larger local tariff cuts would experience declines in both wage and relative wage, as suggested in the third case of the experiments.

1.5.4 Robustness Analysis

The results of the negative impact of tariff cuts on industry labor productivity is puzzling under the classic Melitz framework, in which reallocation of labor within an industry would contribute to an increase in industry labor productivity when trade liberalization occurs. However, one of the underlying key assumptions to support the trade-induced increase in industry labor productivity is the perfect mobility of labor within an industry. This assumption might not be valid in China given the high migration costs. To analyze the impact of tariff reductions on industry labor productivity under a framework in which labor is more mobile, I will choose an industry in a province in China as a unit of analysis, rather than an industry within
the entire country. There are at least two benefits of doing such an analysis. First, labor will be more mobile within a province than within the entire country. Second, I will be able to use the cross-sectional variations in factor prices to exploit the channel in which tariff reductions affect industry labor productivity.

Table A.7 reports the OLS regressions of log of provincial industry labor productivity against levels of four different tariffs with different sets of controls. The unit of analysis here is an industry in a given province in a given year. For instance, the labor productivity of textile industry in Zhejiang province would be potentially different from the labor productivity of textile industry in Liaoning province. Similar to the analysis on national industry level, I further control the number of firms, fraction of exporters, and output share of firms with different ownerships. In addition, province-industry and year fixed effects are also included, and standard errors are clustered at province-industry level. The coefficients and significance of output tariff and input tariff on provincial industry labor productivity are quite similar to the ones based on the national industry level. Consistently, lower output tariff at the national level would also lower the industry labor productivity at the province level, while the impact of input tariff is not statistically significant.

Provincial output/input tariff is a province specific tariff, constructed by a weighted sum of output/input tariffs using the employment share in 1998 as the weights. Column (2) in Table A.7 implies that the impact of provincial output tariff on provincial industry labor productivity is statistically significant, while the impact of provincial input tariff is not. A one standard deviation (3%) decrease in provincial output tariff on average leads to a 9% decrease in provincial industry labor productivity. This is quite significant given the average annual growth of provincial industry productivity is 16%. Robust results are shown in Column (4) when additional controls are added. To study the channel in which provincial output tariff affects provincial industry labor productivity, I add provincial wage as a control in column (3) and
(5). As a result, we see a positively significant relationship between provincial wage and provincial industry labor productivity, and the effect of provincial output tariff becomes smaller and insignificant. This points to a potential wage channel of how trade liberalization affects industry labor productivity.

In sum, I find trade liberalization, measured by either output tariff reduction or provincial tariff reduction, has a negative impact on industry labor productivity, at both national and provincial level. I did not find a positive impact of tariff reductions on industry TFP as predicted in the model, although the tariff reductions effects on industry TFP is less negative and even insignificant. This finding is quite different from what has been found in the empirical literature, in which only a positive effect has been identified, both empirically and theoretically.

1.5.5 What is Special in China?

The negative impact of output tariff reductions on industry labor productivity stays puzzling, although variations at both national- and province-level have been exploited. However, according to the model and Figure A.1 the positive relationship between tariffs and industry labor productivity can be rationalized if trade liberalization is unilateral. Indeed, China’s accession the WTO in 2001 was a unilateral trade liberalization. Being a new member of the WTO, China was required to make changes in many aspects of its trade policies. In particular, it had to substantially lower its tariffs, and reduce its restrictions on the inflow of capital into certain sectors. The simple average tariff was set at the level of 56% in 1982, was reduced to 18% by 1998, and 10% by 2005. At the same time, the share of imports subject to non-tariff trade barriers, such as licensing requirements, dropped significantly from 46% in late 1980s to less than 4% by 2001\textsuperscript{15}. Nevertheless, the tariffs faced by Chinese exporters in the rest of the world (i.e. export tariff) have not changed by too much since 1998

\textsuperscript{15}Nicholas R. Lardy, Integrating China into the Global Economy, pp. 33, 39.
as shown in Figure A.10.

However, we do see an increase of industry labor productivity of capital-intensive industry when the unilateral trade liberalization is proportional. Unilateral trade liberalization is a proportional way is not enough to support the regression analysis in which industry fixed-effect is considered. To ensure industry labor productivity declines in all industries, we need a disproportional unilateral trade liberalization as demonstrated in the third case of the model section. As a matter of fact, the magnitude of unilateral tariff reductions is relatively larger in labor-intensive industry than that in capital-intensive industry during China’s access to the WTO. Figure A.11 plots the 2-digit industry tariff changes between 1998 and 2005 against the capital-labor ratio in 1996 from the Unites States.\footnote{I dropped tobacco and beverage (liquor in particular) industries since they are either highly regulated or much less tradable due to the local preference. Also, I exclude the petroleum industry from the figure due to its extremely high capital-labor ratio (greater than 600). While the positive relationship would be even stronger if it is considered since the tariff reduction in petroleum industry is almost zero.} The capital-labor ratio in the Unites States is used to avoid the endogeneity issue pointed out in Song et al. (2011b). The raw correlation is reported statistically significant as 0.35, which implies that labor-intensive industry in China faces a larger tariff reductions during the WTO accession. For instance, the tariff reduction in textile industry is much larger than that in chemical industry. These two special features in China jointly shed light on the numerical experiments conducted in the model section.

1.6 Sensitivity Analysis

The choice of parameters in the numerical experiments above closely follows Bernard et al. (2007), while in this section, I consider alternative specifications of parameters when the unilateral trade liberalization is disproportionately in the labor-intensive sector. In particular, it covers elasticity of substitution $\sigma$, Pareto shape...
parameter $c$, capital-labor endowment, entry cost $f_e$, probability of exit $\delta$, and productivity lower bound $\lambda$.

1.6.1 Elasticity of Substitution and Shape Parameter

The elasticity of substitution is considered as one of the key parameters in the trade literature, its magnitude directly determines the gains from trade (Broda and Weinstein 2006) and varies at different level of aggregations. Follow Alessandria and Choi (2007, 2014), I simultaneously pin down elasticity of substitution and Pareto shape parameter. Given that both elasticity of substitution and shape parameter are assumed to be the same across sectors, I derive a relationship between elasticity of substitution and shape parameter under the single sector Melitz model.

First of all, the export participation rate is defined as:

$$ p_{ex} = \frac{1 - G(\varphi^*)}{1 - G(\varphi)} = \left( \frac{\varphi^*}{\varphi} \right)^{\sigma - 1} = \left( \frac{\tau f_x}{f} \right)^{\frac{\varphi^*}{\sigma - 1}} $$

thus we have

$$ \frac{1 - \sigma}{p_{ex}} = \frac{\tau - 1}{f} \frac{f_x}{f} $$

(1.25)

Also, the exporter size premium could be defined as:

$$ \text{SizePrem} = \frac{\int_{\varphi^*}^{\varphi} \varphi^{\sigma - 1} \frac{g(\varphi)}{1 - G(\varphi^*)} d\varphi}{\int_{\varphi^*}^{\varphi} \varphi^{\sigma - 1} \frac{g(\varphi)}{1 - G(\varphi^*)} d\varphi} = \left( \frac{\varphi^*}{\varphi} \right)^{\sigma - 1} = \left( \frac{\tau f_x}{f} \right)^{\frac{\varphi^*}{\sigma - 1}} $$

(1.26)

Combine

$$ \frac{\text{SizePrem}}{p_{ex}} = \frac{1 - \sigma}{\ln p_{ex}} \frac{c}{\left( \frac{\sigma - 1}{\ln \text{SizePrem}} \right)} \ln p_{ex} $$

(1.27)

According to the equation above, we know that both elasticity of substitution
and shape parameter are neither affected by fixed costs nor iceberg trade cost. More importantly, once either one of $\sigma$ and $c$ is assumed, the other one will be automatically pinned down given the data moments on export participation rate and exporter size advantage. Follow the quantitative analysis of Tombe et al. (2015) based on China during a similar time framework, I choose the elasticity of substitution as 4, which implies a net markup of 33%. In addition, looking into the firm-level data from China in 2000 before the WTO entrance, the export participation rate and export size premium is registered as 26% and 3.47, respectively. Therefore, back-of-the-envelope calculation implies that the shape parameter is 3.25. The numerical experiment results based on the new values of $\sigma$ and $c$ are displayed in Figure A.3. As we can see, the results are quite consistent.

1.6.2 Capital-Labor Endowment

The initial difference of labor/capital endowment between home and foreign countries is the key driver determining the H-O effect. The original values of labor/capital endowment is assumed to be $L^H = 1200$, $K^H = 1000$, $L^F = 1000$, $K^F = 1200$. To test whether the scale of endowment matters, Figure A.4 provides new pairs of capital-labor endowment by scaling down the original endowment settings, i.e., $L^H = 120$, $K^H = 100$, $L^F = 100$, $K^F = 120$, and keeping the relative size unchanged. Although, the level of variables of interest have all changed, the direction of changes are all consistent with previous findings.

1.6.3 Entry Cost, Exit Probability, and Productivity Lower Bound

Based on the free-entry condition displayed below, sunk cost of entry, $f_e$, pins down the magnitude of the expected value of entry. The smaller distance between export productivity cutoff and production productivity cutoff, the larger is the expected value of entry. In other words, the higher the sunk cost of entry, the smaller
distance between export productivity cutoff and production productivity cutoff, the
larger production productivity cutoff would increase when tariff is reduced. This
could potentially increase the Melitz channel by raising industry TFP more than the
case of a lower sunk cost. In [Bernard et al. 2007], fixed production costs are assumed
to be 5% of sunk entry costs. In Figure A.5, I assume the sunk cost of entry to be 5,
rather than 2. As we can see, the increase in industry TFP turns to be much larger
than the case of a lower sunk entry, while it is still not enough to offset the H-O
effect.

\[
V_i^H = \frac{f_i}{\delta} \int_{\phi_i^H}^{\infty} \left[ \left( \frac{\phi}{\phi_i^H} \right)^{\sigma-1} - 1 \right] g(\phi) d\phi + \frac{f_{ix}}{\delta} \int_{\phi_{ix}^H}^{\infty} \left[ \left( \frac{\phi}{\phi_{ix}^H} \right)^{\sigma-1} - 1 \right] g(\phi) d\phi = f_{ei}
\]

(1.28)

The effect of exit probability is similar to the entry cost according to the free-
entry condition. A higher exit probability corresponds to a higher expected value of
entry. Figure A.6 displays the results of a higher exit probability, and we still see
the decline in industry labor productivity. Finally, Figure A.7 presents the effect of
a lower productivity lower bound. A much larger increase in industry TFP, while
industry labor productivity still goes down as stated in the benchmark model. In sum,
when the trade liberalization is both unilateral and disproportionately in the labor-
intensive sector at labor abundant country, the decline in industry labor productivity,
real wage, and relative wage are quite robust to different specifications of parameters.

1.7 Conclusion

Many trade liberalizations that have occurred in developing countries were unilat-
eral. In this chapter, I theoretically study the impact of unilateral trade liberalization
on industry labor productivity. Under a standard two-country, two-industry, and two-
factor trade model that allows intra-industry trade, inter-industry trade, and resource
reallocation across firms within an industry, I find that industry labor productivity will be negatively affected if the trade liberalization is unilateral. The negative effect is even stronger if the unilateral trade liberalization is disproportionally imposed on labor-intensive industry. In other words, the traditional Heckscher Ohlin effect contributes more to industry labor productivity than the firm entry-exit effect does. Empirical evidence on the performance of Chinese manufacturing industries, at both national and province level, during China’s accession to the WTO corroborates the theoretical predictions of the model.

The findings suggest several avenues for future research. To further strengthen the validity of the model presented in this chapter, it would be interesting to examine the tariff reduction structure of other developing countries that had gone through unilateral trade liberalizations. Furthermore, the production function in the theoretical model presented in this chapter is a value added form, which means the impact of intermediate input tariff is not covered. While the empirical evidence points to an insignificant impact of input tariff reductions on industry labor productivity in China, it would be interesting to study the net impact of unilateral trade liberalization on both output tariff and input tariff in other developing nations in which input tariff does matter. Finally, during the same period, China has gone through a period of dramatic resource reallocation. It would be also interesting to study the interaction between unilateral trade liberalization and resource reallocation in China theoretically and empirically.
CHAPTER 2

DEMAND SHOCK, CREDIT CONSTRAINT, AND EXPORT COLLAPSE

2.1 Introduction

Global trade plunged 16% between 2008 and 2009; indeed, it fell by 14 percent more than the global GDP. (World Bank Databank). Various studies have sought to explain this trade collapse, but there is not a consensus within the scholarship investigating the role of credit constraints. Evidence from the disaggregate-level data shows a positive relation between export collapse and worse credit conditions. In contrast, there is a minor drop in the aggregate leverage ratios among exporters. This chapter attempts to reconcile the micro-evidence with findings at the aggregate level.

This chapter provides a quantitative macro-assessment on the importance of credit constraints in a general equilibrium framework. My contribution are twofold. First, I develop and quantify a dynamic Melitz model that incorporates a working capital constraint in the context of a small open economy by matching a set of moments at the firm level. In contrast to the quantitatively-oriented work in the existing literature, the model emphasizes another channel: the elasticity of substitution among the imported varieties is greater than the one between imported goods and home-produced goods. This channel not only allows a clean mapping between the model

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1 See Amiti and Weinstein (2011); Chor and Manova (2012)
2 See Levchenko et al. (2010)
3 See Brooks and Dovis (2013); Leibovici et al. (2014)
and data that disciplines the quantitative analysis, but also turns out to play critical quantitative roles in a general equilibrium. Second, based on the model, this chapter decomposes sources of the drop in exports through two parts: an impact of tighter credit frictions and an impact of a lower global demand.

This chapter discovers that credit constraints account for a negligible role in the export collapse during the Great Recession based on firm-level evidence in China. This is true both when firms receive identical credit shocks or when heterogeneous credit shocks happen to different firms. However, the mechanisms behind these two contexts differ from each other. Given an identical credit shock, a small response in export is mostly due to a minor change in the aggregate leverage ratios, whereas a small response in export under heterogeneous credit shocks stems from a general equilibrium effect.

I present a dynamic Melitz model with domestic sales and exporting sales that differ in the per-period fixed costs of operating a monopolistically competitive intermediate good firm. Higher fixed costs in exporting sales leads to a selection channel among firms into the foreign market. Productivity is the defining characteristic of a firm. Firms make a decision on their asset savings and export status, and their asset position is jointly determined by age and productivity. A representative competitive final good producer aggregates varieties with a nested CES function; this key feature distinguishes the elasticity of substitution among the home-produced varieties from the one between home composite good and imported composite good. Financial frictions – which I model in the form of working capital constraints – affect the export mostly at the extensive margin.

Why China? First, China has become increasingly influential in the global market, as it is the largest exporter in the world merchandise trade (WTO, 2012). Also, like the U.S., China saw much larger decreases in export than in output throughout the global financial crisis. The export/sales ratio in manufacturing firms decreased
from 23.51% in 2006 to 16.22% in 2009. Secondly, compared to advanced economies, China is still a developing country with a under-developed financial market. Thus, this chapter complements existing firm-level research focusing on developed countries. Thirdly, the sample used in this chapter covers all the manufacturing firms in 2006 and 2009, and thus contains more information than ones which consist of public-traded firms (like Compustat). The result tends to be less biased, as public firms in general are less credit constrained.

The quantitative analysis is disciplined to match key moments in the Chinese firm-level dataset before/after the crisis (2006/2009) respectively. Moments include productivity distribution, size difference between young and old firms, export/sales ratio, debt/asset ratio, and export participation rate. A counter-factual experiment is conducted to assess the improvement of the export/sales ratio and the export participation rate in 2009 with a better financial parameter calibrated in 2006. With respect to the calibration exercise related to 2009-moments, two distinctive credit shocks have been considered. One is that all firms are affected by the same magnitude of credit shock. The other is that different firms are affected by different magnitudes of credit shocks. Motivated by the evidence from the Chinese firm-level data, I impose a much stronger credit shock on the most productive firms than on the rest.

I find that most of the export collapses in China are caused by a negative foreign demand shock, and credit constraints contribute a rather small impact, based on the sample used in this chapter. This conclusion holds not only in the case of homogeneous credit shocks to every firm, but also in the case of heterogeneous credit shocks to firms with different productivities. However, the mechanism underlying the latter case is completely different than the former. A minor change in export induced by identical credit shock is due to a small change in the aggregate credit conditions. In the case of a stronger credit shock to firms with a higher productivity, two GE effects come into force.
The first GE effect comes from different demand elasticities between aggregate exports and exporting varieties. When high-productivity firms are hit by a stronger credit shock and drop out, the aggregate price of Chinese exports increases, since the productivity of firms that exit the market is higher. Given that the demand elasticity of aggregate Chinese exports is not very high ($\eta = 1.5$), Chinese exports will not decrease by a large amount. Instead, the firms are hit less will stay in the market and expand, or others will enter because the varieties of Chinese goods are highly substitutable ($\sigma = 5$). The second effect comes from the labor market. Labor liberated from dropouts drives the wage rate down; thus, low-productivity firms that previously did not export now enter into the exporting market, as labor is cheaper. Eventually, the new entrants and the surviving firms will finance and export more, and this offsets the drop in export and debt-to-asset ratio caused by the dropouts. As a result, we can simultaneously see a strong correlation at micro-level and a weak correlation at the aggregate level. Most of the export collapses are induced by a demand shock.

2.2 Related Literature

This chapter adds to a vast literature on the relationship between firm-level export behavior and credit rationing. See Manova (2010) for an intensive survey. This chapter also contributes to a large body of work investigating the sources of trade collapse during the Great Recession, especially the role of credit constraints. In particular, I provide a quantitative macro-assessment on the importance of credit constraints in the collapse of exports. There have been relatively few quantitatively-oriented studies, and most of them are empirically-oriented.

On one side, some research demonstrate that show credit constraint has a significant impact on trade collapse. Iacovone and Zavacka (2009) find a negative and significant effect by banking crisis on exports growth, especially for the financially-
dependent sectors, by using a difference-in-difference (DID) method. Amiti and Weinstein (2011), using a Japanese bank-firm dataset from 1990 through 2010, demonstrate that firms closely linked to banking experience larger drops in exports. Chor and Manova (2012), by exploiting the variation in the cost of capital (interbank rates) and the variation in external financing needs among different sectors, demonstrate that countries with a tighter credit market exported less to the US during the peak of the crisis.

On the other side, there is a considerable amount of work that argues that credit constraint is not the primary reason behind trade collapse. Levchenko et al. (2010) argue that a compositional effect and a vertical linkage effect could explain most of the trade collapse, while trade credit is less important. They corroborate their argument by using both aggregate and disaggregate evidence. Chor and Manova (2012) find no evidence for a stronger impact on the U.S. trade with countries that experiencing larger credit crunches. Furthermore, evidence from the Compustat database implies that trade credit indicators, such as account payable as a share of costs of goods sold and account receivable/sales, contracted at a rather small magnitude during the recent downturn in trade. Behrens et al. (2013) use a rich firm-level dataset from Belgium to show that the most important factor explaining declines in exports is the growth rate of GDP in destination countries, and that financial variables have an equal effect on trade and domestic operation respectively. Alessandria et al. (2010) suggest the importance of alternative channels, such as input-output linkages or inventory adjustment, in interpreting the trade collapse from the demand side. Eaton et al. (2011) stress that the fall in demand accounts for most of the overall decline in the trade to GDP ratio, while trade frictions are of no importance.

The literature supporting the importance of credit rationing is mostly based on micro-level evidence, whereas papers focusing on aggregate evidence find no impact of credit rationing. A theoretical model with micro-foundations is required to provide
a mechanism whether financial constraints matter or not, and the model built in this chapter reconciles the two arguments above.

The remainder of the chapter is organized as follows: Section 2.3 documents empirical evidence in the Chinese firm-level dataset that motivates the settings in the model. In Section 2.4, I develop the model, and introduce a working capital constraint into a dynamic Melitz model. Section 2.5 discusses the exporting decision rule under both frictionless and financial frictions models. Section 2.6 describes the calibration, and analyzes two different types of credit shocks. Section 7 summarizes the chapter.

2.3 Empirical Motivation

This section documents the main characteristics of export collapse and financial conditions based on the Chinese firm-level data. From the perspective of export, we look at the export participation rate. For the credit condition, we examine debt-to-asset ratio, in which debt denotes liquid/short-term debt, and asset is the total assets.

2.3.1 Chinese Firm-level Data

The Chinese firm-level dataset used in the chapter covers all the industrial firms, and was collected by the National Bureau of Statistics of China. It includes all state-owned firms and non-state firms with sales above US$ 735,000. Mining, manufacturing, and public utilities industries are included. My focus is on manufacturing firms. Firms’ detailed information about age, employment, value added, export, debt, assets, and sales are collected. The 2006 and 2009 sample are chosen to represent the sample before and after the financial crisis respectively. The 2006 sample is exactly the same as the one used in Brandt et al. (2012b), with all firms included (301,961 observations). Due to data missing, we have 422,128 observations for the
2009-sample, which includes 97% of all firms (434,364 observations) reported by the NBS in China. We believe this is still a valid representative of firms in 2009. To obtain a clean sample, we delete the observations with missing or misclassified critical information; our final sample includes 250,579 and 344,880 observations for 2006 and 2009 respectively.

2.3.2 Empirical Underpinnings

This section provides the key empirics motivating the model settings. Three different sets of analysis have been conducted. The first one is the relationship between productivity and export conditional on age; the second is the relationship between leverage ratio, which is measured by short-term debt to the total asset ratio, and export conditional on age, the third one is the relationship between leverage ratio and productivity.

