DIGITAL ACCESS TO SCHOLARSHIP AT HARVARD
DASH.HARVARD.EDU

HARVARD LIBRARY
Office for Scholarly Communication

Essays on Global Sourcing, R&D, and Bank Credit

Citation
Du, Yang. 2016. Essays on Global Sourcing, R&D, and Bank Credit. Doctoral dissertation, Harvard University, Graduate School of Arts & Sciences.

Permanent link
http://nrs.harvard.edu/urn-3:HUL.InstRepos:33493284

Terms of Use
This article was downloaded from Harvard University's DASH repository, and is made available under the terms and conditions applicable to Other Posted Material, as set forth at http://nrs.harvard.edu/urn-3:HUL.InstRepos:dash.current.terms-of-use#LAA

Share Your Story

The Harvard community has made this article openly