2.3.2.1 Age, Productivity, and Export

In a standard Melitz model, high-productivity firms export. However, this does not hold for all the Chinese firm evidence, especially for the labor-intensive sectors, like textile, garments, etc.\(^4\) To avoid this and appeal the standard Melitz, I select seven capital-intensive industries, including Beverage, Tobacco, Chemical, Medical, Ferrous, All purpose, and Transportation. The productivity here is measured by the logarithm of gross value of output per worker, denoted as \(\ln z\). From the equation below, we can see that higher productivity or older firms will have a higher chance to export. During the crisis, older firms will have a higher chance to stay in the market, while high-productivity firms will have a higher chance to exit the market.

\[^4\text{See Lu (2010)}\]
\[ I(e > 0) = -0.057 + 0.083 \times \text{Crisis} + 0.038 \times \text{Age} + 0.006 \times \text{Age} \times \text{Crisis} - 0.001 \times \text{Age}^2 \]

\[ + 0.000 \times \text{Age}^2 \times \text{Crisis} + 0.018 \times \ln z - 0.032 \times \ln z \times \text{Crisis} \]

### 2.3.2.2 Age, Leverage Ratio, and Export

The second regression relates the leverage ratio to the export participation rate. The coefficients on the age variables are consistent with the finding above. With respect to debt-to-asset ratio, there is a hump-shaped pattern between the leverage ratio and the export participation rate. However, during the crisis, the relationship is clear: a lower leverage ratio leads to a lower chance of exporting.

\[ I(e > 0) = 0.060 - 0.141 \times \text{Crisis} + 0.039 \times \text{Age} + 0.006 \times \text{Age} \times \text{Crisis} - 0.001 \times \text{Age}^2 \]

\[ + 0.000 \times \text{Age}^2 \times \text{Crisis} + 0.001 \times \frac{\text{Debt}}{\text{Asset}} + 0.053 \times \frac{\text{Debt}}{\text{Asset}} \times \text{Crisis} \]

\[-0.048 \times \frac{\text{Debt}^2}{\text{Asset}} + 0.003 \times \frac{\text{Debt}^2}{\text{Asset}} \times \text{Crisis} \]

### 2.3.2.3 Leverage Ratio and Productivity

The analysis of the relationship between the leverage ratio and productivity underpins the key assumption of heterogeneous credit shocks. The following regression shows that the relationship between the leverage ratio and productivity is negative, which points the fact that high productivity firms borrow less and are less financially constrained. In addition, the interaction term of productivity and crisis dummy reveals that high productivity firms experience a lower leverage ratio during the crisis. This fact supports the assumption of a stronger credit shock to the high productivity
firms, as I specify in the heterogeneous credit shock.

$$\frac{\text{Debt}}{\text{Asset}} = 0.620 + 0.141\text{Crisis} - 0.019 \ln z - 0.026 \ln z^*\text{Crisis}$$

In summary, based on the firm-level evidence in China, first, I find that either high productivity firms or old firms are more likely to export. Second, high productivity firms tend to have a lower leverage ratio and thus are less financially constrained. In addition, during the crisis, firms with a lower leverage ratio had lower chances of exporting, and firms with higher productivity had a lower leverage ratio. These two facts combined contribute to the key assumption in the model in regard to heterogeneous credit shocks.

2.4 Model

Follow Brooks and Dovis (2013); Leibovici et al. (2014), I present a dynamic Melitz model with a working capital constraint in a small-open economy. The economy is populated by a mass of monopolistically-competitive intermediate goods producers, each of them producing a differentiated variety of goods. Intermediate producers differ exogenously by the variety they produce and the productivity endowed, and endogenously by their asset holdings and export status. Asset position is jointly determined by a firm’s age and productivity.

Export requires a fixed continuation cost and is subject to a working capital constraint. Following the literature, a representative producer aggregates the final good with a nested constant elasticity of substitution aggregator. In the home country, a competitive firm produces the final good by aggregating a home composite good and an imported composite good. In the rest of the world, a competitive firm produces the final good by aggregating an imported composite good from the home country and its own composite good. The home composite good is an Armington aggregator.
covering the full set of domestic intermediates, while the home exporting composite
good is an Armington aggregator over the range of domestic exporting intermediates.
This key feature distinguishes the elasticity of substitution among the home-produced
varieties from the one between home composite good and imported composite good.

2.4.1 Final Good Producers

The final good competitive producer in the home country aggregates a home
composite good \( \bar{Q}_D \) with price \( \bar{P}_D \) and an imported composite good \( IM \) with price \( P_{IM} \) from the rest of the world.

\[
Q_D = \left[ \omega \frac{V}{\sigma} \frac{Q_D}{\bar{Q}_D} + (1 - \omega) \frac{V}{\eta} \frac{IM}{\bar{Q}_D} \right]^{\frac{\eta}{\eta - 1}} \tag{2.1}
\]

where the domestic composite good is defined as \( \bar{Q}_D = \left( \int_{z \in Z_D} q_D (z) \frac{z_{\sigma - 1}}{\sigma} \, dz \right)^{\frac{\sigma}{\sigma - 1}} \), and

\( Z_D \) is the full range of domestic intermediates. \( \sigma \) denotes the elasticity of substitution among all the home intermediates, while \( \eta \) captures the elasticity of substitution between home and imported composite goods. In general, both of them are greater than one and \( \sigma \geq \eta \). Parameter \( \omega \) indexes home bias in the production of the home final good. \( Q_D \) is the numeraire in this economy with \( P_D = 1 \).

There are two profit maximization problems needed to be solved to acquire inverse
demand functions for intermediates. First, competitive home composite good firm
maximizes profits taking prices \( p_D (z), \bar{P}_D \) as given:

\[
\max_{q_D (z), \bar{Q}_D} \quad \bar{P}_D \bar{Q}_D - \int_{z \in Z_D} p_D (z) q_D (z) \, dz \tag{2.2}
\]

s.t. \( \bar{Q}_D = \left( \int_{z \in Z_D} q_D (z) \frac{z_{\sigma - 1}}{\sigma} \, dz \right)^{\frac{\sigma}{\sigma - 1}} \)

Second, home final good firm maximizes its profits taking prices \( P_D, \bar{P}_D, P_{IM} \) as
given:

\[
\max_{\tilde{Q}_D, I M, Q_D} P_D Q_D - \tilde{P}_D \tilde{Q}_D - P_M I M \quad (2.3)
\]

\[
\text{s.t. } Q_D = \left[ \frac{1}{\tilde{\omega}} \frac{\eta^{\frac{1}{\eta - 1}}}{\eta^{\frac{1}{\eta - 1}}} + (1 - \omega) \frac{\tilde{\omega}}{\eta^{\frac{1}{\eta - 1}}} \right]^{\frac{\eta}{\eta - 1}}
\]

the inverse demand function (see Appendix Demand Function) is characterized as:

\[
q_D(z) = \omega \left( \frac{\tilde{P}_D}{P_D(z)} \right)^{\frac{1}{\eta}} \left( \frac{P_D}{\tilde{P}_D} \right)^{\eta} Q_D \quad (2.4)
\]

Likewise, for the rest of the world, the final good producer aggregates a composite good produced in the rest of the world \( M \) with price \( P_M \) and an imported composite good \( \tilde{Q}_D^{ex} \) with imported price \( \tilde{P}_D^{ex} (1 + \tau) \) from the home country. The exporting composite good producer solves a similar problem as the home composite good producer.

\[
\max_{q^{ex}_D(z), \tilde{Q}_D^{ex}} \tilde{P}_D^{ex} \tilde{Q}_D^{ex} - \int_{z \in Z_D^{ex}} p_D^{ex} (z) q^{ex}_D (z) dz \quad (2.5)
\]

\[
\text{s.t. } \tilde{Q}_D^{ex} = \left( \int_{z \in Z_D^{ex}} q^{ex}_D (z)^{\frac{s - 1}{s}} dz \right)^{\frac{s}{s - 1}}
\]

The profit maximization for the final good producer in the rest of the world is characterized as

\[
\max_{M, \tilde{Q}_D^{ex}, Q_F} P_F Q_F - P_M M - (1 + \tau) \tilde{P}_D^{ex} \tilde{Q}_D^{ex} \quad (2.6)
\]

\[
\text{s.t. } Q_F = \left( \frac{\frac{1}{\theta_F} \frac{1}{\mu} \frac{\eta^{\frac{1}{\eta - 1}}}{\eta^{\frac{1}{\eta - 1}}} + \frac{\frac{1}{\theta_F} \frac{1}{\eta} (1 - \mu)^{\frac{1}{\eta}} \left( \tilde{Q}_D^{ex} \right)^{\frac{\eta - 1}{\eta}}}{\eta - 1} \right) \quad (2.7)
\]

\( \theta_F \) denotes a taste/demand shock in the rest of the world, \( \theta_F \) could also be considered as a TFP shock on the final good production function in the rest of the world. \( \tau \)
could be the import tax rate levied by the rest of the world \((\tau > 0)\), or the subsidy provided from the home country \((\tau < 0)\). \(\mu\) indexes home bias in the production of the final good in the rest of the world.

The inverse demand functions for the exporting varieties are characterized as:

\[
q_{D}^{ex} (z) = \theta_{F} \left( \frac{1 - \mu}{1 + \tau} \right) \left( \frac{\hat{P}_{D}^{ex}}{p_{D}^{ex} (z)} \right)^{\sigma} \left( \frac{P_{F}}{\hat{P}_{D}^{ex}} \right)^{\eta} Q_{F}
\]  

(2.7)

Note that the export demand function depends not only on the exporting prices charged by firms and a demand shifting factor \(\hat{\theta}_{F} = \theta_{F} \left( \frac{1 - \mu}{1 + \tau} \right) P_{F}^{\eta} Q_{F}\), but also on the price for the exporting composite good, \(\hat{P}_{D}^{ex}\), which could also be considered as the average price for the exporting goods. Intuitively, the amount of goods a Chinese automobile manufacturer can export relies not only on the price the firm set, but also on the price competitiveness of for typical Chinese suppliers, or the preference on automobiles produced in China over automobiles produced in other countries.

2.4.2 Intermediate Good Producers

Each producer chooses to produce a different variety facing both home and foreign downward sloping demand curves. By using a constant return to scale technology \(q = zn\), at period \(t\), firms choose to operate on either the home market or both the home and the foreign market, how much to produce on each market, and asset holdings \((a_{t+1})\) to maximize present discounted value of dividends. Assets are used as collateral for financing a working capital constraint for both domestic and foreign productions. Each firm can borrow \((\lambda - 1) a_{t+1}\) to finance the labor bills and fixed cost for exporting. Note that the inter-period interest rate is \(r\), while the intra-period interest rate is zero. In other words, at the beginning of period \(t\), firms borrow \((\lambda - 1) a_{t+1}\) to pay out their working capital requirements, and then pay back the
debt at the end of period $t$ without paying any interest rate. One can write down the dynamic problem for the intermediate goods firms:

$$V_t(a_t) = \max_{d_t, a_{t+1}} \{d_t + \beta (1 - \delta) V_{t+1}(a_{t+1})\} \tag{2.8}$$

subject to

$$d_t + a_{t+1} = \frac{1 + r}{1 - \delta} a_t + \pi^*_t(a_t)$$

$$d_t \geq 0$$

where $\pi^*_t(a_t)$ is the maximized static profit given firm’s asset position. Taking the probability of quitting the market $\delta$ into account, future expected value of a firm turns to be $\beta (1 - \delta) V_{t+1}(a_{t+1})$ and returns to firm’s saving is $\frac{1 + r}{1 - \delta}$ instead of $1 + r$. Static profit maximization problem for intermediates is expressed as:

$$\pi(z, a) = \max_{p_D^{ex}, q_D^{ex}, q_D, n_D, n^{ex}_D, e = \{0, 1\}} p_D q_D (p_D) - w n_D + e [p_D^{ex} q_D^{ex} (p_D^{ex}) - w n^{ex}_D - w F^{ex}] \tag{2.9}$$

subject to

$$q_D = z_D n_D, \quad q_D^{ex} = z_D n^{ex}_D$$

$$q_D = \tilde{\theta}_D (p_D) (p_D)^{\eta - \sigma} = \tilde{\theta}_D (p_D)^{\eta - \sigma}$$

$$\lambda a \geq w n_D + e [w n_F + w F]$$

where we assume $\tilde{\theta}_D = \omega P_D^n Q_D$, and $\tilde{\theta}_F = \theta_F (\frac{1 + \mu}{1 + \tau}) P_F^n Q_F$ to capture the exogenous demand variables to this problem. All the incumbent firms are earning positive profits since there is no fixed cost for domestic sales. The fixed cost matters only when firms operate in the foreign market, and $F^{ex}$ is measured in labor units. Also, we do not have a sunk cost for exporters since the financial constraint in the model plays a

---

5Lenders are considering the probability of dying $\delta$ for the firms when they are lending asset $a_t$ in the market, assume the actual return on asset is $\tilde{r}$, the expected return on asset savings is $(1 + \tilde{r}) (1 - \delta)$, to guarantee there is no arbitrage opportunities, we have $(1 + \tilde{r}) (1 - \delta) = (1 + r)$, i.e. $1 + \tilde{r} = \frac{1 + r}{1 - \delta}$. 

40
similar role as the sunk cost.

2.4.3 Household’s Problem

A representative household in the home country receives dividends from all the intermediate goods firms and supply $L = 1$ units of labor. S/he chooses final good consumption $c_t$ and savings $s_{t+1}$ to maximize lifetime utility.

$$\sum_{t=0}^{\infty} \beta^t u(c_t)$$

$$s.t. \ c_t + s_{t+1} = \int_{z \in Z_D} d_t(z) \ dz + wL + (1 + r) s_t$$

under steady-state, $c_t = c_{t+1}$, and the Euler equation $\frac{u'(c_t)}{u'(c_{t+1})} = \beta (1 + r)$ implies $\beta (1 + r) = 1$.

2.4.4 Stationary Competitive Equilibrium

A stationary competitive equilibrium is defined as a set of prices $(w, P_D, \tilde{P}_D, P_{1M}, p_D, P_F, P_M, \tilde{P}_D, \tilde{P}_D^{ex})$ and allocations $(n_D, n^{ex}_D, q_D, q^{ex}_D, e, Q_D, \tilde{Q}_D, IM, Q_F, M, \tilde{Q}_D^{ex})$ such that:

1. Competitive composite good producer, both for domestic sales and exporting sales, in the home country solve profit maximization problems (2.2) and (2.5) respectively taking prices $p_D(z), \tilde{P}_D, p^{ex}_D(z), \tilde{P}_D^{ex}$ as given.

2. Competitive final good producers in the home country and the rest of world solve profit maximization problems (2.3) and (2.6) respectively taking prices $P_D, \tilde{P}_D, P_{1M}, P_F, P_M, \tilde{P}_D^{ex}$ as given.

3. The decision rules for monopolistically-competitive intermediate goods producers solve problems (2.8) and (2.9) given the working capital constraint.
4. Representative consumer maximizes utility according to \((2.10)\).

5. Labor market clears: 
   \[
   \int_{z \in Z_D} n_D(z) \, dz + \int_{z \in Z_{Dx}} n_{Dx}^e(z) \, dz + \int_{z \in Z_D} F_{ex} \cdot I (e > 0) = L.
   \]

6. Home final good market clears: 
   \(c = Q_D\).

Given \(P_{IM}\), there are 12 unknowns we are interested in this small-open economy. They are \(w, n_D, n_{Dx}^e, q_D, q_{Dx}^e, p_D, p_{Dx}^e, \tilde{P}_D, \tilde{P}_{Dx}^e, e, Q_D, IM\) and 12 equations are required. We already have one final good production function, two production functions for intermediates, three inverse demand functions, two pricing rules, two composite good price aggregators, one indifference condition on the export decision, and the labor market clearing condition. In addition, we borrow a moment condition from the data, export/import ratio, to pin down the price of import \(P_{IM}\). All the equations are listed in Appendix System of Equations.

### 2.5 Mechanism

In this section, we study how a firm’s behavior varies by comparing a frictionless model and a model with financial frictions. Comparative statics exercises regarding a negative shock to the financial constraint and a worse financial condition are discussed in a model with financial frictions.

#### 2.5.1 Frictionless Model

We could solve closed-form solutions for the optimal static profits if the financial constraint is not binding at all since domestic and foreign optimal profits could be solved independently. One can solve optimal unconstrained labor demands for domestic and exporting sales as below (See Appendix Intermediate Firm Profit Maximization):
The optimal solution for the export decision exclusively depends on firm’s exogenous productivity. One could solve the threshold of productivity for exporting using

\[ \hat{n}_D = \left( \frac{\sigma}{\sigma - 1} w \right)^{-\sigma} \tilde{\theta}_D z_D^{\sigma-1} \]

\[ \hat{n}_{Dex} = \left( \frac{\sigma}{\sigma - 1} w \right)^{-\sigma} \tilde{\theta}_F z_D^{\sigma-1} \]

where \( \tilde{\theta}_F = \theta_F \left( \frac{1 - \mu}{1 + \tau} \right) P_F^\eta Q_F \) captures the foreign demand factors. As we can see from above, a lower \( \tilde{\theta}_F \) (a negative demand shock) indicates a lower labor demand for foreign sales, and a higher threshold of productivity for exporting in a frictionless economy. Any allocation of dividends and asset savings will be optimal given a steady-state economy.

2.5.2 Financial Frictions Model

Firm’s exporting behavior varies with not only the productivity but also asset holdings in an economy with financial frictions. Different from a frictionless model, firms with a high productivity might not export due to a low asset position. We compute the exporting decision rule using grid points on productivity and asset since it is complicated to acquire a closed-form solution. The comparison between frictionless and friction models presented in Figure 2.1.

Under an economy without financial frictions, the decision rule is just a vertical dash line. Firms on the RHS of the dash line export. With financial frictions, the decision rules become more complicated. With financial frictions, firms solve dynamic
problem differently. Firms keep accumulating assets as long as they are financially
constrained, especially for when they are still young. If the working capital is not
binding, since firms are indifferent between periods, we assume that corporations will
choose positive dividends and the optimal $a_{t+1}$ will be the least asset requirement
for a non-binding working capital constraint. (See Appendix Dynamic Problem for
Intermediate Firm)

Figure 2.1. Decision Rules
2.5.3 Comparative Statics

In Figure 2.2, we can see a negative demand shock and a worse financial constraint affect firm’s decision rule differently. A negative demand shock shifts the exporting decision rule toward the northwest parallelly. The threshold for exporting increases and the least asset requirement for a productive firm increase as well. However, a worse financial constraint only shifts the exporting decision rule upward with the same threshold productivity as before. In other words, we can have more firms export under a better financial condition. It is important to point out that the comparative statics exercise conducted in Figure 2.2 is taking wage rate as given. In other words, it is a partial equilibrium. In the next section, we will discuss the case of general equilibrium, in which the selection of firms into or exit the exporting market will increase or decrease the wage rate respectively, then the threshold of productivity will change as well. For instance, because of a higher wage rate, a better credit condition will encourage fewer firms to enter the market in a general equilibrium setup than the case in a partial equilibrium.

Figure 2.2. Comparative Statics
2.6 Calibration

In this section, we present our approach to calibrate the model. There are two sets of parameters, the first group of parameters are standard values taken from the literature, the second set of parameters are calibrated to match key moments of the data.

2.6.1 Parameters

The first group of parameters are invariant over time, including $\sigma, \eta, \beta, \gamma, \sigma_\epsilon$. The elasticity of substitution across varieties $\sigma$ is set as 5, while the elasticity of substitution between composite export and import goods is set as 1.5 (See Ruhl 2008 for $\sigma$, Alessandria et al. 2014 for $\eta$). We set the discount factor $\beta$ as 0.96, and the hazard rate of firms across year as 7%. For the distribution of firm’s productivity $z$, we assume it conforms log-normal distribution: $\log z \sim N(0, \sigma^2_\epsilon)$, where $\sigma_\epsilon = 1$ since the standard deviation of log value added per worker is 1 from the data. (See Table B.2)

The second group of parameters are calibrated to match the key moments of the data. They are the foreign demand shifting factor ($\tilde{\theta}_F = \theta F (\frac{1-\mu}{1+\tau}) P^o F Q_F$), credit constraint parameter ($\lambda$), fixed cost for exporters per period ($F_{ex}$), the initial asset holdings ($a_0$). We choose them to match the following moments respectively: (1) export-to-sales ratio, (2) liquid debt-to-asset ratio, (3) the fraction of exporters, and (4) the size difference between young and old firms.

Eventually, we will have a distribution over the Age-Productivity (Asset-Productivity) grid. In detail, we create a grid for the productivities, 100 grid points between 0 and 2.5. Then we can calculate probabilities for each grid point based on the assumed log-normal distribution. On the other hand, in the home country, there is a measure of one unit monopolistically-competitive intermediate goods producers. In every period, $\delta \in (0, 1)$ units of firms die and $\delta$ units of firms are born to keep the measure of one unit intermediates. In equilibrium, the measure of age-1 firms in any
period is $\delta$, the measure of age-2 firms is $\delta (1 - \delta)$, the measure of age-T firms is $\delta (1 - \delta)^{T-1}$. To guarantee that the measure of firms is still one in any period, the measure of the oldest firm, Age-T+1, would be $1 - \sum_{t=1}^{T} \delta (1 - \delta)^{t-1}$. An interaction between age measures and productivity probability produce a distribution over the Age-Productivity grid.

2.6.2 Procedures

The calibration procedures are illustrated as follows:

First, I guess values for foreign demand factor $\tilde{\theta}_F = \frac{\theta_F}{1 + \tau} P F Q_F^{0.7}$, financial parameter $\lambda$, fixed cost $F_{ex}$, and initial asset $a_0$.

Second, given the system of 12 equations plus the export-to-import ratio from the data, we calibrate equilibrium values, including wage rate $w$, labor demand $n_D, n_{ex}^D$, outputs of each variety $q_D, q_{ex}^D$, prices of each variety $p_D, p_{ex}^D$, domestic final good $Q_D$, imported final good $IM$ with imported price $P_{IM}$, prices for composite goods $\tilde{P}_D, \tilde{P}_{ex}^D$, and the exporting decision rule $e$.

Third, with those equilibrium values, I calculate the four moments we are interested in. Keep iterating until convergence and all the moments are matched in 2006 and 2009 respectively. In detail,

- Foreign demand shifting factor $\tilde{\theta}_F$ is calibrated to match export-to-sales ratio.
- Financial constraint parameter $\lambda$ is calibrated to match the liquid debt-to-asset ratio at the aggregate level, this is the key that distinguishes uniform credit shock from the heterogeneous credit shocks. In the case of uniform credit shock to every firm, $\lambda$ is the same for all the firms, while in the case of heterogeneous credit shocks, higher productivity firms receive a much stronger credit shock than the less productive firms.
- Fixed cost $F_{ex}$ is calibrated to match the probability of exporting.
• Initial asset $a_0$ is calibrated to match the size difference between young and old firms.

Finally, to see how big are the impacts from the foreign demand shock and financial constraint separately, I conduct two counter-factual experiments. First, I use all the calibrated parameters in 2009 except foreign demand factor $\tilde{\theta}_F$, which is replaced by the one from the 2006, to see how all the moments will react to a better foreign demand. Second, I use all the calibrated parameters in 2009 except financial constraint parameter $\lambda$, which is replaced by the one from the 2006, to see how all the moments will response to a better financial condition.

2.6.3 Results

This section discusses calibration results displayed in Table B.3, B.4, B.5, B.6, and Figure B.1. By comparing the changes between the model in 2009 with identical credit shocks and counter-factual experiments, we can see that 50% of the drop in the export-to-sales ratio is induced by the foreign demand shock, while only 0.1% is related to financial constraint based on the Chinese firm-level data. The rest of drop is mostly explained by the change in the fixed costs. Likewise, at the extensive margin, a better foreign demand condition in 2006 increases the fraction of exporters in 2009 by 25%, a better credit condition increases the export participation rate by 2.4%, and the residuals are explained by the change in the fixed costs.

In the 2009 model with heterogeneous credit shocks (the right-most column in Table B.3), high-productivity firms get hit by a stronger credit shock ($\lambda = 0.1$) and drop out. The aggregate price of Chinese exports $\tilde{P}_x$ increases from 2.54 to 2.64 in the model. Given that the demand elasticity of aggregate Chinese exports is not very high ($\eta = 1.5$), Chinese exports will not decrease by a large amount, instead the firms that get hit less ($\lambda = 1.88$) will stay in the market and expand. Potential entrants will start exporting because the varieties of Chinese goods are highly substitutable
This effect can be observed from the new entrants in the green-shaded field above the productivity threshold, which is pinned down in a frictionless economy in Figure B.1. The second effect comes from a lower wage rate. This is different from the 2009 model with identical credit shocks in which the wage rate increases. Labor force liberated from the dropouts drives the wage rate down, which is lower than the one in 2006. Therefore, low-productivity firms that used not to export now enter the exporting market since the labor cost is cheaper. This effect can be observed from the new entrants in the green-shaded field below productivity threshold, which is pinned down in a frictionless economy in Figure B.1.

Eventually, the new entrants and surviving firms will finance and export more to offset the drop in export and debt-to-asset ratio caused by the dropouts. As a result, we achieve the same export-to-sales ratio and export participation rate as the ones in 2006 without a dramatic change in the debt-to-asset ratio at the aggregate level. Thus the export collapse in the Great Recession is mostly caused by demand shock. This result is consistent with both micro and macro findings on the impact of credit constraints on export collapse.

Table B.7 displays the comparison between the partial equilibrium effect and the general equilibrium effect. In the first column, the export sales ratio would have declined by 2% if the general equilibrium effect is not taken into account. When the general equilibrium is considered, increase in aggregate exporting price and drop in wage rate together ensures that the export sales ratio stays unchanged. Likewise, in the second column, the export participation rate would have declined by 3% if only the partial equilibrium effect is considered. The export participation rate stays the same when I allow both aggregate exporting price and wage rate to vary.

To test the model’s prediction on cross-sectional correlation, I run the following regression to test the relationship between export collapse and credit shock. According to the results in Table B.8, the positive correlation between export participation rate
and leverage ratio conditional on crisis predicted by the model with heterogeneous credit shock is quite consistent with the evidence from the data.

\[ I(e > 0) = \alpha + \beta \text{Crisis} + \gamma \frac{\text{Debt}}{\text{Asset}} + \delta \frac{\text{Debt}}{\text{Asset}} \times \text{Crisis} \]

2.7 Concluding Remarks

I developed a quantitative theory linking credit constraints to firms’ export behavior. Financial frictions distort the selection of firms into the exporting market. The two general equilibrium effects from the final good market and the labor market in my model reconcile the different findings in micro-level and macro-level evidence. Under a uniform credit shock, all firms are hit in a similar manner; thus, the impact of credit constraint would be very little if the credit shock is small. In the case of heterogeneous credit shock, firms with different productivities experience different magnitudes of shocks, which is the key assumption in my model. High-productivity firms drop out the market, potential entrants start exporting, and surviving firms expand their business. Eventually, there is no significant change of both export behavior and credit conditions at the aggregate level. However, at the disaggregate level, firms with a worse credit condition do export less, while firms with a better credit condition do export more. Thus, there is a positive correlation between export and credit condition.

Another contribution I have made in this chapter is that financial frictions in a model with heterogeneous credit shocks could potentially affect exports at both extensive and intensive margins. The sales expansion among existing firms in the exporting market is mostly driven by a larger aggregate exporting price, which is at the intensive margin. The ability of new firms to enter the market is mostly driven by a lower wage rate, which is at the extensive margin.

In conclusion, by using the Chinese firm-level evidence, I find that the export
collapse in the Great Recession was not mostly driven by credit constraints, while
demand shock plays a larger role. Another possible reason for the export collapses
is that there was not a significant financial crisis in China between 2008 and 2009.
Future research will focus on the firm-level evidence from Korea during the severe
1999 Asian financial crisis.
CHAPTER 3

PRODUCTIVITY AND LIQUIDITY MANAGEMENT UNDER COSTLY FINANCING

3.1 Introduction

One of the most fundamental decisions firms make is that of resource allocation. Broadly speaking, firms either allocate resources toward acquiring capital assets, such as land, factory and machinery, or toward holding liquid assets, such as cash, receivables, and inventory. The return on capital assets is usually risky and varies greatly across firms with different levels of productivity. In contrast, liquid assets usually generate uniform, risk-free return. How much to invest in growth versus liquidity naturally depends on the productivity of capital and the cost of financing. This decision of how to optimally allocate limited resources is especially relevant when financing is very costly, as it is for firms in emerging markets.

The objective of this chapter is to investigate, theoretically and empirically, how firms with different levels of productivity allocate resources between capital assets and liquid assets in the presence of costly financing. We develop a tractable continuous time model to study the joint decision of capital investment and liquidity management. In the model, firms allocate resources between investing in capital, which has risky returns that vary for firms depending on their productivity, and holding cash, which earns risk-free return for all firms. Firms pay out dividends when their total assets are sufficiently high, and must refinance when total assets are
too low. Because future dividends are discounted, firms prefer to pay out early.\footnote{Every firm’s objective is to maximize discounted dividends or shareholders’ consumption stream.} On the other hand, because refinancing is costly, firms like to hold precautionary savings. Optimal liquidity management therefore represents a balance between paying out (or consuming) early and avoiding costly refinancing. Solving the model leads to the surprising conclusion that it could be optimal for more productive firms to have less capital and more cash when financing frictions are sufficiently severe. The underlying mechanism is that in equilibrium, more productive firms endogenously choose to pay out at lower asset levels. Their greater productivity allows them to expedite consumption relative to less productive firms.\footnote{That more productive firms pay out earlier appears to contradict the conclusion drawn from traditional constrained growth models, such as Buera et al. (2011), Song et al. (2011a) and Moll (2013). These models, however, generally do not have cash, and therefore firms can only alleviate financial constraint by delaying consumption. In our model, cash is an alternative solution, on which high productivity firms optimally choose to rely more so than do low productivity firms. In other words, holding liquid assets allow high productivity firms to endogenously take advantage of their productivity superiority and consume earlier.} This in turn expedites the need to refinance. As a result, high productivity firms are more risk averse and hence rely on cash holdings to mitigate downsizing risk. When financing becomes sufficiently costly, the risk aversion of high productivity firms dominates their relative advantage of holding capital. This theoretical prediction leads to an empirically testable hypothesis: a positive correlation between firm productivity and liquid assets/cash holdings in under-developed markets. This conclusion is in contrast to that obtained in a financially frictionless environment, where basic economic intuition suggests that more productive firms should acquire more capital.

We test our hypothesis using a large sample of Chinese manufacturing firms from 1999 to 2007. We find that, consistent with our theoretical prediction, firms in the highest productivity decile on average have a 32% higher net liquid to total assets ratio and a 21% higher cash to total assets ratio compared to those in the lowest decile. This pattern is highly robust, salient regardless of firm size, ownership structure,
industry affiliation, or how productivity and liquidity are measured. On the other hand, the productivity of manufacturers in the US—an operating environment where financing frictions are less severe—is negatively correlated with the holding of liquid assets, which is consistent with economic intuition.

We quantitatively analyze our model using parameters estimated from observed sample moments. Our model generates a distribution of liquid asset holdings that matches the observed pattern. Furthermore, we are able to infer the magnitude of some unobservable variables in the model. For example, the inferred magnitude of refinancing cost would suggest that financing frictions are much more severe in countries with less developed financial markets than previously documented. Finally, we find that lowering the cost of refinancing leads to a significant improvement in total productivity.

Our finding adds to the current understanding of liquidity management and external financing. Corporate finance studies on the determinants of firm liquidity abound, and precautionary savings is one of the primary theories. Almeida et al. (2004), Khurana et al. (2006) and Riddick and Whited (2009) all argue that the sensitivity of corporate cash holdings (or savings) to cash flow is an indicator of costly external financing. On the one hand, we document an observation consistent with this view: a positive correlation between liquidity and productivity (prominently) exists only in the Chinese sample. Our explanation for this observation hinges on the substantial external financing costs that Chinese firms face operating in an environment where the financial market is far from being developed. On the other hand, we complement the aforementioned studies by demonstrating the important role financial constraints play in the liquidity management and investment decisions.

3In estimating productivity, in addition to using the value added measure reported in the data divided by capital, we also follow a recent technique developed by Ackerberg et al. (2015).

4See Bates et al. (2009) for a review of studies on firm liquidity and Gao et al. (2013) for a summary of those related to precautionary savings.
of firms that face the same level of external finance costs but have varying levels of productivity. Moreover, we show that the severity of financing frictions matters: sufficiently severe financing frictions can incentivize high productivity firms to avoid costly external financing by maintaining higher internal liquidity.

The fact that high productivity firms may invest less proportionally in capital under significant financing frictions suggests a potentially serious capital misallocation problem. The literature on development economies, including Restuccia and Rogerson (2008), Hsieh and Klenow (2009), Greenwood et al. (2010), Buera et al. (2011), and Song et al. (2011a), has identified broad capital misallocation in emerging economies and argues that it leads to productivity losses. In particular, recent work by ? compares the efficiency of capital structure between firms in the US and those in China based on implications of the Hsieh and Klenow (2009) model. They use the same datasets as ours (Compustat and the NBS survey in China) and find substantially less efficient allocation between debt and equity among Chinese firms.

We reveal another potential layer of misallocation between fixed and liquid assets: not only do high productivity firms hold less capital than what is socially optimal, they actually trade off more capital for liquidity than do low productivity firms. Our understanding of emerging market economies would be incomplete without considering this hitherto undocumented potential for exacerbated capital misallocation. In support of this statement, we study the welfare implications of our model in the quantitative analysis section and show that a reduction of refinancing costs can indeed lead to a more efficient allocation of capital.

The model and data used in this chapter contribute to both the theoretical methodology as well as the empirical scope of the research on liquidity management. On the modeling side, our model is close to Bolton et al. (2011) and DeMarzo et al. (2012) but differs in several ways: first, firms in our model solve a dynamic portfolio

\footnote{See Restuccia and Rogerson (2013) for a more thorough literature review of the relevant studies.}
choice problem; second, capital price is endogenous in our model as we consider a
general equilibrium approach, and we manage to aggregate total firm wealth to solve
capital price, which is a challenging task in general equilibrium models; third, we
consider firms with heterogeneous productivity rather than a single representative
firm. On the empirical side, this chapter joins those that examine liquidity manage-
ment either for private firms or for firms outside the US, for example Dittmar et al.
(2003), Brav (2009), Lins et al. (2010), Bigelli and Sanchez-Vidal (2012), and Gao
et al. (2013). However, these studies do not measure productivity and are therefore
mute on the efficiency implications of firms’ liquidity management. To our knowl-
edge, this is the first large-scale study of private firms from an emerging economy
to document a positive correlation between firms’ productivity and their liquidity
demand—a counterintuitive observation for which we offer one explanation.

3.2 Model

This section presents a continuous time dynamic model based on the standard
liquidity management model of Bolton et al. (2011) but extended to allow heteroge-
neous productivity and a general equilibrium of capital. In the model, firms solve a
portfolio choice problem between capital and cash, subject to costly refinancing. The
solution offers several testable hypotheses. In particular, we find that more produc-
tive firms may hold proportionally more liquid assets compared to less productive
firms if the cost of refinancing is sufficiently high.

3.2.1 Basic Environment

There is a continuum of firms who are risk neutral with discount rate \( \rho \). Each
firm keeps two types of assets: physical capital for production and cash for meeting
the firm’s liquidity needs. Capital does not depreciate, but its output is risky. A firm
holding $K_t$ units of capital can produce $dY_t$ units of output according to

$$dY_t = K_t dA_t,$$  \hspace{1cm} (3.1)

where $dA_t = \mu_s dt + \sigma dZ_t$ is the idiosyncratic productivity of each firm. $s \in \{l, h\}$ is a state variable denoting firms’ productivity which for simplicity takes two values: either a low type $\mu_l$ or a high type $\mu_h$. The fraction of high productivity firms is $\pi$. The production technology of capital is constant returns to scale. Finally, the technology shocks, represented by the standard Brownian motion term $Z_t$, are assumed to be i.i.d. across all firms. In other words, there is no aggregate shock. Let $P_t$ be the price of capital, which firms take as given. The return per unit of capital is

$$dR_t = \frac{dA_t + dP_t}{P_t}.$$  \hspace{1cm} (3.2)

In contrast, holding cash is risk free. Cash earns an interest rate of $r$ which we assume is exogenous.\footnote{The condition $r < \rho$ is necessary for a non-trivial solution: if the risk free interest rate is higher than firms’ discount rate, firms can just hoard cash and postpone paying out dividends forever. Nevertheless, this condition does not necessarily mean that firms are more impatient than their creditors. It can be interpreted as the carrying cost of cash a la \textbf{Bolton et al.} (2011), which lowers the effective interest rate of holding cash.} Let $W_t$ denote a firm’s total assets and $\alpha$ the fraction of $W_t$ allocated to capital investment. The dynamics of $W_t$ follows

$$dW_t = \alpha_t W_t dR_t + (1 - \alpha_t) W_t r dt.$$  \hspace{1cm} (3.3)

We focus on the case where $\alpha_{s,t} \in [0, 1]$. That is, firms keep a positive balance in both physical capital and cash inventory. This is consistent with studies that show in the past decade firms in both emerging economies as well as in the US have become...
net lenders rather than borrowers.

Firms maximize the present value of dividends minus the cost of financing. We use the word “dividend” in a general sense: we do not restrict ourselves to public firms, and therefore dividends simply refer to firm value that is consumed rather than saved by firm owners. Due to production risks, firms will distribute dividends only when they have accumulated sufficient wealth. Standard argument implies that lump sum dividends $W_t - \bar{W}$ are made when $W_t$ exceeds a reflecting boundary $\bar{W}$. Meanwhile, production risks can also bring large losses of firm wealth. When $W_t$ is too low, firms must refinance. In reality, refinancing is seldom inexpensive. Whether firms refinance through debt or equity, there usually are substantial costs involved, including search costs, agency costs, underwriting fees, and other costs due to new covenants or change of control. We abstract away from the micro-market details by introducing a reduced form costly refinancing scenario: we assume refinancing occurs when $W_t$ is below some threshold $\bar{W}$; firms pay a marginal cost $1 + \delta > 1$ for each unit of asset raised; and they raise just enough external wealth that makes $W_t$ also a reflecting boundary.

These assumptions allow a simple yet general enough model to focus our attention on liquidity management. In the Appendix we discuss further.

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7 See Armenter (2012), Armenter and Hnatkovska (2012), Karabarbounis and Neiman (2012) and Gruber and Kamin (2015) for evidence in the US and other developed economies, and Cardarelli and Ueda (2006) and Bayoumi et al. (2012) for evidence in emerging economies. On the one hand, this assumption could be read as simply a no (net) borrowing constraint due to, for instance, contract enforceability in the credit market. In practice, lack of enforcement is prevalent in emerging economies, where financial markets are less developed. Allen et al. (2005), Lu and Tao (2009), Du et al. (2012) provide evidence of financing frictions in China in particular. On the other hand, such restriction does not necessarily imply that we rule out borrowing completely. Firms can still be allowed to hold debt, but it is common both in theory and in practice that borrowing is highly constrained in less developed markets, which can result in an overall positive liquidity balance. In all, we regard the assumption $\alpha_{s,t} \in [0, 1]$ as a reduced form of capturing the result after firms have balanced all liquid assets (cash and receivables) and all liabilities (debt and payables).

8 Firms can also choose to liquidate. We assume liquidation yields a low enough return such that firms always prefer refinancing over liquidation.

9 It does not matter qualitatively whether $\delta$ is the same for both high and low productivity firms. As later analysis shows, our theoretical predictions rely mainly on the overall level of $\delta$, rather than its distribution.
the technique of rationalizing this reflecting refinancing boundary, including ruling out constant refinancing from firms’ optimal equilibrium choice set by introducing an additional fixed refinancing cost.

Finally, to properly define an equilibrium, we need to introduce a market for capital. We assume a fixed capital (for example, land) supply of one unit. We then define the equilibrium of this economy:

**Definition 1** An equilibrium consists of firms’ optimal payout and refinancing decisions plus their liquidity management choice $\alpha_t$ and the dynamics of firm assets (3.3). The price of capital is determined by a market clearing condition

$$\pi \int \alpha_{ht} W_{ht} dF(W_{ht}) + (1 - \pi) \int \alpha_{lt} W_{lt} dF_l(W_{lt}) = P_t ,$$

(3.4)

where $F(W_{st})$ is the distribution of assets among firms with productivity $s$. The market clearing condition stems from the fact that aggregate investment in capital by all firms must equal the total value of capital, which is one times the price of capital.

Furthermore, we define a steady state equilibrium in which the distribution of firm value $F(W_{st})$ does not vary with time (so the subscript $t$ can be dropped). We show that such steady state equilibrium exists and, due to its tractability, focus our analysis on its properties.

We next proceed to establish formally the firm’s optimization problem. Then, we solve for the optimal choice of capital holdings $\alpha_{st}$ (or cash holdings $1 - \alpha_{st}$) and demonstrate its variation across productivity levels.

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10One can equivalently assume that capital can be created but with an adjustment cost so that firms do not accumulate infinite capital.
3.2.2 Model Solution

We first solve the model in the simplest way by treating capital price $P_t$ as a constant. Then, we show that $P_t$ is indeed a constant in the steady state equilibrium. Under a constant $P_t$, we can drop the time subscript and write $dR_t = \frac{dA_t}{P_t}$. That is, the return on capital is the return from the output only. We also observe that the solution method for high and low productivity firms is identical except for the different value $\mu$ represents, allowing us to drop the productivity index $s$ as well.

Substituting $dR_t$ back into $dW_t$ and using Ito’s lemma, the value of the firm solves the HJB equation:

$$
\rho V(W_t) = \max_{\alpha_t \in [0,1]} \left[ \left( \frac{\mu}{P} - r \right) \alpha_t W_t + r W_t \right] V'(W_t) + \frac{1}{2} \frac{\alpha_t^2}{P^2} \sigma^2 W_t^2 V''(W_t). \quad (3.5)
$$

Firms pay out dividends when $W$ exceeds the payout boundary $W$ and refinance when $W$ falls below the refinancing boundary $W$. These boundaries are determined by the following conditions:

$$
V'(W) = 1, \quad (3.6)
$$

$$
V'(W) = 1 + \delta, \quad (3.7)
$$

The above characterization of the firm’s optimization problem is intuitive: optimal firm value $V_t$ is a function of the firm’s assets $W_t$. Higher weight on capital $\alpha_t$ means firms can produce more but at the same time bear more risk. At both the payout and refinancing boundaries, the marginal value of assets inside the firm equals the marginal value of dividends or the value of new external equity.

Differentiating equation (3.5) with respect to $\alpha_t$, the usual first order condition implies

$$
\alpha_t = -\frac{\mu P - rP^2}{\sigma^2} \frac{V'(W_t)}{W_t V''(W_t)}. \quad (3.8)
$$

This solution of $\alpha_t$ takes the typical Merton form: net return of the risky asset less
the risk free interest rate divided by the variance of return and multiplied by the inverse of the coefficient of relative risk aversion.

The HJB equation (3.5) can potentially have multiple solutions. We focus on one particular solution: constant $\alpha_t^{11}$. This means we conjecture and later verify that $V(W_t)$ satisfies $\frac{V'(W_t)}{V(W_t)} = -\frac{1}{\gamma} W_t$ for some constant $\gamma$. The HJB equation is then simplified to

$$\rho V = \left( \frac{\phi^2}{2\gamma} + r \right) W_t V'(W_t),$$

(3.9)

where

$$\phi = \frac{\mu - rP}{\sigma}.$$  

(3.10)

We refer to $\phi$ as the risk-adjusted return of a firm’s capital. $\phi$ depends on each firm’s productivity $\mu$. As we assume $r$, $P$ and $\sigma$ are uniform for all firms, a high productivity firm also has a high level of risk-adjusted return on capital.

The firm’s HJB has the following closed-form solution:

$$V(W) = \theta W^{1-\gamma},$$  

(3.11)

where $\theta$ is a constant coefficient to be determined by matching the boundary conditions, and $\gamma$ measures the firm’s (endogenously implied) degree of risk aversion. A higher $\gamma$ implies a more risk averse firm. While firms in this model are risk-neutral by nature, they are effectively risk averse due to the concern of avoiding costly refinancing, a standard result of dynamic investment models. We relegate to the Appendix the algebraic details on the derivation of parameters for $V(W)$.

Combining (3.11) with the formula for $\alpha$, we arrive at the following lemma:

**Lemma 1** The fraction of capital held by a firm of productivity $s \in \{l,h\}$, $\alpha_s$ is

\footnote{This is the solution in a standard Merton problem if there is sufficient adjustment cost for $\alpha_t$}
given by
\[ \alpha_s = \frac{\phi_s P}{\gamma_s \sigma}. \] (3.12)

where \( \phi_s \) is the risk-adjusted return of capital defined in (3.10) and \( \gamma_s \) is the firm’s (endogenously implied) degree of risk aversion

Lemma 1 states that a firm’s liquidity choice, \( 1 - \alpha \), is driven by two forces. A firm holds more capital and thus less cash if it has a higher return from capital and a lower degree of risk aversion. While more productive firms naturally have higher return from capital, the following result shows that they are also endogenously more risk averse than low productivity firms:

**Lemma 2** The (endogenously implied) degree of risk aversion of a firm of productivity \( s \in \{l, h\} \), \( \gamma_s \), satisfies \( 0 < \gamma_l < \gamma_h < 1 \).

While this might seem somewhat surprising, it is a natural result of firms’ optimal liquidity management. To see why, we explicitly solve for the payout boundary \( W \) from (3.6), which yields
\[ W = (1 + \delta)^{\frac{1}{2}} W. \] (3.13)

Therefore, Lemma 2 implies \( W_h < W_l \); that is, high productivity firms pay out dividends earlier. On the one hand, firms discount the future, so early dividends are more valuable. One the other hand, earlier dividends mean that \( W \) stops growing earlier and there is higher chance of hitting the refinancing boundary. Therefore, high productivity firms that take advantage of their ability to pay out earlier have less slack between the payout boundary and the refinancing boundary. As such, these firms have stronger incentive to maintain higher asset levels and are more averse to losses than low productivity firms.

\[ \text{See Appendix for the algebraic details.} \]

\[ \text{Examining the differences between our model and models of dynamic risk management such as} \]
It should be noted that Lemma 2 and equation (3.13) do not necessarily imply that we expect high productivity firms to be on average smaller than low productivity firms in the data. Equation (3.13) is about the payment boundary, whereas average firm size also depends on the distribution of firm size. It is possible that in equilibrium more productive firms are clustered near the payment boundary resulting in bigger average size. We also assume uniform refinancing cost for simplicity. In practice it is very likely that refinancing cost is correlated with productivity, for example due to differentially skilled management teams. Despite these possibilities, our main result regarding productivity and liquidity does not rely on how productivity and average firm size are correlated. In the quantitative analysis section, we use the observed moments of size in the data to parameterize our model and therefore do not make specific predictions regarding average size alone.\(^{14}\)

The final step is to replace the endogenous price of capital \(P\) in equation (3.12) in Lemma 1 by demonstrating that there is a steady state equilibrium in which \(P\) is indeed a constant. Substituting (3.8), the first order condition of \(\alpha_t\), into (3.3), the dynamics of \(W_t\), implies that in between \(W\) and \(\bar{W}\), \(W_t\) follows

\[
\frac{dW_t}{W} = \left[ \frac{(\mu - rP)^2}{2\gamma \sigma^2} + r \right] dt + \frac{\mu - rP}{\gamma \sigma} dZ_t. \tag{3.14}
\]

Equation (3.14) suggests that \(W_t\) is a geometric Brownian motion with two reflecting barriers or RGBM for short. This type of processes has closed form stationary

\[\text{Rampini and Viswanathan (2010) and Moll (2013) reveal another justification for the early payout of high productivity firms. In those models, firms face borrowing constraints but can save internal net worth until they are large enough that the constraints no longer bind. Firms with higher productivity grow faster and become unconstrained earlier. In our model, the reflecting boundary means that firms cannot grow infinitely large. The Brownian motion implies that no matter how large a firm gets, there is always the possibility of large enough losses such that refinancing is necessary. Consequently, firms never become unconstrained and must all optimally balance between expediting payout and maintaining sufficient liquidity.}\]

\[\text{14Since the majority of our sample is private firms with no information on payout, we are not able to directly test the relationship between productivity and the payment boundary other than through how it affects firms’ liquidity policy.}\]
distributions with easy to compute moments. Consider a generic RGBM \( W_t \), where \( \frac{dW_t}{W_t} = \mu_W dt + \sigma_W dZ_t \) between an upper reflecting barrier \( \bar{W} \) and a lower reflecting barrier \( \underline{W} \). Let \( \eta \equiv \frac{2\mu_W}{\sigma_W^2} \). Zhang and Du (2010) shows that the stationary distribution of \( W_t \) is given by the density function

\[
f(W) = \frac{\eta - 1}{W^\eta - \underline{W}^\eta} W^{\eta-2}.
\]

(3.15)

This density function is a power function, which is consistent with the cross-sectional distribution of firm size found by Ai et al. (2013). The power distribution can also be easily integrated to obtain its expectation:

\[
E(W) = \int_W^{\bar{W}} \frac{\eta - 1}{W^\eta - \underline{W}^\eta} W^{\eta-1}dW = \frac{(\eta - 1)}{\eta (\bar{W}^\eta - \underline{W}^\eta)} (\bar{W}^\eta - \underline{W}^\eta) .
\]

(3.16)

Putting \( E(W) \) back into the market clearing condition (3.4) allows us to solve for the equilibrium capital price \( P \). Combining it with the formula for liquidity management choice \( \alpha \), we have the following conclusion regarding \( \alpha \) as a function of productivity:

**Proposition 1** In the steady state equilibrium, a firm’s optimal holdings of capital \( \alpha_s \) are a function of the firm’s productivity on capital \( \mu_s \), the volatility of return on capital \( \sigma \), and the refinancing cost \( \delta \). In particular, \( \alpha_l < \alpha_h \) if \( \delta \) is low, and \( \alpha_l > \alpha_h \) if \( \delta \) is sufficiently high.

Proposition 1 highlights the importance of refinancing costs in the relationship between firms’ liquidity management and productivity. Intuitively, a higher refinancing cost makes both low and high productivity firms more risk averse, but high productivity firms are more sensitive to refinancing as they accumulate less wealth before dividend payout. Recall Lemma 1 which shows that a firm’s optimal capital holdings are positively correlated with its return on capital but inversely correlated with its
implied degree of risk aversion, and Lemma 2, which shows that more productive firms are effectively more risk averse. When refinancing cost is low, the effect of the return on capital dominates, and more productive firms hold more capital and less cash. In contrast, when refinancing cost is high, the effect of risk aversion dominates, and more productive firms may hold less capital and more cash.

Proposition 1 implies the following testable hypothesis:

**Hypothesis 1** More productive firms hold more cash and/or liquid assets than less productive firms when there is a substantial cost of external refinancing. The correlation between productivity and cash/liquid asset holdings is zero or negative when refinancing cost is low.

We test this hypothesis in the next section for two economies with significantly different levels of financial development: an emerging economy (China) versus a developed economy (the U.S.). There is abundant empirical evidence that external financing is indeed costly in emerging economies. La Porta et al. (1997, 1998, 2000) show that countries with less formal creditor rights protection and weaker legal enforcement systems have smaller domestic loans, narrower debt markets, and greater difficulty in raising external financing. Allen et al. (2005) and Ayyagari et al. (2010) find costly informal financing in a country with less developed formal financial markets. We also provide supporting evidence of such financing frictions when we quantitatively solve for the refinancing cost in China in section 3.4.

3.3 Empirical Results

In this section we empirically test our hypothesis. Our tests focus on data from China, where substantial frictions are known to exist in its financial markets, and compare our results to those obtained using US data. We define two liquidity measures: net liquid assets to total assets ratio and net cash holdings to total assets ratio.
We find that there is a robust positive correlation between both liquidity measures and productivity in the Chinese sample, a pattern distinctively different from what is observed in the US sample.

3.3.1 Data and Summary Statistics

The primary dataset we use is the Annual Survey of Industrial Production from 1999 to 2007 conducted by the National Bureau of Statistics of China (NBS). It has been used in development economic studies such as Cai and Liu (2009a), Hsieh and Klenow (2009) and Khandelwal et al. (2013). The dataset includes all state-owned firms as well as non-state-owned firms with sales exceeding five million yuan (about $700,000) per year and spans 37 two-digit manufacturing industries and 31 provinces or province-equivalent municipal cities. It contains over 200,000 firms a year on average, significantly larger and more representative than datasets that rely on publicly available information such as firm disclosure.

The data report firm production information as well as balance sheet information. Cai and Liu (2009a) describes the collection procedure and reliability of the data set as follows:

*NBS collects the data to compute the Gross Domestic Product. For that purpose, every industrial firm in the dataset is required to file an annual report of production activities and accounting and financial information with the NBS. The information reported to the NBS should be quite reliable, because the NBS has implemented standard procedures in calculating the national income account since 1995 and has strict double checking procedures for above-scale firms. Moreover, firms do not have clear incentives to misreport their information to the NBS, because such information cannot be used against them by other government agencies such as the tax authorities. Misreporting of statistical data was commonly suspected for some time in China, the most notorious was local GDP data provided by local governments. However, the*
national income accounting of above-scale firms is done by the central NBS, hence is much less subject to manipulation by local governments. The NBS designates every firm in the dataset a legal identification number and specifies its ownership type. Firms are classified into one of the following six primary categories: state-owned enterprises (SOEs), collective firms, private firms, mixed-ownership firms (mainly joint stock companies), foreign firms, and Hong Kong, Macao and Taiwan firms. The NBS does not treat publicly listed companies in China separately, which are all grouped under the mixed-ownership category. By the end of 2005, there were about 1,300 publicly listed companies in China's two stock exchanges; only slightly over 700 of them were manufacturing firms, a fraction of our sample.

Our variables of interest are firms' liquidity management and productivity. The value of gross output is measured by the total value of goods produced in each period, which differs from sales due to changes in inventories and is also more closely linked to the intermediate inputs. Intermediate inputs mainly measure the cost of materials used in production. The tax on value added in China is 17% for most firms (with the exception of very small firms, which are rarely included in our dataset). The dataset provides information on value added, which is defined as the value of gross output net of intermediate inputs plus tax. A measure of productive used is the value added per capital, which is obtained from dividing the value added by the value of fixed assets.

Measuring productivity with value added per capital may raise several concerns. First, production also requires labor and intermediate goods. A firm that employs more workers may produce more than another firm with the same amount of capital. Secondly, capital and labor are endogenously chosen given each firm's underlying technology. Finally, if for some reason capital is mis-measured, then value added per capital may be subject to the same bias. To overcome these issues, we construct an alternative productivity measure: total factor productivity (TFP). Commonly used in
development economics, TFP is the residual from regressing output on capital, labor, and intermediate inputs, and is arguably the most unbiased measure of productivity available. The specific estimation procedure has undergone constant improvement. We adopt the latest technique in this field following Ackerberg et al. (2015). This technique has been used in the most recent empirical studies on productivity such as Greenstone et al. (2010), Brandt et al. (2012a), and De Loecker and Warzynski (2012). Details of the Ackerberg et al. (2015) are laid out in the Appendix. The calculated TFP is strongly positively correlated with the value added per capital measure reported in our dataset, suggesting that there is unlikely to be any systemic bias or measurement error in capital or value added in our sample.¹⁵

Using TFP as the productivity measure also eliminates the concern that value added per capital is driven by decreasing returns to scale in capital, and thus its correlation with liquidity demand is merely a reflection of the difference in liquidity management between large and small firms. The procedure used in Ackerberg et al. (2015) explicitly removes the potential confounding factor of size on productivity, as TFP is defined as the residual term in a regression with capital and labor as explanatory variables. In our empirical analysis below, we also control for firm size in all regressions to further reduce such concern.

We define two measures that reflect firms’ liquidity management decisions. The first is firm’s net liquid assets to total assets ratio. Net liquid assets is the difference between liquid assets and liquid debt. Our second liquidity measure is cash holdings to total assets ratio, which is commonly used in corporate finance studies of liquidity management. However, examining only the level of cash holdings can be biased, as a cash-rich firm may also hold a large amount of debt and is a net borrower, whereas another firm may have less cash but also no debt. Therefore we use a “net” cash

¹⁵We also construct value added per worker as an alternative productivity measure. Using value added per worker produces almost the exact results as using value added per capital which further confirms that our results are not driven by unobservable measurement errors in capital.
measure, which equals cash plus accounts receivables minus accounts payables\textsuperscript{16}. Throughout this chapter, the term “cash holdings” always refers to the “net” cash measure.

Table C.1 Panel A summarizes the main firm variables\textsuperscript{17}. We then compare our sample of Chinese manufacturing firms to their US counterpart from Compustat North America. We find that the firms in our sample are much smaller, in terms of total employment, profit and size. Most balance sheet variables are within a comparable range except for the composition of debt. Chinese firms use more liquid debt and significantly less long-term debt. This reflects the difficulty of financing for most Chinese firms, as long-term debt usually comes with stronger collateral requirement, better credit-history, and more covenant restrictions that are typically difficult to satisfy in a market with significant financing frictions.

As a result of significant economic transitions in China, the firms in our sample have particularly complicated ownership structures. There are two general ways of defining firm ownership. One way is based on paid-up capital, which is capital funded by investors. Each firm has six types of investors: state, collective, legal-person, individual, HMT (Hong Kong, Macau, Taiwan), and foreign. We define ownership based on the type of investor that supplies the largest share of capital. As such, we have six ownership types: SOE (State-owned enterprise), COE (Collective-owned enterprise), DPE (Domestic private-owned enterprise), HMT (Hong Kong, Macau, Macau, Macau, Taiwan), foreign.

\textsuperscript{16}It is also common in the literature to add short-term investments and subtract the current portion of long-term debt from a cash holdings measure. However, in our sample the median value for both terms is 0 and we therefore exclude them from our cash holdings measure. Adding them back does not alter our findings qualitatively.

\textsuperscript{17}The number of observations for TFP is smaller because TFP calculation requires a panel of firms that survive throughout the sample period.

\textsuperscript{18}Tian (2000) in “Property Rights and the Nature of Chinese Collective Enterprises” describes the COE as follows: Collective-owned is a special type of ownership seen in China. It is like Township and Village Enterprises (TVEs). It has at least five features. First, the TVE has no well-defined owners, although a TVE is conceptually owned by the people of a community. There exists no well-defined relation-to-person shares. Therefore, by the standard definition of property rights, the
Taiwan-owned enterprise), FE (Foreign-owned enterprise) and LPE (Legal person-owned enterprise). Legal person could be an individual, company, or other entity that has legal rights and obligations.

Panel B of Table C.1 summarizes the distribution of ownership in our sample based on paid-up capital. The majority of the firms in our sample are private. One drawback of this classification is that, within the ”legal person” category, which accounts for 22% of the sample, we cannot further distinguish investor identity among individual, company, or other entity. To circumvent this issue, we also construct an alternative measure of ownership as the fraction of state-own capital. This by definition is a continuous variable and thus can capture the incremental effect state ownership has on firms’ liquidity policy when used as an explanatory variable in a regression. The average state ownership is 10% in our sample while the median is 0%. That is, most firms are 100% privately owned.

3.3.2 Observations

To uncover the relationship between firm productivity and liquidity management, we sort firms into deciles based on their productivity. Within each decile, we compute the average of our two liquidity measures. Our first productivity measure is value added per capital, which is directly computed from the data. The distribution of our liquidity measures conditional on value added per capital is shown in Figure C.1.

Our second productivity measure is TFP, which is calculated according to the

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TVE has no well-defined owners. Second, in the majority of TVEs, funds are drawn mainly from the assets of the people of the community, although some are drawn from government loans. Only a small portion of TVEs, the so-called red-hatted collective TVEs, are individual, partnership, or cooperative stock-sharing enterprises, which, in order to obtain low interest rate loans or for ideological reasons, are registered as collective enterprises. Third, the people of the community cannot share directly in the profits of the local TVEs. Only employees are compensated in the form of wages. Fourth, most TVEs are controlled by their community’s administration, particularly the chief leaders. The chief leader can appoint the manager of a TVE and may participate in production decision making. Fifth, TVE capital cannot be transferred or sold. When an individual leaves a community, he automatically loses common ownership of that TVE.
latest technique as proposed by Ackerberg et al. (2015). The distribution of liquidity conditional on TFP is shown in Figure C.2.

It is evident from these two distributions shown above that more productive firms hold more liquid assets and cash. The pattern is robust to the two productivity measures as well the two liquidity measures, albeit the dispersion of net liquid assets is larger than that of cash holdings, and the dispersion across productivity deciles is larger using value added per capital than using TFP. Moreover, these figures reveal that firms in our sample are on average net savers, which justify our model assumption \( \alpha \in [0, 1] \).

We conduct a range of robustness checks to confirm that our finding is not driven by any other firm characteristics. We control for firm ownership, industry fixed effects as well as firm size. Figure C.3 shows the result for SOE firms only and DPE firms only. Ownership is defined by paid-up capital. The concern that firm ownership matters in China is well grounded. Major banks in China are state-owned, and these SOEs usually have a much lower hurdle for external financing. We find that despite SOEs’ generally keeping a lower fraction of assets for liquidity, there is no systematic difference between SOE and DPE in terms of the correlation between liquid asset holdings and productivity. This finding is consistent with Bayoumi et al. (2012). We also define ownership according to firms’ registration type, and the same pattern still holds.

It should be noted that while studies have argued that SOE faces lower financing cost than DPE, the fact that liquidity asset holdings is higher for more productive firms in both groups of firms is not inconsistent with our theoretical prediction. Proposition I states that liquidity and productivity should be positively correlated when financing is costly enough. It is possible that in an overall under-developed financial market, financing costs are high enough for both SOE and DPE such that Proposition I holds. Later in this section we provide contrasting liquidity policy
using a sample of US public firms, which, regardless of their ownership structures, should have lower financing costs compared to most Chinese firms.

We also check the robustness of our finding against potential industry fixed effects. It is possible that the distribution of productivity differs dramatically from one industry to another. We thus remove industry fixed effects using two different approaches. In one approach, we subtract the average industry productivity from each firm’s productivity, thus taking into account the difference in average productivity across industries. With the second approach, we first construct productivity deciles within each industry and then aggregate firms that belong to the same decile across all industries to create overall deciles. Results are shown in Figure [C.4]. Again, we find no systematic difference from our baseline analysis. We also plot the same graphs of our liquidity measures against productivity deciles for each industry individually. Results are not reported in the interest of space, but we find a strong positive correlation between liquidity and productivity in all industries except for the tobacco industry which is heavily regulated and should not be treated the same as other manufacturing firms.

We provide regression results to formally support the aforementioned findings. We regress our liquidity measures, net liquid assets and cash ratio, against our two productivity measures, TFP and valued added per capital. For control variables, we follow [Gao et al. (2013)], which also studies liquidity policy from a sample of private firms, in constructing these control variables. Due to data limitation, the inclusion of certain control variables reduces our sample size significantly. We therefore report regression results for two sets of controls: in the first set, we include basic firm characteristics that as firm size, age, ownership and well as variables that are available throughout the sample: sales growth, leverage, capital investment, foreign sales, etc.

19 Also, not all variables in [Gao et al. (2013)], such as dividend, are available in our data. However, our sample includes a much larger number of firms.
The second, more extensive set additionally includes cash flow and R&D expenditure, which are only available in our data starting in 2005. Industry and year fixed effects are also included, and standard errors are clustered in all regressions.

Table C.2 reports three OLS regressions of firms’ net liquid assets to total assets ratio against our productivity measures. The coefficients on productivity in all regressions are positive and significant, both statistically and economically. For example, a one standard deviation increase in TFP on average leads to a 2.8% increase in net liquid asset holdings, which is fairly substantial given that the average net liquid assets ratio is around 4.6% in the sample. Economic significance is also stronger using value added per capital as the productivity measure: a one standard deviation increase in value added per capital on average implies a 1.9% increase in net liquid assets.

Table C.3 reports similar regressions of cash holdings. Results are consistent with those from regressing net liquid assets: all coefficients on productivity are positive and significant. On average, a one standard deviation increase in TFP and value added per capital implies a 1.7% and 1.2% increase in cash holdings, respectively.

We check the robustness of our regression results in a number of alternative specifications. For example, defining ownership using the firm’s registered type; using a subsample of 100% privately-owned firms; including more control variables such as industry-median adjusted net liquid assets or cash (that is, the ratio of a firm’s liquid assets/cash to the industry median). Results hold in all the robustness checks and are thus omitted here.

To further test the prediction of Hypothesis 1, we investigate whether the correlation between firm productivity and liquidity found in the Chinese sample holds

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20Moreover, controlling for cash flow and sales rules out the possibility that high productivity firms hold more liquid assets or cash simply because they have more unspent cash income at the time the survey is conducted. However, since cash flow is only available from 2005-2007, we are then unable to include cash flow volatility as a control due to the data limitation.
for firms in the US, where financial markets are known to be far more developed. Our sample of US firms comes from Compustat. In a recent study, İmrohoroğlu and Tüzel (2014) calculate TFP for Compustat firms using a modern technique similar to ours. We thus construct productivity deciles for Compustat firms using their TFP data directly. We also compute the net liquid assets to total assets ratio as well as the cash holdings to total assets ratio for the Compustat firms.

The results are shown in Figure C.5. Unlike for Chinese firms, the relationship with productivity varies across different liquidity measures. The net liquid assets ratio displays a negative correlation with productivity except for the highest decile, whereas cash holdings exhibit a less obvious pattern. Furthermore, the range over which the net liquid assets ratio and cash holdings vary across productivity deciles is smaller for Compustat firms. As a further robustness check, we reverse engineer İmrohoroğlu and Tüzel (2014) to compute the value added per capital measure for Compustat firms as well. We do not find any clear patterns of net liquid assets or cash holdings for Compustat firms ranked by value added per capital. We omit the graph in the interest of space.

We complement our comparison of Chinese manufacturers and their US Compustat counterpart with regression results. Table C.4 shows the results from regressing the two liquidity measures against TFP, obtained from İmrohoroğlu and Tüzel (2014). We use the sample period of 1999-2007 and include all the controls used in Table C.2 and C.3, consistent with regressions run for the Chinese sample. We find a negative coefficient on productivity for net liquid assets, and an insignificant coefficient for cash holdings. This is contrary to the regression results for the Chinese sample but is consistent with economic intuition. The economic magnitude of the coefficient is also smaller. With a one standard deviation increase in TFP, the net liquid assets ratio decreases by 0.59% while the sample average is 28%.

From both graphical illustrations and regression results, we find no evidence of a
positive correlation between productivity and liquidity demand for the sample of US manufacturers in Compustat. It should be noted that whereas Compustat contains large public firms, our Chinese sample consists of mostly small private ones. Nevertheless, we show that our findings for the Chinese sample are robust to ownership and firm size. Furthermore, this difference is consistent with Hypothesis[1] since the difference in financing costs should be the greatest between large US public firms and small Chinese private firms.

In sum, we empirically verify that corporate savings, measured by either net liquid assets or cash holdings, has a positive correlation with productivity in a developing economy (China), a pattern that is not observed in a developed economy (US). This is consistent with our theoretical prediction that financing frictions lead more productive firms to maintain more liquidity due to a stronger precautionary savings motive.

3.4 Quantitative Analysis

The purpose of this section is two-fold: first, while the empirically documented liquidity management behavior is consistent with that predicted by our model, the lack of identification means we fall short of proving that the liquidity policies we observe are caused by costly financing. To further validate our theory, we calibrate the model-implied distribution of cash holdings using parameters according to comparable studies as well as moments calculated from our data. We show that the model implied distribution matches the observed distribution well, evidence that our model is likely a reasonable approximation of liquidity management in practice.

The second purpose of this section is to quantitatively infer the level of refinancing cost, which is not directly observable from the data. Furthermore, the calibration exercise allows us to examine the welfare gain in terms of the change in aggregate productivity if refinancing costs were lowered. Overall, we find refinancing costs in
China to be almost twice that previously documented for the U.S., and that reducing them can lead to significant welfare improvements.

3.4.1 Parameter Choices

To begin, we set $r = 3\%$, following the average one-year interest rate on deposits in China in our sample period. We set $\rho = 6.5\%$, following the one-year interest rate on commercial loans. In the model, $\rho - r$ can be interpreted as the wedge between firm owners’ required rate of return and the risk-free savings rate, which is commonly proxied by the loan-deposit spread. In China, the loan-deposit spread is set by the People’s Bank of China (the central bank) and therefore does not move from day to day. Historically it has been stable, around 3.5% from 1998-2008. The actual loan rate could vary, especially across firms with different ownership structures; private firms usually bear higher rates than state-owned firms. Given that SOEs account for only 5% of our sample, we decide on 6.5% as the uniform rate at which firms discount future dividends. Alternatively, the $\rho - r$ spread can be modeled as the “carrying cost” of cash due to, for example, agency costs of cash. Bolton et al. (2011) sets a carrying cost of 1%. We argue that it is likely higher for the firms in our sample, which are mostly small private firms and are much more likely to be plagued with severe agency problems as found by La Porta et al. (1997, 1998, 2000).

We estimate the average expected return on capital $\mu$ to be 15% by utilizing the value added measure in our data combined with information on labor and capital. However, a precise mapping of a productivity measure into the mean and volatility of risk-adjusted productivity shocks $\mu$ and $\sigma$ proves to be challenging. The procedure we follow is broadly consistent with Bai et al. (2006b), Hsieh and Klenow (2009), Asker et al. (2012), as well as the standard literature on industrial organization. There is no uniform method for determining the range of $\mu$; nor is there consensus on the average value for various developing markets. We assign $\mu = 15\%$ for firms in the 5th
productivity decile of our sample and estimate $\mu_s$ for the rest of the deciles based the ratio of each group’s TFP estimate over the TFP of the 5th decile. As such, $\mu = 10\%$ for firms in the 1st decile and $\mu = 40\%$ for firms in the 10th decile, a range that is comparable to the variation in TFP\(^{21}\).

In the model, the volatility of capital return $\sigma$ is fixed for simplicity. In practice, $\sigma$ could vary across firms and be correlated with firms’ productivity. We calculate $\sigma$ to be 0.4 for most firms except those in the largest productivity deciles. We have to manually assign $\sigma$ to a number of firms due to the brevity of our sample period. The Appendix provides more details on the procedure used to calculate average $\mu$ and average $\sigma$.

For variables not directly observable from data—payout boundary $W$, refinancing boundary $\tilde{W}$, price of capital $P$, risk-adjusted return on capital $\phi_s$, firm’s degree of risk aversion $\gamma_s$—we utilize their mathematical relationship with other model parameters. In particular, we take advantage of the fact that our steady-state distribution of firm assets (3.15) satisfies the power law and measure the coefficient of the power distribution $\eta$ directly from the data. In the model, $\eta_s$ is a function of risk-adjusted return on capital $\phi_s$ and firm’s degree of risk aversion $\gamma_s$. Using the mathematical expression for $\eta$ derived in the Appendix and replacing $\gamma_s$ with $\phi_s$ from (C.4), we can calculate $\phi_s$ from (C.21) and infer $\gamma_s$. All parameters and their values are summarized in Table C.5.

3.4.2 Quantitative Results

We first test the validity of our model by computing the model-implied cash holdings ratio $1 - \alpha_s$ with the observed cash holdings for each productivity decile. Results are shown in Panel C of Table C.5. Compared to the distribution of actual

\(^{21}\)We do not claim that our parameter choices for $\mu$ are flawless, and the values we use do do affect the performance of our quantitative analysis later. However, our choice for $\mu$ is not ungrounded. It is informed by our sample; moreover, we are not aware of a clearly better method of estimation.
cash holdings, our model generates very similar distributions in terms of correlation with productivity, with the only exception being the 10th decile. This is mainly due to the fact that our estimate for $\mu$ relies on the observed dispersion of productivity in our sample, which is most extreme in the right tail.\[^{22}\] In general, our model predicts well the distribution of cash holdings conditional on productivity and, in particular, how it correlates with increasing productivity.

Next, we use equation (3.13) to calculate the refinancing cost $\delta$. Our calibration implies that $\delta$ equals to 14%. This is quite substantial compared to what is found for large public firms in the US, as estimated by Altinkilic and Hansen (2000) for example. But it is broadly in line with studies on Chinese firms, such as Zou and Qian (2005), Shen (2007), and Park and Shen (2008). There are two main reasons why refinancing cost is higher in our study than that found in Altinkilic and Hansen (2000): one, it is well-known that financial markets in China are much less developed than in the US. Two, most previous studies only focus on public (listed) firms, while our sample comprises of mostly small private firms with more limited access to financing. Overall, the implied cost of refinancing is consistent with the common knowledge that financial markets in China are far less developed than in the U.S. and with the prediction of Proposition 1 that severe financing frictions are an important driver of the positive correlation between cash holdings and productivity.

3.4.3 Capital Allocation and Welfare

The fact that high productivity firms hold less capital suggests a potentially large capital misallocation problem. Misallocation due to financial frictions has been extensively discussed in the literature. Buera et al. (2011), Hsieh and Klenow (2009), Moll (2013) argue that asset misallocation plays a significant role in explaining cross-

\[^{22}\]In fact, if we remove the 5% observations from each tail, and recalculate the productivity dispersion, we would have $\mu = 29.0\%$ for the last decile, which implies a cash holdings ratio of 35.2%—much closer to the observation from data.
sectional productivity discrepancies across different industries and countries. Our study contributes to the debate. We argue that financial frictions, such as costly refinancing, could result in high productivity firms simultaneously deploying an insufficient level of capital and maintaining an excessive level of liquidity.

We conduct a quantitative experiment to examine how much the distribution of capital, cash, and the overall productivity of capital in the economy would change, if financial frictions were reduced. More specifically, we hypothesize a reduction of $\delta$ from the value we calculated above, and solve the payout boundary $W$ and firm’s portfolio weight on capital $\alpha_s$ for each productivity decile accordingly. Since $\alpha_s$ is a constant independent of $W$, we define total productivity $\mu^*$ as the total output from capital divided by the total amount of capital. That is,

$$
\mu^* = \frac{\sum_{s=1}^{10} \left( \int_W^{W_s} \mu_s \alpha_s W_s dF(W_s) \right)}{\sum_{s=1}^{10} \left( \int_W^{W_s} \alpha_s W_s dF(W_s) \right)} \tag{3.17}
$$

We calculate that if refinancing cost $\delta_s$ were reduced by 20% from its current level, total productivity $\mu^*$ would increase by 12%; if $\delta_s$ were reduced by 50%, total productivity would increase by 26%. To understand the mechanism behind such productivity gain, note that payout boundaries for all firms are lower under a smaller refinancing cost, because firms have a weaker precautionary savings motive and are able to pay out dividends sooner. All firms hold more capital and less cash. However, with a large reduction in refinancing cost, high productivity firms may hold more capital than low productivity firms. Overall, reducing the cost of refinancing has a significant positive effect on total productivity, thanks to the reallocation of capital from low to high productivity firms.
3.5 Conclusion

In recent years, firms worldwide have been holding an increasing amount of cash and liquid assets, prompting many to ask why corporations save so much. This chapter is a step towards answering that question by seeking to understand how a firm’s liquidity management relates to its productivity and the welfare consequences of such management. We show theoretically and empirically that there exists an equilibrium where high productivity firms actually hold more liquid assets and less capital than low productivity firms, due to an overwhelmingly strong precautionary savings motive associated with significant financing frictions. Improvements to the financial market, such as reduction of financing costs, could redistribute capital more efficiently across firms, leading to an overall increase in aggregate productivity.

We capture financial frictions in the model through a simple refinancing cost to highlight the basic mechanism and yet maintain the model’s tractability. In practice, financial frictions may come from various sources. We do not distinguish in detail how each specific friction affects capital allocation and corporate savings behaviors, which is an area of growing interest for both theoretical and empirical studies. Our model also applies to asset allocation from a mergers and acquisitions perspective. It can be modified, following Maksimovic and Phillips (2002), Yang (2008), and Warusawitharana (2008), to study M&As in the presence of strong liquidity demand and how M&As impact the overall efficiency of the economy.

We restrict our study to cross-sectional analysis of asset distribution and liquidity management. Many equally interesting questions remain regarding the time-series of these corporate decisions. Eisfeldt and Rampini (2006) shows that the redistribution of firm wealth is strongly pro-cyclical, whereas the socially optimal reallocation should be counter-cyclical. While we resort to a steady-state analysis due to our short-sample period, our model is equipped to incorporate aggregate shocks and transitory dynamic analysis. Furthermore, our sample ends in 2007, right before the global financial
crisis. Research such as Campello et al. (2011) shows that firms with various levels of financing constraints manage liquidity differently during crisis times. It remains a question whether the same is true of firms with different levels of productivity. Our model is flexible in capturing the implications of firm characteristics on liquidity management and asset allocation from a time-series perspective.
APPENDIX A

FIGURES, TABLES, AND MATHEMATICAL APPENDIX OF CHAPTER 1

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Figure A.10. Import Tariff vs. Export Tariff for Manufacturing Goods in China


Figure A.11. Sectoral Tariff Changes and Capital-Labor Ratio

Source: Calculations based on Song et al. (2011b).
A.2 Tables
<table>
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<th>Median</th>
<th>Std. Dev.</th>
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<td>0.25</td>
<td>0.19</td>
<td>1240</td>
</tr>
<tr>
<td>SOE Output Share</td>
<td>0.20</td>
<td>0.14</td>
<td>0.19</td>
<td>1240</td>
</tr>
<tr>
<td>DPE Output Share</td>
<td>0.25</td>
<td>0.24</td>
<td>0.15</td>
<td>1240</td>
</tr>
<tr>
<td>HMT Output Share</td>
<td>0.13</td>
<td>0.11</td>
<td>0.10</td>
<td>1240</td>
</tr>
<tr>
<td>FE Output Share</td>
<td>0.16</td>
<td>0.14</td>
<td>0.12</td>
<td>1240</td>
</tr>
<tr>
<td>∆Industry Labor Productivity*</td>
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<td>0.59</td>
<td>0.31</td>
<td>620</td>
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<tr>
<td>∆Industry TFP</td>
<td>0.10</td>
<td>0.10</td>
<td>0.13</td>
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<tr>
<td>∆Output Tariff*</td>
<td>-0.05</td>
<td>-0.05</td>
<td>0.04</td>
<td>620</td>
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<tr>
<td>∆Input Tariff*</td>
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<td>-0.05</td>
<td>0.02</td>
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<td>0.31</td>
<td>0.47</td>
<td>620</td>
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<td>∆Fraction of Exporters</td>
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<td>0.02</td>
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<td>∆DPE Output Share</td>
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<td>0.17</td>
<td>0.10</td>
<td>620</td>
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<tr>
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<td>0.00</td>
<td>0.06</td>
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</tr>
<tr>
<td>∆FE Output Share</td>
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<td>Variable</td>
<td>Mean</td>
<td>Median</td>
<td>Std. Dev.</td>
<td>N</td>
</tr>
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<td>--------------------------------</td>
<td>------</td>
<td>--------</td>
<td>-----------</td>
<td>----</td>
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<td>Prov Ind Labor Prod</td>
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<td>3.66</td>
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<tr>
<td>Output Tariff</td>
<td>0.13</td>
<td>0.12</td>
<td>0.08</td>
<td>29008</td>
</tr>
<tr>
<td>Input Tariff</td>
<td>0.12</td>
<td>0.11</td>
<td>0.05</td>
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<td>0.13</td>
<td>0.03</td>
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<td>0.23</td>
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<td>0.16</td>
<td>0.32</td>
<td>29008</td>
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<td>0.16</td>
<td>0.26</td>
<td>29008</td>
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<tr>
<td>HMT Output Share</td>
<td>0.08</td>
<td>0.00</td>
<td>0.16</td>
<td>29008</td>
</tr>
<tr>
<td>FE Output Share</td>
<td>0.11</td>
<td>0.01</td>
<td>0.20</td>
<td>29008</td>
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</table>
TABLE A.3

STOCK OF MIGRANT WORKERS

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<thead>
<tr>
<th></th>
<th>Intra-Provincial</th>
<th>Inter-Provincial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Stock (millions)</td>
<td>90.1</td>
<td>120.4</td>
</tr>
<tr>
<td>Share of Total Employment</td>
<td>14.30%</td>
<td>17.70%</td>
</tr>
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</table>

Source: Tombe et al. (2015)
TABLE A.4

TARIFF, INDUSTRY LABOR PRODUCTIVITY, AND INDUSTRY TFP

<table>
<thead>
<tr>
<th></th>
<th>Industry Labor Productivity</th>
<th>Industry TFP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Output Tariff</td>
<td>1.6890**</td>
<td>1.8294**</td>
</tr>
<tr>
<td></td>
<td>(2.56)</td>
<td>(2.32)</td>
</tr>
<tr>
<td>Input Tariff</td>
<td>-0.4911</td>
<td>0.4185</td>
</tr>
<tr>
<td></td>
<td>(-0.33)</td>
<td>(0.38)</td>
</tr>
<tr>
<td>Number of Firms (Log)</td>
<td>-0.0210</td>
<td>-0.0031</td>
</tr>
<tr>
<td></td>
<td>(-0.48)</td>
<td>(-0.14)</td>
</tr>
<tr>
<td>Fraction of Exporters</td>
<td>-0.8936***</td>
<td>-0.2552**</td>
</tr>
<tr>
<td></td>
<td>(-3.20)</td>
<td>(-2.17)</td>
</tr>
<tr>
<td>SOE Output Share</td>
<td>-1.0669***</td>
<td>-0.1448</td>
</tr>
<tr>
<td></td>
<td>(-5.46)</td>
<td>(-1.35)</td>
</tr>
<tr>
<td>DPE Output Share</td>
<td>-0.1709</td>
<td>-0.0945</td>
</tr>
<tr>
<td></td>
<td>(-0.78)</td>
<td>(-0.92)</td>
</tr>
<tr>
<td>HMT Output Share</td>
<td>0.2344</td>
<td>0.1606</td>
</tr>
<tr>
<td></td>
<td>(0.71)</td>
<td>(1.36)</td>
</tr>
<tr>
<td>FE Output Share</td>
<td>0.2532</td>
<td>0.1949</td>
</tr>
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<td></td>
<td>(0.87)</td>
<td>(1.64)</td>
</tr>
<tr>
<td>Industry FE</td>
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<td>YES</td>
</tr>
<tr>
<td>Year FE</td>
<td>YES</td>
<td>YES</td>
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<tr>
<td>Observations</td>
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<td>1,240</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.903</td>
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### TABLE A.5

**TARIFF, INDUSTRY LABOR PRODUCTIVITY, AND INDUSTRY TFP**

*(5-YEAR CHANGES)*

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<thead>
<tr>
<th></th>
<th>ΔIndustry Labor Productivity</th>
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<th>ΔIndustry TFP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>ΔOutput Tariff</td>
<td>1.5268**</td>
<td>1.6843**</td>
<td>0.9940*</td>
</tr>
<tr>
<td></td>
<td>(2.32)</td>
<td>(2.19)</td>
<td>(1.86)</td>
</tr>
<tr>
<td>ΔInput Tariff</td>
<td>-0.5436</td>
<td>0.4509</td>
<td>-0.6056</td>
</tr>
<tr>
<td></td>
<td>(-0.39)</td>
<td>(0.44)</td>
<td>(-1.60)</td>
</tr>
<tr>
<td>ΔNumber of Firms (Log)</td>
<td>-0.0204</td>
<td>-0.0033</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-0.49)</td>
<td>(-0.18)</td>
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</tr>
<tr>
<td>ΔFraction of Exporters</td>
<td>-0.9845***</td>
<td>-0.3147***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-3.29)</td>
<td>(-2.90)</td>
<td></td>
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<tr>
<td>ΔSOE Output Share</td>
<td>-1.1609***</td>
<td>-0.1597*</td>
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</tr>
<tr>
<td></td>
<td>(-6.18)</td>
<td>(-1.72)</td>
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<tr>
<td>ΔDPE Output Share</td>
<td>-0.2924</td>
<td>-0.1583*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-1.37)</td>
<td>(-1.71)</td>
<td></td>
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<tr>
<td>ΔHMT Output Share</td>
<td>0.1621</td>
<td>0.1669</td>
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</tr>
<tr>
<td></td>
<td>(0.46)</td>
<td>(1.64)</td>
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<tr>
<td>ΔFE Output Share</td>
<td>0.2193</td>
<td>0.1756</td>
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<tr>
<td></td>
<td>(0.68)</td>
<td>(1.43)</td>
<td></td>
</tr>
<tr>
<td>Industry FE</td>
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<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>5-year Window FE</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
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<td>Observations</td>
<td>620</td>
<td>620</td>
<td>620</td>
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<tr>
<td>$R^2$</td>
<td>0.051</td>
<td>0.052</td>
<td>0.261</td>
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**TABLE A.6**

TARIFF, PROVINCIAL WAGE, AND PROVINCIAL RELATIVE WAGE

<table>
<thead>
<tr>
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<th>ΔProvincial Wage</th>
<th>ΔProvincial Relative Wage</th>
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<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>ΔProvincial Output Tariff</td>
<td>0.0150*</td>
<td>0.0188*</td>
</tr>
<tr>
<td></td>
<td>(1.72)</td>
<td>(1.76)</td>
</tr>
<tr>
<td>ΔProvincial Input Tariff</td>
<td>-0.0439***</td>
<td>-0.0355*</td>
</tr>
<tr>
<td></td>
<td>(-2.89)</td>
<td>(-1.98)</td>
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<tr>
<td>ΔSOE Output Share</td>
<td>0.0242</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.16)</td>
<td></td>
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<tr>
<td>ΔDPE Output Share</td>
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<td>ΔHMT Output Share</td>
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<td>(0.87)</td>
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<td>ΔFE Output Share</td>
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<td>Province FE</td>
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<td>YES</td>
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<tr>
<td>Year FE</td>
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<td>YES</td>
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<tr>
<td>$R^2$</td>
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## TABLE A.7

TARIFF AND PROVINCIAL INDUSTRY LABOR PRODUCTIVITY

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<th>(3)</th>
<th>(4)</th>
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<tr>
<td><strong>Output Tariff</strong></td>
<td>0.8786***</td>
<td>0.8721***</td>
<td>0.7539***</td>
<td>0.7572***</td>
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<tr>
<td></td>
<td>(3.42)</td>
<td>(3.42)</td>
<td>(3.08)</td>
<td>(3.12)</td>
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<tr>
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<td>0.2933</td>
<td>0.2992</td>
<td>0.5584</td>
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<td></td>
<td>(0.54)</td>
<td>(0.56)</td>
<td>(1.10)</td>
<td>(1.04)</td>
</tr>
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<td><strong>Prov Output Tariff</strong></td>
<td>2.9358**</td>
<td>1.2155</td>
<td>2.6524*</td>
<td>1.0645</td>
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<td>(2.03)</td>
<td>(0.83)</td>
<td>(1.93)</td>
<td>(0.76)</td>
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<td><strong>Prov Input Tariff</strong></td>
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<td>4.2652</td>
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<tr>
<td></td>
<td>(0.79)</td>
<td>(1.50)</td>
<td>(0.47)</td>
<td>(1.19)</td>
</tr>
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<td><strong>Prov Wage (Log)</strong></td>
<td>0.3901***</td>
<td>0.3800***</td>
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</tr>
<tr>
<td></td>
<td>(7.85)</td>
<td>(7.88)</td>
<td></td>
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</tr>
<tr>
<td><strong>Number of Firms (Log)</strong></td>
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<td>0.0669***</td>
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<td>(3.71)</td>
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<tr>
<td><strong>Fraction of Exporters</strong></td>
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<td>(-0.39)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SOE Output Share</strong></td>
<td>-0.4979***</td>
<td>-0.4911***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-13.60)</td>
<td>(-13.41)</td>
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<td></td>
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<tr>
<td><strong>DPE Output Share</strong></td>
<td>0.0160</td>
<td>0.0132</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>(0.47)</td>
<td>(0.39)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>HMT Output Share</strong></td>
<td>0.2687***</td>
<td>0.2598***</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>(4.56)</td>
<td>(4.41)</td>
<td></td>
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<tr>
<td><strong>FE Output Share</strong></td>
<td>0.2619***</td>
<td>0.2647***</td>
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<td>(4.79)</td>
<td>(4.85)</td>
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<td><strong>Province-Industry FE</strong></td>
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<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td><strong>Year FE</strong></td>
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<td>YES</td>
<td>YES</td>
<td>YES</td>
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<td><strong>Observations</strong></td>
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<td>29,008</td>
<td>29,008</td>
<td>29,008</td>
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<tr>
<td><strong>R^2</strong></td>
<td>0.743</td>
<td>0.744</td>
<td>0.757</td>
<td>0.758</td>
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### TABLE A.8

**QUANTITATIVE ANALYSIS**

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<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Value</th>
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</thead>
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<tr>
<td>$\overline{L^H}$</td>
<td>Labor endowment at home</td>
<td>1200</td>
</tr>
<tr>
<td>$\overline{K^H}$</td>
<td>Capital endowment at home</td>
<td>1000</td>
</tr>
<tr>
<td>$\overline{L^F}$</td>
<td>Labor endowment at foreign</td>
<td>1000</td>
</tr>
<tr>
<td>$\overline{K^F}$</td>
<td>Capital endowment at foreign</td>
<td>1200</td>
</tr>
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<td>$f_1^H = f_2^H = f_1^F = f_2^F$</td>
<td>Fixed operation cost</td>
<td>0.1</td>
</tr>
<tr>
<td>$f_{x1}^H = f_{x2}^H = f_{x1}^F = f_{x2}^F$</td>
<td>Fixed exporting cost</td>
<td>0.1</td>
</tr>
<tr>
<td>$f_{c1}^H = f_{c2}^H = f_{c1}^F = f_{c2}^F$</td>
<td>Entry cost</td>
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<tr>
<td>$\delta$</td>
<td>Probability of firm death</td>
<td>0.025</td>
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<tr>
<td>$\alpha$</td>
<td>Expenditure share on industry 1</td>
<td>0.5</td>
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<tr>
<td>$\sigma$</td>
<td>Elasticity of substitution</td>
<td>3.8</td>
</tr>
<tr>
<td>$\beta_1$</td>
<td>Skilled labor factor intensity in industry 1</td>
<td>0.4</td>
</tr>
<tr>
<td>$\beta_2$</td>
<td>Skilled labor factor intensity in industry 2</td>
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<tr>
<td>$c$</td>
<td>Pareto parameter</td>
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<tr>
<td>$\lambda$</td>
<td>Productivity Lower Bound</td>
<td>0.2</td>
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</tbody>
</table>
A.3 Mathematical Appendix

Labor market equilibrium:

\[ w^H L^H = (1 - \beta_1) R^H_1 + (1 - \beta_2) R^H_2 \]  \hspace{1cm} (A.1) \\
\[ w^F L^F = (1 - \beta_1) R^F_1 + (1 - \beta_2) R^F_2 \]  \hspace{1cm} (A.2) \\
\[ r^H K^H = \beta_1 R^H_1 + \beta_2 R^H_2 \]  \hspace{1cm} (A.3) \\
\[ r^F K^F = \beta_1 R^F_1 + \beta_2 R^F_2 \]  \hspace{1cm} (A.4) \\
\[ w^H L^H_1 = (1 - \beta_1) R^H_1 \]  \hspace{1cm} (A.5) \\
\[ w^H L^H_2 = (1 - \beta_2) R^H_2 \]  \hspace{1cm} (A.6) \\
\[ r^H K^H_1 = \beta_1 R^H_1 \]  \hspace{1cm} (A.7) \\
\[ r^H K^H_2 = \beta_2 R^H_2 \]  \hspace{1cm} (A.8) \\
\[ w^F L^F_1 = (1 - \beta_1) R^F_1 \]  \hspace{1cm} (A.9) \\
\[ w^F L^F_2 = (1 - \beta_2) R^F_2 \]  \hspace{1cm} (A.10) \\
\[ r^F K^F_1 = \beta_1 R^F_1 \]  \hspace{1cm} (A.11) \\
\[ r^F K^F_2 = \beta_2 R^F_2 \]  \hspace{1cm} (A.12)

Productivity cutoffs, entry and exit:

\[ \Lambda^H_1 = \gamma^F_1 \left( \frac{P^H_1}{P^F_1} \right) \left( \frac{R^H f_{x1}}{R^F f_1} \right)^{\frac{1}{\sigma-1}} \]  \hspace{1cm} (A.13) \\
\[ \Lambda^H_2 = \gamma^F_2 \left( \frac{P^H_2}{P^F_2} \right) \left( \frac{R^H f_{x2}}{R^F f_2} \right)^{\frac{1}{\sigma-1}} \]  \hspace{1cm} (A.14) \\
\[ \Lambda^F_1 = \gamma^H_1 \left( \frac{P^F_1}{P^H_1} \right) \left( \frac{R^F f_{x1}}{R^H f_1} \right)^{\frac{1}{\sigma-1}} \]  \hspace{1cm} (A.15) \\
\[ \Lambda^F_2 = \gamma^H_2 \left( \frac{P^F_2}{P^H_2} \right) \left( \frac{R^F f_{x2}}{R^H f_2} \right)^{\frac{1}{\sigma-1}} \]  \hspace{1cm} (A.16)
\[ \varphi_1^H = \left[ f_1 + f_{1x} (\Lambda_1^H)^{-c} \right]^{\frac{\gamma}{\varepsilon}} \left( \frac{1}{f_{e1}} \right)^{\frac{1}{\sigma - 1}} \left[ \frac{1}{\delta} \left( \frac{c}{\gamma} - 1 \right) k^c \right]^\frac{1}{\sigma - 1} \]  
(A.17)

\[ \varphi_2^H = \left[ f_2 + f_{2x} (\Lambda_2^H)^{-c} \right]^{\frac{\gamma}{\varepsilon}} \left( \frac{1}{f_{e2}} \right)^{\frac{1}{\sigma - 1}} \left[ \frac{1}{\delta} \left( \frac{c}{\gamma} - 1 \right) k^c \right]^\frac{1}{\sigma - 1} \]  
(A.18)

\[ \varphi_1^F = \left[ f_1 + f_{1x} (\Lambda_1^F)^{-c} \right]^{\frac{\gamma}{\varepsilon}} \left( \frac{1}{f_{e1}} \right)^{\frac{1}{\sigma - 1}} \left[ \frac{1}{\delta} \left( \frac{c}{\gamma} - 1 \right) k^c \right]^\frac{1}{\sigma - 1} \]  
(A.19)

\[ \varphi_2^F = \left[ f_2 + f_{2x} (\Lambda_2^F)^{-c} \right]^{\frac{\gamma}{\varepsilon}} \left( \frac{1}{f_{e2}} \right)^{\frac{1}{\sigma - 1}} \left[ \frac{1}{\delta} \left( \frac{c}{\gamma} - 1 \right) k^c \right]^\frac{1}{\sigma - 1} \]  
(A.20)

\[ \varphi_{1x}^* = \Lambda_1^H \varphi_1^H \]  
(A.21)

\[ \varphi_{2x}^* = \Lambda_2^H \varphi_2^H \]  
(A.22)

\[ \varphi_{1x}^* = \Lambda_1^F \varphi_1^F \]  
(A.23)

\[ \varphi_{2x}^* = \Lambda_2^F \varphi_2^F \]  
(A.24)

Weighted average productivities

\[ \bar{\varphi}_1^H = \left( \frac{c}{c - \sigma + 1} \right)^{\frac{1}{\sigma - 1}} \varphi_1^H \]  
(A.25)

\[ \bar{\varphi}_2^H = \left( \frac{c}{c - \sigma + 1} \right)^{\frac{1}{\sigma - 1}} \varphi_2^H \]  
(A.26)

\[ \bar{\varphi}_1^F = \left( \frac{c}{c - \sigma + 1} \right)^{\frac{1}{\sigma - 1}} \varphi_1^F \]  
(A.27)

\[ \bar{\varphi}_2^F = \left( \frac{c}{c - \sigma + 1} \right)^{\frac{1}{\sigma - 1}} \varphi_2^F \]  
(A.28)
\[
\tilde{\varphi}_{1x}^H = \left( \frac{c}{c - \sigma + 1} \right)^{\frac{1}{\sigma - 1}} \tilde{\varphi}_{1x}^H \quad (A.29)
\]
\[
\tilde{\varphi}_{2x}^H = \left( \frac{c}{c - \sigma + 1} \right)^{\frac{1}{\sigma - 1}} \tilde{\varphi}_{2x}^H \quad (A.30)
\]
\[
\tilde{\varphi}_{1x}^F = \left( \frac{c}{c - \sigma + 1} \right)^{\frac{1}{\sigma - 1}} \tilde{\varphi}_{1x}^F \quad (A.31)
\]
\[
\tilde{\varphi}_{2x}^F = \left( \frac{c}{c - \sigma + 1} \right)^{\frac{1}{\sigma - 1}} \tilde{\varphi}_{2x}^F \quad (A.32)
\]

Probability of exporting:

\[
\chi_{1x}^H = \left( \frac{\tilde{\varphi}_{1x}^H}{\tilde{\varphi}_{1x}^*} \right)^c \quad (A.33)
\]
\[
\chi_{2x}^H = \left( \frac{\tilde{\varphi}_{2x}^H}{\tilde{\varphi}_{2x}^*} \right)^c \quad (A.34)
\]
\[
\chi_{1x}^F = \left( \frac{\tilde{\varphi}_{1x}^F}{\tilde{\varphi}_{1x}^*} \right)^c \quad (A.35)
\]
\[
\chi_{2x}^F = \left( \frac{\tilde{\varphi}_{2x}^F}{\tilde{\varphi}_{2x}^*} \right)^c \quad (A.36)
\]

Average firm revenue:

\[
\bar{r}_{1x}^H = \left( \frac{\tilde{\varphi}_{1x}^H}{\tilde{\varphi}_{1x}^*} \right)^{\sigma - 1} \sigma f_1 (r^H)^{\beta_1} (w^H)^{1 - \beta_1} + \chi_{1x}^H \left( \frac{\tilde{\varphi}_{1x}^H}{\tilde{\varphi}_{1x}^*} \right)^{\sigma - 1} \sigma f_{1x} (r^H)^{\beta_1} (w^H)^{1 - \beta_1} \quad (A.37)
\]
\[
\bar{r}_{1x}^F = \left( \frac{\tilde{\varphi}_{1x}^F}{\tilde{\varphi}_{1x}^*} \right)^{\sigma - 1} \sigma f_1 (r^F)^{\beta_1} (w^F)^{1 - \beta_1} + \chi_{1x}^F \left( \frac{\tilde{\varphi}_{1x}^F}{\tilde{\varphi}_{1x}^*} \right)^{\sigma - 1} \sigma f_{1x} (r^F)^{\beta_1} (w^F)^{1 - \beta_1} \quad (A.38)
\]
\[
\bar{r}_{2x}^F = \left( \frac{\tilde{\varphi}_{2x}^F}{\tilde{\varphi}_{2x}^*} \right)^{\sigma - 1} \sigma f_2 (r^F)^{\beta_2} (w^F)^{1 - \beta_2} + \chi_{2x}^F \left( \frac{\tilde{\varphi}_{2x}^F}{\tilde{\varphi}_{2x}^*} \right)^{\sigma - 1} \sigma f_{2x} (r^F)^{\beta_2} (w^F)^{1 - \beta_2} \quad (A.39)
\]
Pricing rule:

\[ p_{1d}^H (\bar{\varphi}_1^H) = \frac{\sigma}{\sigma - 1} \frac{1}{\bar{\varphi}_1^H} (r^H)_{\beta_1} (w^H)^{1-\beta_1} \]  
\( (A.41) \)

\[ p_{2d}^H (\bar{\varphi}_2^H) = \frac{\sigma}{\sigma - 1} \frac{1}{\bar{\varphi}_2^H} (r^H)_{\beta_2} (w^H)^{1-\beta_2} \]  
\( (A.42) \)

\[ p_{1d}^F (\bar{\varphi}_1^F) = \frac{\sigma}{\sigma - 1} \frac{1}{\bar{\varphi}_1^F} (r^F)_{\beta_1} (w^F)^{1-\beta_1} \]  
\( (A.43) \)

\[ p_{2d}^F (\bar{\varphi}_2^F) = \frac{\sigma}{\sigma - 1} \frac{1}{\bar{\varphi}_2^F} (r^F)_{\beta_2} (w^F)^{1-\beta_2} \]  
\( (A.44) \)

Mass of firms:

\[ M_1^H = \frac{R_1^H}{r_1^H} \]  
\( (A.45) \)

\[ M_2^H = \frac{R_2^H}{r_2^H} \]  
\( (A.46) \)

\[ M_1^F = \frac{R_1^F}{r_1^F} \]  
\( (A.47) \)

\[ M_2^F = \frac{R_2^F}{r_2^F} \]  
\( (A.48) \)

Industry price index:

\[ P_1^H = \left[ M_1^H (p_{1d}^H (\bar{\varphi}_1^H))^{1-\sigma} + \chi_1^F M_1^F (r_1^F \frac{\bar{\varphi}_1^F}{\bar{\varphi}_1^F} p_{1d}^F (\bar{\varphi}_1^F))^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \]  
\( (A.49) \)

\[ P_2^H = \left[ M_2^H (p_{2d}^H (\bar{\varphi}_2^H))^{1-\sigma} + \chi_2^F M_2^F (r_2^F \frac{\bar{\varphi}_2^F}{\bar{\varphi}_2^F} p_{2d}^F (\bar{\varphi}_2^F))^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \]  
\( (A.50) \)

\[ P_1^F = \left[ M_1^F (p_{1d}^F (\bar{\varphi}_1^F))^{1-\sigma} + \chi_1^H M_1^H (r_1^H \frac{\bar{\varphi}_1^H}{\bar{\varphi}_1^H} p_{1d}^H (\bar{\varphi}_1^H))^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \]  
\( (A.51) \)

\[ P_2^F = \left[ M_2^F (p_{2d}^F (\bar{\varphi}_2^F))^{1-\sigma} + \chi_2^H M_2^H (r_2^H \frac{\bar{\varphi}_2^H}{\bar{\varphi}_2^H} p_{2d}^H (\bar{\varphi}_2^H))^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \]  
\( (A.52) \)

Aggregate expenditure for each industry from the consumption of variety pro-
duced at the home market:

\[
E^H_1 = \left( \frac{P^H_1}{p^H_{1d}(\tilde{\varphi}^H_1)} \right)^{\sigma - 1} \alpha R^H M^H_1 \tag{A.53}
\]

\[
E^H_2 = \left( \frac{P^H_2}{p^H_{2d}(\tilde{\varphi}^H_2)} \right)^{\sigma - 1} (1 - \alpha) R^H M^H_2 \tag{A.54}
\]

\[
E^F_1 = \left( \frac{P^F_1}{p^F_{1d}(\tilde{\varphi}^F_1)} \right)^{\sigma - 1} \alpha R^F M^F_1 \tag{A.55}
\]

\[
E^F_2 = \left( \frac{P^F_2}{p^F_{2d}(\tilde{\varphi}^F_2)} \right)^{\sigma - 1} (1 - \alpha) R^F M^F_2 \tag{A.56}
\]

Aggregate expenditure for each industry from the consumption of variety produced in the external market (similar to import):

\[
G^H_1 = \left( \frac{P^H_1}{\tau^F \frac{\bar{\varphi}^F}{\bar{\varphi}^F_{1z}} p^F_{1d}(\tilde{\varphi}^F_1)} \right)^{\sigma - 1} \alpha R^H M^H_1 \tag{A.57}
\]

\[
G^H_2 = \left( \frac{P^H_2}{\tau^F \frac{\bar{\varphi}^F}{\bar{\varphi}^F_{2z}} p^F_{2d}(\tilde{\varphi}^F_2)} \right)^{\sigma - 1} (1 - \alpha) R^H M^H_2 \tag{A.58}
\]

\[
G^F_1 = \left( \frac{P^F_1}{\tau^H \frac{\bar{\varphi}^H}{\bar{\varphi}^H_{1z}} p^H_{1d}(\tilde{\varphi}^H_1)} \right)^{\sigma - 1} \alpha R^F M^F_1 \tag{A.59}
\]

\[
G^F_2 = \left( \frac{P^F_2}{\tau^H \frac{\bar{\varphi}^H}{\bar{\varphi}^H_{2z}} p^H_{2d}(\tilde{\varphi}^H_2)} \right)^{\sigma - 1} (1 - \alpha) R^F M^F_2 \tag{A.60}
\]

Total revenue equals to total expenditure for each industry:

\[
R^H_1 = E^H_1 + G^F_1 \tag{A.61}
\]

\[
R^H_2 = E^H_2 + G^F_2 \tag{A.62}
\]

\[
R^F_1 = E^F_1 + G^H_1 \tag{A.63}
\]

\[
R^F_2 = E^F_2 + G^H_2 \tag{A.64}
\]
Total revenue equals total labor income:

\[ R^H = r^H K^H + w^H L^H \]  
\[ R^F = r^F K^F + w^F L^F \]  
\[ (A.65) \]

In total, we have 66 equations and 66 unknowns:

- \((r^H, w^H, r^F, w^F)\)
- \((K_1^H, K_2^H, L_1^H, L_2^H)\)
- \((K_1^F, K_2^F, L_1^F, L_2^F)\)
- \((P_1^H, P_2^H, P_1^F, P_2^F)\)
- \((E_1^H, E_2^H, E_1^F, E_2^F)\)
- \((G_1^H, G_2^H, G_1^F, G_2^F)\)
- \((R_1^H, R_2^H, R_1^F, R_2^F)\)
- \((R^H, R^F)\)
- \((M_1^H, M_2^H, M_1^F, M_2^F)\)
- \((\Lambda_1^H, \Lambda_2^H, \Lambda_1^F, \Lambda_2^F)\)
- \((\phi_1^H, \phi_2^H, \phi_1^F, \phi_2^F)\)
- \((\phi_1^{*H}, \phi_2^{*H}, \phi_1^{*F}, \phi_2^{*F})\)
- \((\phi_1^{*x}, \phi_2^{*x}, \phi_1^{x}, \phi_2^{x})\)
- \((\phi_1^H, \phi_2^H, \phi_1^F, \phi_2^F)\)
- \((\phi_1^{*H}, \phi_2^{*H}, \phi_1^{*F}, \phi_2^{*F})\)
- \((\phi_1^{*x}, \phi_2^{*x}, \phi_1^{x}, \phi_2^{x})\)
- \((\chi_1^H, \chi_2^H, \chi_1^F, \chi_2^F)\)
- \((AR_1^H, AR_2^H, AR_1^F, AR_2^F)\)
APPENDIX B

FIGURES, TABLES, AND MATHEMATICAL APPENDIX OF CHAPTER 2

B.1 Figures

Figure B.1. Heterogeneous Credit Shocks
### TABLE B.1

CHANGE OF INDEX BY FIRM SIZE FROM 2006 TO 2009

<table>
<thead>
<tr>
<th>Index</th>
<th>Small</th>
<th>Medium</th>
<th>SMEs</th>
<th>Large</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Export/Sales</td>
<td>-0.37</td>
<td>-0.32</td>
<td>-0.37</td>
<td>-0.18</td>
<td>-0.31</td>
</tr>
<tr>
<td>Debt/Sales</td>
<td>-0.11</td>
<td>-0.05</td>
<td>-0.09</td>
<td>0.02</td>
<td>-0.06</td>
</tr>
<tr>
<td>Liquid debt/Sales</td>
<td>-0.11</td>
<td>-0.05</td>
<td>-0.09</td>
<td>0.01</td>
<td>-0.06</td>
</tr>
<tr>
<td>Fraction of exporter</td>
<td>-0.24</td>
<td>-0.13</td>
<td>-0.24</td>
<td>-0.09</td>
<td>-0.24</td>
</tr>
<tr>
<td>Debt/Asset</td>
<td>-0.04</td>
<td>-0.03</td>
<td>-0.04</td>
<td>-0.02</td>
<td>-0.03</td>
</tr>
<tr>
<td>Liquid debt/Asset</td>
<td>-0.04</td>
<td>-0.02</td>
<td>-0.03</td>
<td>-0.04</td>
<td>-0.03</td>
</tr>
<tr>
<td>Debt/Fixed asset</td>
<td>-0.08</td>
<td>-0.02</td>
<td>-0.05</td>
<td>0.04</td>
<td>-0.02</td>
</tr>
<tr>
<td>Liquid debt/Fixed asset</td>
<td>-0.08</td>
<td>-0.02</td>
<td>-0.04</td>
<td>0.02</td>
<td>-0.02</td>
</tr>
</tbody>
</table>

### TABLE B.2

IN Variant PARAMETERS

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<tr>
<th>Parameters</th>
<th>$\sigma$</th>
<th>$\eta$</th>
<th>$\beta$</th>
<th>$\gamma$</th>
<th>$\sigma_\epsilon$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Values</td>
<td>5</td>
<td>1.5</td>
<td>0.96</td>
<td>0.07</td>
<td>1</td>
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</tbody>
</table>
TABLE B.3

CALIBRATION AND EXPERIMENTS (1)

<table>
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<tr>
<th>Parameters</th>
<th>06(Data)</th>
<th>06(Model)</th>
<th>09(Data)</th>
<th>09(Model)</th>
<th>2009(Model)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>w/ identical λ</td>
<td>w/ identical λ</td>
<td>w/ heterogeneous λ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_D$</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>$Q_D$</td>
<td>7.3486</td>
<td>6.3830</td>
<td>7.2473</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\tilde{P}_D$</td>
<td>3.4175</td>
<td>2.9331</td>
<td>3.5303</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\tilde{Q}_D$</td>
<td>1.1627</td>
<td>1.2677</td>
<td>1.0918</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\tilde{P}_D^{ex}$</td>
<td>2.5464</td>
<td>2.0633</td>
<td>2.6525</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\tilde{Q}_D^{ex}$</td>
<td>1.6219</td>
<td>1.5379</td>
<td>1.5275</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$w$</td>
<td>4.0690</td>
<td>3.4990</td>
<td>3.8970</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\tilde{\theta}_F$</td>
<td>6.6000</td>
<td>4.6000</td>
<td>6.6000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\lambda$</td>
<td>2.0000</td>
<td>1.9300</td>
<td>0.1 or 1.88*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$F_{ex}$</td>
<td>0.0220</td>
<td>0.0300</td>
<td>0.0240</td>
<td></td>
<td></td>
</tr>
<tr>
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<td>0.0240</td>
<td>0.0320</td>
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</tr>
<tr>
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<td>0.7427</td>
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<tr>
<td>Export Import</td>
<td>1.224</td>
<td>1.224</td>
<td>1.195</td>
<td>1.195</td>
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</tr>
<tr>
<td>Export Sales</td>
<td><strong>0.2351</strong></td>
<td><strong>0.2343</strong></td>
<td><strong>0.1622</strong></td>
<td><strong>0.1611</strong></td>
<td><strong>0.2398</strong></td>
</tr>
<tr>
<td>Liquid Debt Asset</td>
<td>0.51</td>
<td>0.5127</td>
<td>0.48</td>
<td>0.4827</td>
<td>0.4784</td>
</tr>
<tr>
<td>$\int_{Z_D} I(e &gt; 0) , dz$</td>
<td><strong>0.2880</strong></td>
<td><strong>0.2943</strong></td>
<td><strong>0.2174</strong></td>
<td><strong>0.2249</strong></td>
<td><strong>0.3001</strong></td>
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<tr>
<td>Size ratio</td>
<td>1.94</td>
<td>1.92</td>
<td>1.80</td>
<td>1.82</td>
<td>1.88</td>
</tr>
</tbody>
</table>

*Based on the empirics, I consider an extreme case, in which the firms with productivities above 2.8485 (the maximum is 3) are shocked by a severe credit condition $\lambda = 0.1$, while the rest of them by a minor change $\lambda = 1.88$. 

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TABLE B.4

DECOMPOSITION EXERCISE

<table>
<thead>
<tr>
<th>Moments</th>
<th>06(Model)</th>
<th>09(Model)</th>
<th>$\Delta 09 \left( \tilde{\theta}^{06}_{F} \right)$</th>
<th>$\Delta 09 \left( \lambda^{06} \right)$</th>
<th>$\Delta 09 \left( F^{06}_{ex} \right)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Export Sales</td>
<td>0.23</td>
<td>0.16</td>
<td>50%</td>
<td>0.1%</td>
<td>41%</td>
</tr>
<tr>
<td>$\int_{Z_{D}} I \left( e &gt; 0 \right) dz$</td>
<td>0.29</td>
<td>0.22</td>
<td>25%</td>
<td>2.4%</td>
<td>71%</td>
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TABLE B.5

CALIBRATION AND EXPERIMENTS (2)

<table>
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<tr>
<th>Parameters</th>
<th>06(Model)</th>
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<th>09($\tilde{\theta}_F^{2006}$)</th>
<th>09($\lambda^{2006}$)</th>
<th>09($F_{ex}^{2006}$)</th>
</tr>
</thead>
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<td>$P_D$</td>
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<td>1</td>
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<td>4.6000</td>
<td>4.6000</td>
</tr>
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TABLE B.6
CALIBRATION AND EXPERIMENTS (3)

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### TABLE B.7

**PARTIAL EQUILIBRIUM VS GENERAL EQUILIBRIUM**

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<td><strong>PE</strong></td>
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<td>std($\hat{\delta}$)</td>
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B.3 Mathematical Appendix

B.3.1 Demand Function

The profit maximization for the home composite good producer:

$$\max_{q_D(z), Q_D} \tilde{P}_D \tilde{Q}_D - \int_{z \in Z_D} p_D(z) q_D(z) dz$$

s.t. $$\tilde{Q}_D = \left( \int_{z \in Z_D} q_D(z) \frac{\sigma - 1}{\sigma} dz \right)^{\frac{1}{\sigma - 1}}$$

FONC derives

$$q_D(z) = \left( \frac{\tilde{P}_D}{p_D(z)} \right)^{\sigma} \tilde{Q}_D \quad (B.1)$$

The profit maximization for the home final good producer:

$$\max_{Q_D, IM, Q_D} P_D Q_D - \tilde{P}_D \tilde{Q}_D - P_{IM} IM$$

s.t. $$Q_D = \left[ \omega^{\frac{1}{\eta}} \tilde{Q}_D^{\frac{\eta - 1}{\eta}} + (1 - \omega)^{\frac{1}{\eta}} IM^{\frac{\eta - 1}{\eta}} \right]^{\frac{1}{\eta - 1}}$$

FONC derives

$$\tilde{Q}_D = \omega \left( \frac{P_D}{\tilde{P}_D} \right)^{\frac{\eta}{\eta}} Q_D \quad (B.2)$$

$$IM = (1 - \omega) \left( \frac{P_D}{P_{IM}} \right)^{\frac{\eta}{\eta}} Q_D \quad (B.3)$$

combine (B.1) and (B.3), we get (2.4)

$$q_D(z) = \omega \left( \frac{\tilde{P}_D}{p_D(z)} \right)^{\sigma} \left( \frac{P_D}{P_D} \right)^{\eta} Q_D$$
The profit maximization for the home exporting composite good producer:

$$\max_{q_{D}^{\text{ex}}, \tilde{Q}_{D}^{\text{ex}}} p_{D}^{\text{ex}} \tilde{Q}_{D}^{\text{ex}} - \int_{z \in Z_D} p_{D}^{\text{ex}} (z) q_{D}^{\text{ex}} (z) \, dz$$

s.t. \( \tilde{Q}_{D}^{\text{ex}} = \left( \int_{z \in Z_D} q_{D}^{\text{ex}} (z) \frac{\sigma - 1}{\sigma} \, dz \right)^{\frac{\sigma}{\sigma - 1}} \)

FONC derives

$$q_{D}^{\text{ex}} (z) = \left( \frac{\tilde{p}_{D}^{\text{ex}}}{\tilde{p}_{D}^{\text{ex}} (z)} \right)^{\sigma} \tilde{Q}_{D}^{\text{ex}} \quad (B.4)$$

The profit maximization for the final good producer in the rest of the world:

$$\max_{M, Q_{D}^{\text{ex}}, Q_{F}} P_{F}Q_{F} - P_{M}M - (1 + \tau) \tilde{p}_{D}^{\text{ex}} \tilde{Q}_{D}^{\text{ex}}$$

s.t. \( Q_{F} = \left( \theta_{F}^{\frac{1}{\eta}} \mu^{\frac{1}{\eta}} M^{\frac{\alpha - 1}{\eta}} + \theta_{F}^{\frac{1}{\eta}} (1 - \mu)^{\frac{1}{\eta}} \left( \tilde{Q}_{D}^{\text{ex}} \right)^{\frac{\alpha - 1}{\eta}} \right)^{\frac{\eta}{\eta - 1}} \)

FONC derives

$$\tilde{Q}_{D}^{\text{ex}} = \theta_{F} \left( \frac{1 - \mu}{1 + \tau} \right) \left( \frac{P_{F}}{\tilde{p}_{D}^{\text{ex}}} \right)^{\sigma} Q_{F} \quad (B.5)$$

$$M = \theta_{F} \mu \left( \frac{P_{F}}{P_{M}} \right)^{\sigma} Q_{F} \quad (B.6)$$

Combine (B.4) and (B.5), we get (2.7)

$$q_{D}^{\text{ex}} (z) = \theta_{F} \left( \frac{1 - \mu}{1 + \tau} \right) \left( \frac{\tilde{p}_{D}^{\text{ex}}}{\tilde{p}_{D}^{\text{ex}} (z)} \right)^{\sigma} \left( \frac{P_{F}}{\tilde{p}_{D}^{\text{ex}}} \right)^{\eta} Q_{F}$$

where the import demand \( (\tilde{q}_{D}^{\text{ex}} (z)) \) from the rest of the world is positively correlated to \( \theta_{F}, \tilde{p}_{D}, P_{F}, Q_{F} \), negatively correlated to \( \mu, \tau, p_{D} (z) \).
B.3.2 System of Equations

Given \( P_{IM} \), 12 unknowns: \( w, n_D, n_D^{ex}, q_D, q_D^{ex}, p_D, p_D^{ex}, \tilde{P}_D, \tilde{P}_D^{ex}, e, Q_D, IM \)

\[
Q_D = \left[ \frac{1}{\eta} \left( \left( \int_{z \in Z_D} q_D(z) \frac{\sigma}{\sigma-1} dz \right)^{\frac{\sigma-1}{\eta}} \right) + (1 - \omega) \frac{1}{\eta} IM \frac{\sigma-1}{\eta} \right]^{\frac{1}{\sigma-1}} \tag{B.7}
\]

\[
q_D(z) = \omega \tilde{P}_D^{\sigma-\eta} p_D^{\eta} Q_D p_D(z)^{-\sigma} = \tilde{\theta}_D \tilde{P}_D^{\sigma-\eta} p_D(z)^{-\sigma} \tag{B.8}
\]

\[
q_D^{ex}(z) = \theta_F \left( \frac{1 - \mu}{1 + \tau} \right) \left( \tilde{P}_D^{ex} \right)^{\sigma-\eta} F_Q p_D^{ex}(z)^{-\sigma} = \tilde{\theta}_F \left( \tilde{P}_D^{ex} \right)^{\sigma-\eta} p_D^{ex}(z)^{-\sigma} \tag{B.9}
\]

\[
\tilde{P}_D = \left[ \int_{z \in Z_D} p_D(z)^{1-\sigma} dz \right]^{\frac{1}{1-\sigma}} \tag{B.10}
\]

\[
\tilde{P}_D^{ex} = \left[ \int_{z \in Z_D^{ex}} p_D^{ex}(z)^{1-\sigma} dz \right]^{\frac{1}{1-\sigma}} \tag{B.11}
\]

\[
IM = (1 - \omega) \left( \frac{P_D}{P_{IM}} \right) ^{\eta} Q_D \tag{B.12}
\]

\[
L = \int_{z \in Z_D} n_D(z) \, dz + \int_{z \in Z_D^{ex}} n_D^{ex}(z) \, dz \tag{B.13}
\]

\[
p_D(z) = \frac{\sigma}{\sigma-1} MC \tag{B.14}
\]

\[
p_D^{ex}(z) = \frac{\sigma}{\sigma-1} MC \tag{B.15}
\]

\[
q_D(z) = zn_D \tag{B.16}
\]

\[
q_D^{ex}(z) = zn_D^{ex} \tag{B.17}
\]

\[
e = \begin{cases} 
0, & p_D^{ex} q_D^{ex} - w n_D^{ex} < w F^{ex} \\
1, & p_D^{ex} q_D^{ex} - w n_D^{ex} \geq w F^{ex} 
\end{cases} \tag{B.18}
\]

Need one more condition from the data to pin down \( P_{IM} \):

\[
\frac{\text{Export}}{\text{Import}} = \frac{\int_{z \in Z_D^{ex}} p_D^{ex}(z) q_D^{ex}(z) \, dz}{P_{IM} \cdot IM} = \text{Ratio} \tag{B.19}
\]
B.3.3 Intermediate Firm Profit Maximization

Intermediate firm’s static profit maximization:

\[
\pi (z, a) = \max_{p_D, q_D, \tilde{q}_D, n_D, \tilde{n}_D, e \in \{0, 1\}} \quad p_D q_D - w n_D + e [p_D^{ex} q_D^{ex} - w n_D^{ex} - w F_{ex}]
\]

s.t. \( q_D \leq z_D n_D \)

\( q_D^{ex} \leq z_D n_D^{ex} \)

\( q_D = \tilde{\theta}_D p_D^{-\sigma} \)

\( q_D^{ex} = \tilde{\theta}_F (p_D^{ex})^{-\sigma} \)

\( \lambda a \geq w n_D + e (w n_D^{ex} + w F_{ex}) \)

Set up Lagrangian

\[
\mathcal{L} = p_D q_D - w n_D + e [p_D^{ex} \text{ distinguishes } q_D^{ex} - w n_D^{ex} - w F_{ex}] - \gamma_1 (q_D - z_D n_D)
\]

\[-\gamma_2 (q_D^{ex} - z_D n_D^{ex}) \]

\[-\gamma_3 (q_D - \tilde{\theta}_D p_D^{-\sigma}) - \gamma_4 (q_D^{ex} - \tilde{\theta}_F (p_D^{ex})^{-\sigma}) - \gamma_5 (w n_D + e (w n_D^{ex} + w F_{ex})) \]

Under financial frictionless economy, \( \gamma_5 = 0 \), profit maximization problems for domestic and exporting sales are independent, FONCs:
∂L
∂p_D = 0 ⇔ q_D - γ_3 σ \tilde{θ}_D p_D^{-σ-1} = 0
∂L
∂q_D = 0 ⇔ p_D - γ_1 - γ_3 = 0
∂L
∂n_D = 0 ⇔ -w + γ_1 z_D = 0
∂L
∂\tilde{p}_D^e = 0 ⇔ q_D^e - γ_4 σ \tilde{θ}_F (p_D^e)^{-σ-1} = 0
∂L
∂\tilde{q}_D^e = 0 ⇔ p_D^e - γ_2 - γ_4 = 0
∂L
∂\tilde{n}_D^e = 0 ⇔ -w + γ_2 z_D = 0

Since the optimal labor allocation under frictionless economy is independent, we could the optimal home production based on the three FONCs above

\hat{p}_D = \frac{\sigma w}{\sigma - 1 \tilde{z}_D}
\hat{q}_D = \tilde{θ}_D \left( \frac{\sigma w}{\sigma - 1 \tilde{z}_D} \right)^{-σ}
\hat{n}_D = \left( \frac{\sigma}{\sigma - 1} w \right)^{-σ} \tilde{θ}_D \tilde{z}_D^{σ-1}

also, the net price home exporters can acquire is \hat{\tilde{p}}_D^e = \hat{p}_D = \frac{\sigma w}{\sigma - 1 \tilde{z}_D}. Similarly,

\hat{\tilde{q}}_D^e = \tilde{θ}_F \left( \frac{\sigma w}{\sigma - 1 \tilde{z}_D} \right)^{-σ}
\hat{\tilde{n}}_D^e = \left( \frac{\sigma}{\sigma - 1} w \right)^{-σ} \tilde{θ}_F \tilde{z}_D^{σ-1}

How to determine the optimal e? Firm will not export unless the profits from their foreign sales are positive given its productivity. Thus, firms who are at the threshold of productivity will be indifferent between exporting or not. Zero profit on foreign sales implies that the profits \hat{\tilde{p}}_D^e \hat{q}_D^e - w \hat{n}_D = w \tilde{F}_e. Then, the threshold
productivity is

\[ \frac{1}{\sigma} \tilde{\theta}_F (p_D^{ex})^{1-\sigma} = wF_{ex} \]

\[ \frac{1}{\sigma} \tilde{\theta}_F \left( \frac{\sigma}{\sigma - 1} z_D \right)^{1-\sigma} = wF_{ex} \]

\[ \frac{\sigma - 1}{\sigma} \frac{z_D}{w} = \left( \frac{\sigma wF_{ex}}{\tilde{\theta}_F} \right) \frac{1}{\sigma - 1} \]

\[ z_D^{ex} = \left( \frac{\sigma wF_{ex}}{\tilde{\theta}_F} \right) \frac{1}{\sigma - 1} \frac{\sigma}{w} \]

With financial frictions, we need to solve a nested profit maximization problem. The maximized profit for only producing domestically is given by:

\[ \pi_D (z, \lambda D) = \max_{p_D, n_D} p_D q_D - w n_D \]

\[ \text{s.t. } q_D = z_D n_D, \quad q_D = \tilde{\theta}_D p_D^{1-\sigma} \]

\[ \lambda D \geq w n_D \]

The maximized profits for operating on both markets:

\[ \pi_D^{ex} (z, \lambda) = \max_{p_D^{ex}, q_D^{ex}, n_D^{ex}, \lambda D} p_D^{ex} q_D^{ex} - w n_D^{ex} + e \left( p_D^{ex} q_D^{ex} - w n_D^{ex} - w F_{ex} \right) \]

\[ \text{s.t. } q_D = z_D n_D \]

\[ q_D^{ex} = z_D n_D^{ex} \]

\[ q_D = \tilde{\theta}_D p_D^{1-\sigma} \]

\[ q_D^{ex} = \tilde{\theta}_F (p_D^{ex})^{-\sigma} \]

\[ \lambda D = w n_D + e (w n_D^{ex} + w F_{ex}) \]
The maximized profits would be:

$$\pi(z, a) = \max \{\pi_D(z, a), \pi^*_D(z, a)\}$$
B.3.4 Dynamic Problem for Intermediate Firm

Dynamic problem for the intermediate goods producers:

\[
V_t(a_t) = \max_{d_t, a_{t+1}} \left\{ d_t + \beta (1 - \delta) V_{t+1}(a_{t+1}) \right\} \\
\text{s.t. } d_t + a_{t+1} = \frac{1 + r}{1 - \delta} a_t + \pi_t(a_t) \\
\quad d_t \geq 0
\]

Set up Lagrangian:

\[
\mathcal{L}_t = d_t + \beta (1 - \delta) V_{t+1}(a_{t+1}) - \xi_{1,t} \left( d_t + a_{t+1} - \frac{1 + r}{1 - \delta} a_t - \pi_t(a_t) \right) - \xi_{2,t} (-d_t)
\]

FONCs:

\[
\frac{\partial \mathcal{L}_t}{\partial d_t} = 0 \iff 1 - \xi_{1,t} + \xi_{2,t} = 0 \\
\frac{\partial \mathcal{L}_t}{\partial a_{t+1}} = 0 \iff \beta (1 - \delta) \frac{\partial V_{t+1}(a_{t+1}, z)}{\partial a_{t+1}} - \xi_{1,t} = 0
\]

Complementary slackness condition:

\[
\xi_{2,t} \cdot d_t = 0
\]

Envelope theorem implies:

\[
\frac{\partial V_t(a_t, z)}{\partial a_t} = \left[ \frac{1 + r}{1 - \delta} + \frac{\partial \pi_t(a_t, z)}{\partial a_t} \right] \xi_{1,t} \\
\Rightarrow \frac{\partial V_{t+1}(a_{t+1}, z)}{\partial a_{t+1}} = \left[ \frac{1 + r}{1 - \delta} + \frac{\partial \pi_{t+1}(a_{t+1}, z)}{\partial a_{t+1}} \right] \xi_{1,t+1} = \left( \frac{1 + r}{1 - \delta} + \lambda \phi_{t+1} \right) \xi_{1,t+1}
\]
where $\phi_{t+1}$ is the Lagrangian multiplier on the working capital constraint. With some substitutions

$$\beta (1 - \delta) \frac{\partial V_{t+1}(a_{t+1}, z)}{\partial a_{t+1}} = \xi_{1,t}$$

$$\beta (1 - \delta) \left( \frac{1 + r}{1 - \delta} + \lambda \phi_{t+1} \right) = \frac{\xi_{1,t}}{\xi_{t+1}}$$

and if we assume $\beta (1 + r) = 1$,

$$\beta (1 - \delta) \lambda \phi_{t+1} = \frac{\xi_{1,t}}{\xi_{t+1}} - 1$$

- if the working capital constraint is binding, $\phi_{t+1} > 0$, $\xi_{1,t} > \xi_{1,t+1} \geq 1$, $\xi_{2,t} = \xi_{1,t} - 1 > 0$, $d_t = 0$.

- if the working capital constraint is not binding, $\phi_{t+1} = 0$, $\xi_{1,t} = \xi_{1,t+1} \geq 1$, $\xi_{2,t} = \xi_{1,t} - 1 \geq 0$, any non-negative dividend $d_t \geq 0$ is optimal since $\beta (1 + r) = 1$.

In summary, corporation will save everything in the current period as long as the working capital is binding in the next period. If the working capital is not binding, since firms are indifferent between periods, we assume that they will choose a big enough $a_{t+1}$ to guarantee $\phi_{t+1} = 0$, then corporations will choose positive dividends and the optimal $a_{t+1}$ will be the least asset requirement for a non-binding working capital constraint.
APPENDIX C

FIGURES, TABLES, AND MATHEMATICAL APPENDIX OF CHAPTER 3

C.1 Figures

Figure C.1. Liquidity Management and Productivity (Value Added per Capital)
Figure C.2. Liquidity Management and Productivity (TFP)
Figure C.3. Liquidity Management and Productivity, Controlling for Ownership
Productivity decile with industry fixed effect removed

Productivity decile as the sum of 10 productivity groups for each industry

Figure C.4. Liquidity Management and Productivity, Controlling for Industry FE
Figure C.5. Liquidity Management and Productivity Between China and U.S.
### TABLE C.1  
**SUMMARY STATISTICS**

#### Panel A: Summary of Variables

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<th>Mean</th>
<th>Median</th>
<th>Std. Dev.</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total assets (billions of RMB)</td>
<td>0.0792</td>
<td>0.0132</td>
<td>0.5794</td>
<td>1,818,926</td>
</tr>
<tr>
<td>Value added per (1k RMB of) capital</td>
<td>0.0061</td>
<td>0.0013</td>
<td>0.0534</td>
<td>1,793,251</td>
</tr>
<tr>
<td>TFP</td>
<td>0.1440</td>
<td>0.0919</td>
<td>0.1722</td>
<td>1,046,990</td>
</tr>
<tr>
<td>Firm age</td>
<td>11.071</td>
<td>7.000</td>
<td>11.523</td>
<td>1,826,670</td>
</tr>
<tr>
<td>MNC</td>
<td>0.2191</td>
<td>0.0000</td>
<td>0.4136</td>
<td>1,834,472</td>
</tr>
<tr>
<td>State capital participation</td>
<td>0.1010</td>
<td>0.0000</td>
<td>0.2888</td>
<td>1,805,148</td>
</tr>
<tr>
<td>Fixed asset*</td>
<td>0.3304</td>
<td>0.2970</td>
<td>0.2172</td>
<td>1,805,148</td>
</tr>
<tr>
<td>Liquid asset*</td>
<td>0.5755</td>
<td>0.5882</td>
<td>0.2350</td>
<td>1,818,926</td>
</tr>
<tr>
<td>Short-term investment*</td>
<td>0.0030</td>
<td>0.0000</td>
<td>0.0288</td>
<td>1,060,147</td>
</tr>
<tr>
<td>Account receivables*</td>
<td>0.1832</td>
<td>0.1304</td>
<td>0.1790</td>
<td>1,818,926</td>
</tr>
<tr>
<td>Inventory*</td>
<td>0.1884</td>
<td>0.1449</td>
<td>0.1679</td>
<td>1,818,926</td>
</tr>
<tr>
<td>Net liquid assets*</td>
<td>0.0463</td>
<td>0.0572</td>
<td>0.3484</td>
<td>1,818,926</td>
</tr>
<tr>
<td>Cash*</td>
<td>0.2383</td>
<td>0.2269</td>
<td>0.2782</td>
<td>1,060,147</td>
</tr>
<tr>
<td>Long-term investment*</td>
<td>0.0107</td>
<td>0.0000</td>
<td>0.0482</td>
<td>1,818,926</td>
</tr>
<tr>
<td>Total debt*</td>
<td>0.5969</td>
<td>0.6000</td>
<td>0.3373</td>
<td>1,818,926</td>
</tr>
<tr>
<td>Long-term debt*</td>
<td>0.0562</td>
<td>0.0000</td>
<td>0.1408</td>
<td>1,818,926</td>
</tr>
<tr>
<td>Liquid debt*</td>
<td>0.5293</td>
<td>0.5242</td>
<td>0.3247</td>
<td>1,818,926</td>
</tr>
<tr>
<td>Account payables*</td>
<td>0.1610</td>
<td>0.0946</td>
<td>0.1916</td>
<td>1,060,147</td>
</tr>
<tr>
<td>Capital Investment*</td>
<td>0.0040</td>
<td>0.0000</td>
<td>0.3939</td>
<td>1,250,485</td>
</tr>
<tr>
<td>Operating Cash Flow (Net) *</td>
<td>0.0504</td>
<td>0.0000</td>
<td>0.3317</td>
<td>812,119</td>
</tr>
<tr>
<td>R&amp;D*</td>
<td>0.0018</td>
<td>0.0000</td>
<td>0.0130</td>
<td>961,063</td>
</tr>
</tbody>
</table>

#### Panel B: Ownership Structure

<table>
<thead>
<tr>
<th></th>
<th>SOE</th>
<th>COE</th>
<th>DPE</th>
<th>HMT</th>
<th>FE</th>
<th>LPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>N of firms</td>
<td>183,718</td>
<td>196,490</td>
<td>742,603</td>
<td>127,559</td>
<td>126,605</td>
<td>408,618</td>
</tr>
<tr>
<td>% of firms</td>
<td>10.01%</td>
<td>10.71%</td>
<td>40.48%</td>
<td>6.95%</td>
<td>6.90%</td>
<td>22.27%</td>
</tr>
</tbody>
</table>
### TABLE C.2

**PRODUCTIVITY AND NET LIQUID ASSET TO TOTAL ASSET RATIO (CHINESE SAMPLE)**

<table>
<thead>
<tr>
<th>Net Liquid Asset to Total Asset Ratio</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TFP</td>
<td>0.1603***</td>
<td>0.1298***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0021)</td>
<td>(0.0023)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value Added per capital</td>
<td></td>
<td></td>
<td>0.3655***</td>
<td>0.3849***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.0127)</td>
<td>(0.0170)</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.534</td>
<td>0.501</td>
<td>0.542</td>
<td>0.502</td>
</tr>
<tr>
<td>Observations</td>
<td>1,033,719</td>
<td>568,907</td>
<td>1,225,713</td>
<td>652,508</td>
</tr>
<tr>
<td>Basic Controls</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Additional Controls</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Industry FE</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Year FE</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Cluster SE</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>
# TABLE C.3

**PRODUCTIVITY AND CASH HOLDINGS (CHINESE SAMPLE)**

<table>
<thead>
<tr>
<th>Cash to Total Asset Ratio</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TFP</td>
<td>0.0963***</td>
<td>0.0920***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0026)</td>
<td>(0.0026)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value Added per capital</td>
<td>0.2259***</td>
<td>0.2242***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0143)</td>
<td>(0.0153)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.076</td>
<td>0.075</td>
<td>0.072</td>
<td>0.070</td>
</tr>
<tr>
<td>Observations</td>
<td>661,484</td>
<td>568,907</td>
<td>773,276</td>
<td>652,508</td>
</tr>
<tr>
<td>Basic Controls</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Additional Controls</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Industry FE</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Year FE</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Cluster SE</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>
### TABLE C.4

PRODUCTIVITY AND LIQUIDITY MANAGEMENT (US SAMPLE)

<table>
<thead>
<tr>
<th></th>
<th>Net Liquid Asset</th>
<th>Cash</th>
</tr>
</thead>
<tbody>
<tr>
<td>TFP</td>
<td>-0.0114*</td>
<td>0.0011</td>
</tr>
<tr>
<td></td>
<td>(0.0065)</td>
<td>(0.0119)</td>
</tr>
</tbody>
</table>

Adjusted $R^2$  
Observations 8,197 4,194

<table>
<thead>
<tr>
<th></th>
<th>Net Liquid Asset</th>
<th>Cash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Industry FE</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Year FE</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Cluster SE</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>
### Panel A: List of Parameters Measured from Data
<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition in the Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r$</td>
<td>Risk free savings rate</td>
</tr>
<tr>
<td>$\rho$</td>
<td>Firm discount rate</td>
</tr>
<tr>
<td>$\mu$</td>
<td>Expected return from capital</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>Volatility of returns from capital</td>
</tr>
<tr>
<td>$w$</td>
<td>Payout boundary (log)</td>
</tr>
<tr>
<td>$\eta$</td>
<td>Power coefficient of the distribution of firm size</td>
</tr>
</tbody>
</table>

### Panel B: Parameter Value

<table>
<thead>
<tr>
<th></th>
<th>Decile 1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r$</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>$\rho$</td>
<td>6.5%</td>
<td>6.5%</td>
<td>6.5%</td>
<td>6.5%</td>
<td>6.5%</td>
<td>6.5%</td>
<td>6.5%</td>
<td>6.5%</td>
<td>6.5%</td>
<td>6.5%</td>
</tr>
<tr>
<td>$\mu$</td>
<td>10.0%</td>
<td>11.0%</td>
<td>12.2%</td>
<td>13.4%</td>
<td>15.0%</td>
<td>17.6%</td>
<td>18.2%</td>
<td>21.6%</td>
<td>24.0%</td>
<td>40%</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>0.400</td>
<td>0.400</td>
<td>0.400</td>
<td>0.400</td>
<td>0.400</td>
<td>0.400</td>
<td>0.400</td>
<td>0.410</td>
<td>0.420</td>
<td>0.450</td>
</tr>
<tr>
<td>$\bar{w}$</td>
<td>13.33</td>
<td>12.98</td>
<td>12.75</td>
<td>12.54</td>
<td>12.32</td>
<td>12.18</td>
<td>11.95</td>
<td>11.78</td>
<td>11.58</td>
<td>11.41</td>
</tr>
<tr>
<td>$\eta$</td>
<td>1.08</td>
<td>1.09</td>
<td>1.13</td>
<td>1.14</td>
<td>1.15</td>
<td>1.17</td>
<td>1.20</td>
<td>1.23</td>
<td>1.26</td>
<td>1.29</td>
</tr>
</tbody>
</table>

### Panel C: Model implied distribution of cash holdings

<table>
<thead>
<tr>
<th></th>
<th>Decile 1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td>13.8%</td>
<td>17.2%</td>
<td>19.6%</td>
<td>21.8%</td>
<td>23.7%</td>
<td>25.4%</td>
<td>27.0%</td>
<td>29.0%</td>
<td>30.9%</td>
<td>34.3%</td>
</tr>
<tr>
<td>Model</td>
<td>9.2%</td>
<td>12.4%</td>
<td>16.2%</td>
<td>19.6%</td>
<td>21.3%</td>
<td>24.2%</td>
<td>26.7%</td>
<td>29.8%</td>
<td>30.2%</td>
<td>16.9%</td>
</tr>
</tbody>
</table>
C.3 Mathematical Appendix

**Proof of Lemma 1** In this equilibrium, firms choose optimal portfolio follows

\[
\alpha = \frac{\mu P - rP^2}{\gamma \sigma^2}.
\]  

(C.1)

Define \( \phi = \frac{\mu - rP}{\sigma} \) as the Sharp ratio of capital investment, obviously \( \phi \) must be larger than 0 in equilibrium, otherwise firms will hold cash only. Substituting \( \phi \) into the dynamics of firm assets yields

\[
\frac{dW_t}{W_t} = \left[ \frac{\phi^2}{\gamma} + r \right] dt + \frac{\phi}{\gamma} dZ_t.
\]  

(C.2)

Combine (C.1) and (C.2) into firm’s value function yields

\[
\rho V = \left( \frac{\phi^2}{2\gamma} + r \right) W_t V'(W_t).
\]  

(C.3)

The solution is \( V(W_t) = \theta W^{1-\gamma}, \) where

\[
\rho = \left( \frac{\phi^2}{2\gamma} + r \right) (1 - \gamma).
\]  

(C.4)

The coefficient \( \theta \) and payout boundary can be pinned down by matching the refinancing boundary condition: \( V'(W) = (1 - \gamma)\theta W^{-\gamma} = 1 + \delta \) and the payout boundary condition \( V'(\overline{W}) = (1 - \gamma)\theta \overline{W}^{-\gamma} = 1, \) we obtain

\[
\theta = \frac{1 + \delta}{1 - \gamma} W^\gamma,
\]  

(C.5)

\[
\overline{W} = (1 + \delta)^{\frac{1}{\gamma}} W.
\]  

(C.6)
Combining (C.1) and the definition of φ and γ implies

\[ \alpha_s = \frac{\phi_s P}{\gamma_s \sigma} \]  \hspace{1cm} (C.7)

\[ \square \]

**Proof of Lemma 2:**

Equation (C.4) implies that γs is the solution to an equation Γ(γs) = 0, where Γs(x) takes a quadratic form:

\[ \Gamma_s(x) \equiv 2rx^2 + (\phi_s^2 + 2\rho - 2r)x - \phi_s^2. \]  \hspace{1cm} (C.8)

Notice that Γs(0) < 0 and Γs(1) > 0, which implies Γs(x) = 0 always has one negative root and one positive root that is between 0 and 1. We keep positive root

\[ \gamma_s = \frac{\sqrt{(\phi_s^2 + 2\rho - 2r)^2 + 8r\phi_s^2} - (\phi_s^2 + 2\rho - 2r)}{4r}. \]  \hspace{1cm} (C.9)

Taking the derivative of the numerator with respect to \( \phi_s \) yields

\[ \frac{2\phi_s(\phi_s^2 + 2\rho - 2r)^2 + 8r\phi_s}{\sqrt{(\phi_s^2 + 2\rho - 2r)^2 + 8r\phi_s^2}} - 2\phi_s > 0, \]  \hspace{1cm} (C.10)

where the last inequality comes from

\[ (\phi_s^2 + 2\rho - 2r) + 4r > \sqrt{(\phi_s^2 + 2\rho - 2r)^2 + 8r\phi_s^2}. \]  \hspace{1cm} (C.11)

That is, the numerator increases in \( \phi_s \). Thus \( \phi_h > \phi_l \) implies \( 0 < \gamma_l < \gamma_h < 1. \) \[ \square \]

**Proof of Proposition 1:**

We first proof the following useful result:

**Lemma A.1:** Suppose capital price \( P \) is exogenously given, then \( \alpha_l > \alpha_h \) \( (\alpha_l < \alpha_h) \) if \( P \) is sufficiently high (low).
Proof: Equation \((C.1)\) implies
\[
\frac{\alpha_l}{\alpha_h} = \frac{\mu_l P - r P^2}{\mu_h P - r P^2} \cdot \frac{\gamma_h \sigma^2}{\gamma_l \sigma^2} = \frac{\phi_l \gamma_h}{\phi_h \gamma_l}.
\] (C.12)

Substituting in \((C.9)\), we have
\[
\frac{\alpha_l}{\alpha_h} = \sqrt{\left(\frac{\phi_h + 2(\rho - r)}{\phi_h}\right)^2 + 8r - \left(\frac{\phi_h + 2(\rho - r)}{\phi_h}\right)}.
\] (C.13)

Define function \(H(y) \equiv \sqrt{y^2 + 8r} - y\), then
\[
\frac{\alpha_l}{\alpha_h} = \frac{H(y_h)}{H(y_l)}\text{ where } y_s \equiv \phi_s + \frac{2(\rho - r)}{\phi_s}.
\]
Note that \(H'(y) < 0\) as long as \(r > 0\), therefore \(\frac{\alpha_l}{\alpha_h} > 1\) as long as \(y_h < y_l\), or
\[
\phi_h + \frac{2(\rho - r)}{\phi_h} < \phi_l + \frac{2(\rho - r)}{\phi_l}.
\] (C.14)

Since \(\phi_s = \frac{\mu_s - r P}{\sigma}\), given any level of \(\mu_h\) and \(\mu_l\), the above quation is equivalent to
\[
r^2 P^2 - r(\mu_h + \mu_l) + 2(\rho - r)^2 \sigma^2 < 0,
\] (C.15)

The left hand side of the above unequally can be analyzed as a quadratic function of \(P\). Set the left hand side to 0, it has two roots \(P_1, P_2\) where \(0 < P_1 < P_2\), given
\[
r(\mu_h + \mu_l) < 2\sigma \sqrt{\rho - r}.
\] (C.16)

However \(P_2 > \frac{\mu_h + \mu_l}{2r} > \frac{\mu_l}{r}\) which would imply that \(\phi_l < 0\). Therefore we only focus on the smaller root which implies that \(\alpha_l > \alpha_h\) if
\[
P > \frac{r(\mu_h + \mu_l) - \sqrt{r^2(\mu_h + \mu_l)^2 - 4(\rho - r)^2 \sigma^2}}{2r}.
\] (C.17)

We now prove the proposition under endogenous \(P\) using the market clearing.
condition for capital. A geometric Brownian motion \( \frac{dW_t}{W_t} = \mu dt + \sigma dZ_t \) with two reflecting barriers \( W \) and \( W \) has a stationary distribution. Define \( \eta = \frac{2\mu}{\sigma} \), the stationary distribution is characterized by the density function:

\[
f(W) = \frac{\eta - 1}{W^{\eta-1} - W^{\eta-1}} W^{\eta-2}
\]

The price of capital \( P \) is the solution to the market clearing condition (3.4). Since \( \alpha_s \) is constant, the market clearing condition in the steady-state equilibrium can be written as

\[
P = \pi E[\alpha_h E(W_h)] + (1 - \pi) E[\alpha_l E(W_l)],
\]

where

\[
E(W_s) = \frac{(\eta_s - 1)}{\eta_s (W_s^{\eta_s-1} - W_s^{\eta_s-1})} (W_s^{\eta_s} - W_s^{\eta_s}),
\]

\( W_s \) is given by (C.6), and \( \eta_s \) is given by

\[
\eta_s = \frac{2 \left( \frac{\phi_s^2 + r}{\gamma_s} \right)}{\left( \frac{\phi_s}{\gamma_s} \right)^2} = 2 \left( \frac{r \gamma_s^2}{\phi_s^2} \right)
\]

Finally, combing (3.4), (C.1), (C.21) and manipulating the algebra implies

\[
1 + \delta = \pi_s \left( \frac{\eta_s \phi_s}{W(\eta_s - 1)\gamma_s \sigma^2} \right)^{\gamma_s} > \pi_s \left( \frac{\alpha_s}{\bar{W}} \right)^{\gamma_s}
\]

Let \( \Omega \) stands for the right hand side of (C.17), then \( P > \Omega \) if

\[
1 + \delta > \frac{\pi_s}{\bar{W}} > \pi_s \left( \frac{1}{\bar{W}} \right)^{\gamma_s} > \pi_s \left( \frac{\alpha_s}{\bar{W} \Omega} \right)^{\gamma_s} > \pi_s \left( \frac{\alpha_s}{\bar{W} \bar{P}} \right)^{\gamma_s}
\]

for both \( s \in \{l, h\} \). It should be noted that this is a sufficient condition for theoretical argument only. In our quantitative analysis, parameters do not have to follow such condition in order for the results to hold. \( \square \)
C.4 Measuring Total Factor Productivity (TFP)

Estimating production technology and measuring productivity heterogeneity using micro-level data is the critical first step in understanding firm decisions. One of the most common measures of productivity is value added per worker or value added per unit of fixed assets. While it is simple and usually directly observable from data, this measure could be biased for several reasons.

First, the premise of using value added as a proxy for productivity is that output is a linear function of labor or capital. In actuality, however, firm output usually depends on a combination of various inputs. Value added per worker or fixed assets is likely to be a biased measure of productivity. For instance, Firm A and Firm B could have the same number of employees, but firm A produces more output because it has better machinery. Using value-added per worker to estimate productivity would lead to the erroneous conclusion that Firm A’s workforce is more productive. The solution is usually to estimate a concave production function, for example a Cobb-Douglas function or a translog function.

The second issue is endogeneity. To illustrate, assume a firm has a Cobb-Douglas production function, whose natural log form is given by

\[ y_i = \beta_0 + \beta_k k_i + \beta_\ell \ell_i \]

The firm specific productivity is defined as \( a_i \equiv \ln(A_i) = \beta_0 \), which is usually obtained as the residual term from estimating the production function. In this case, firm’s profit maximization will create an upward endogeneity bias. Assuming that at least labor is partially adjustable, the first order condition for the firm’s profit maximization implies that

\[ \frac{\partial \pi_i}{\partial \ell_i} = 0 \Leftrightarrow p_i A_i \beta_\ell K_i^{\beta_k} L_i^{\beta_\ell - 1} = W \]  

(C.24)

Take log,

\[ \ln p_i + \ln A_i + \ln \beta_\ell + \beta_k \ln K_i + (\beta_\ell - 1) \ln L_i = \ln W \]  

(C.25)

\[ \ln L_i = \frac{1}{1 - \beta_\ell} [\ln \beta_\ell + \ln p_i - \ln W_i + \beta_k k_i + a_i] \]  

(C.26)
Since productivity is not exogenous, firms will adjust their labor demand according to the perception of their productivity. If higher productivity leads to higher demand for labor, this estimation would introduce an upward bias in $\beta_\ell$, which in turn implies a downward-biased estimate of TFP. Also, measurement errors in the inputs, typically more severe for capital $k_i = k_i^* + u_i$, would cause a downward bias in $\beta_k$.

Besides ones described above, there are other important problems when estimating the production function: serial correlation or unobserved heterogeneity in productivity, and sample selection or the exit of unproductive firms.

An innovative approach developed by Olley and Pakes (1996) is considered a panacea for all aforementioned issues. They propose a dynamic model in which each firm makes two decisions: first, to remain in operation or to shut down, which depends on whether productivity is above a certain threshold monotonically increasing in capital stock; second, if a firm decides to stay in operation, it must then decide how much to invest, which is a function of both productivity and capital stock, $i_{it} = i_{it}(\omega_{it}, k_{it})$.

To estimate the model, four key assumptions are made. First, the production function shock has two components: $a_{it} = \omega_{it} + e_{it}$, in which the unobserved productivity $\omega_{it}$ is a FOMP (First-Order Markov Process, $P(\omega_{it+1} | \{\omega_{it}\}_{t=0}^t) = P(\omega_{it+1} | \omega_{it})$, which is more general than AR(1)). Second, labor is a flexible input chosen after observing $\omega_{it}$, which means productivity $\omega_{it}$ is exogenous to the choice of labor. Third, capital is quasi-fixed with the time-to-build feature ($K_{it} = (1 - \delta) K_{it-1} + I_{it-1}$). Finally, the investment function is strictly monotonic in $\omega_{it}$ conditional on $k_{it}$. The crucial assumption that productivity is a function of capital and investment allows the correction of simultaneity in the following way:

$$y_{it} = \beta_\ell \ell_{it} + \beta_k k_{it} + h_{it}(k_{it}, i_{it}) + e_{it}$$  \hspace{1cm} (C.27)

$$= \beta_\ell \ell_{it} + \phi(k_{it}, i_{it}) + e_{it}$$  \hspace{1cm} (C.28)
The equation above allows consistent estimates of $\beta_\ell$ and $\phi(k_{it},i_{it})$ by regressing output $y_{it}$ on labor $\ell_{it}$ and a polynomial function of capital $k_{it}$ and investment $i_{it}$. Given a consistent $\beta_\ell$, we can solve the correlated effects and sample selection issues together as follows:

\[
E[y_{it} - \beta_\ell \ell_{it} | \chi_{it} = 1] = \beta_k k_{it} + E[\omega_{it} | \chi_{it} = 1] \tag{C.29}
\]

\[
= \beta_k k_{it} + E[\omega_{it} | \omega_{it} \geq \bar{\omega}(k_{it})] \tag{C.30}
\]

\[
= \beta_k k_{it} + g(\omega_{it-1}, \bar{\omega}(k_{it})) \tag{C.31}
\]

$g(\omega_{it-1}, \bar{\omega}(k_{it}))$ is a function of the unobserved firm productivity (lagged) and the survival probability ($P_{it} = P(\chi_{it} = 1 | \omega_{it-1}, \bar{\omega}(k_{it}))$), which must be estimated. Olley and Pakes (1996) suggest using $h_{it-1} = \phi_{it-1} - \beta_k k_{it-1}$ as a proxy for the first, and the predicted probability of survival from a probit or semi-parametric estimate of exit as a proxy for the latter. Then,

\[
\hat{\phi}_{it} = \beta_k k_{it} + g(\hat{\phi}_{it-1} - \beta_k k_{it-1}, \hat{P}_{it}) + \xi_{it} \tag{C.32}
\]

Since the functional form of $g(\cdot)$ is unknown, Olley and Pakes (1996) suggest modeling it as a polynomial in $h(\cdot)$ and $P_{it}$ or as a kernel regression. In practice, as long as one maintains an unbalanced panel, the $P_{it}$ typically does not change results too much. Finally, we can search for more control functions that rely on better data. For instance, Levinsohn and Petrin (2003) propose using intermediate inputs instead of investment, since there are a large number of observations with zero investment in firm-level datasets from developing countries while intermediate inputs are usually well reported in micro-level datasets.

The technique proposed by Ackerberg et al. (2015) further improves upon Olley and Pakes (1996) and is currently considered the state-of-the-art approach to esti-
mating productivity. It has been adopted in a number of the most recent empirical studies such as Greenstone et al. (2010), Brandt et al. (2012a), and De Loecker and Warzynski (2012). Ackerberg et al. (2015) argue that the first stage estimation in both Olley and Pakes (1996) and Levinsohn and Petrin (2003) does not identify the labor coefficient due to functional dependence. They suggest an alternative estimation procedure that avoids this problem. Specifically, they invert investment or the intermediate demand function which are both conditional on labor input. As a result, their moment conditions produce consistent estimates even if labor is chosen prior to other inputs, there are unobserved and serially correlated shocks to the price of labor, and/or there are firm-specific adjustment costs to labor.

Our procedure to compute the alternative TFP closely follows Ackerberg et al. (2015). We consider the production function

\[ y_{it} = \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + \beta_{ll} l_{it}^2 + \beta_{kk} k_{it}^2 + \beta_{mm} m_{it}^2 + \beta_{lk} l_{it} k_{it} + \beta_{lm} l_{it} m_{it} + \beta_{km} k_{it} m_{it} + \omega_{it} + \epsilon_{it} \]  

(C.33)

where \( y_{it} \) is the gross output of firm \( i \) in year \( t \), \( l_{it} \) is the amount of labor employed, \( k_{it} \) is the book value of fixed capital after depreciation, \( m_{it} \) is the value of intermediate inputs, and \( \omega_{it} \) is firm productivity.

To proxy for firm’s productivity, we follow Levinsohn and Petrin (2003) by inverting the material demand, \( m_{it} = m_t(k_{it}, \omega_{it}, z_{it}) \). Assuming that \( m_t \) is a monotonic function, we can rely on \( \omega_{it} = h_t(m_{it}, k_{it}, z_{it}) \) to proxy for productivity in the production function estimation.

Our first stage estimation is

\[ y_{it} = \phi(l_{it}, k_{it}, m_{it}, z_{it}) + \epsilon_{it} \]  

(C.34)

from this we recover the estimate for expected output \( \hat{\phi}_{it} \) and for the residual \( \epsilon_{it} \).
The expected output is given by

$$
\hat{\phi}_{it} = \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + \beta_{ll} l_{it}^2 + \beta_{kk} k_{it}^2 + \\
\beta_{mm} m_{it}^2 + \beta_{lk} l_{it} k_{it} + \beta_{lm} l_{it} m_{it} + \beta_{km} k_{it} m_{it} + h_t(m_{it}, k_{it}, z_{it}).
$$

(C.35)

In the second stage, we rely on the law of motion for productivity to estimates:

$$
\omega_{it} = g_{it}(\omega_{it-1}) + \xi_{it},
$$

(C.36)

where $\xi_{it}$ is an idiosyncratic shock. From the first stage, we can compute productivity for any value of $\beta$, where $\beta = (\beta_l, \beta_k, \beta_m, \beta_{ll}, \beta_{kk}, \beta_{mm}, \beta_{lk}, \beta_{lm}, \beta_{km})$, using

$$
\omega_{it}(\beta) = \hat{\phi}_{it} - (\beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + \beta_{ll} l_{it}^2 + \beta_{kk} k_{it}^2 + \\
\beta_{mm} m_{it}^2 + \beta_{lk} l_{it} k_{it} + \beta_{lm} l_{it} m_{it} + \beta_{km} k_{it} m_{it}).
$$

(C.37)

Given $\beta$ and $\xi_{it}(\beta)$, the idiosyncratic shock to productivity can be obtained by nonparametrically regressing $\omega_{it}(\beta)$ on its lag $\omega_{it-1}(\beta)$. To obtain the estimates of the production function, we estimate the following moment conditions

$$
E(\xi_{it}(\beta) Y_{it}') = 0
$$

(C.38)

by using standard GMM technique and relying on block bootstrapping for the standard errors, where $Y_{it} = \{l_{it-1}, l_{it-1}^2, m_{it-1}, m_{it-1}^2, k_{it}, k_{it}^2, l_{it-1} m_{it-1}, l_{it-1} k_{it}, m_{it-1} k_{it}\}$. Eventually, we use the GMM estimates to recover the TFP for each firm.
C.5 Technical Discussions

In the paper we assume a refinancing boundary $W$ that is reflecting and exogenous. We provide some additional discussion here how to endogenously form such boundary using the same technique as in [Bolton et al. (2011)]: in addition to the marginal refinancing cost $\delta$, firms must also pay a fixed cost $\xi$ each time they raise external funding. The fixed cost ensures that firms will only refinance when assets are sufficiently low and in lump-sum rather than as a flow. These assumptions imply that the boundary condition associated with the HJB at $W = \overline{W}$ are

$$V'(W) = 1 + \delta, \quad (C.39)$$

and

$$V(W) = \xi + (1 + \delta)W. \quad (C.40)$$

$W = \overline{W}$ is then endogenous and can be derived using the value-matching procedure introduced above. Specifically, substituting $V(W) = \theta W^{1-\gamma}$ into the boundary conditions above yields

$$\theta W^{1-\gamma} = \xi + (1 + \delta)W \quad (C.41)$$

and

$$(1 - \gamma)\theta W^{-\gamma} = 1 + \delta \quad (C.42)$$

together one can solve for $\overline{W}$

$$\overline{W} = \frac{(1 - \gamma)\xi}{\gamma(1 + \delta)} \quad (C.43)$$

Measuring the Return and Volatility on Capital

We estimate the marginal return to capital $\mu$ following the procedure used in [Bai et al. (2006b)]. In particular, we assume the production function is Cobb-Douglas,
where $y = z^k \ell^\lambda$. The marginal return to capital is

$$\mu = \frac{p_y y - wL}{p_k k} - \Delta = \frac{\lambda_k}{p_k k / p_y y} - \Delta$$

(C.44)

\(\lambda_k\) is the capital share of income. While it is not directly observable, in a Cobb-Douglas function, it equals one minus \(\lambda_l\), the labor share of income, which is usually reported in the data. However, our data, the Annual Surveys of Industrial Production in China, report only wage payments and do not provide information on non-wage compensation. Therefore, we resort to the aggregate labor share in manufacturing reported in the Chinese input-output tables and the national accounts to set \(\lambda_k = \lambda_l = 0.5\). Following Hsieh and Klenow (2009), we define \(p_k k\) as the book value of fixed capital net of depreciation and \(p_y y\) as the value added. To compute the average marginal return to capital, we use the formula

$$\bar{\mu} = \frac{\lambda_k}{(\sum_i p_k k_i) / (\sum_i p_y y_i)}$$

(C.45)

which averages out noise across different types of firms. We use a similar formula to compute the average marginal return to capital for each value added per capital decile.

To estimate productivity volatility \(\sigma\), we use a balanced panel with 34,035 firms from 1999 to 2007. For simplicity, we first use OLS to estimate TFP by assuming a Cobb-Douglas production function. Then we impose an AR(1) process on the TFP and compute the standard deviation of the residuals as \(\sigma\). Overall, the standard deviation of the white noise for the AR(1) process is between 0.4 and 0.55, consistent with the findings in Asker et al. (2012) in the World Bank Survey.


Steven Olley and Ariel Pakes. The dynamics of productivity in the telecommunications. 1996.


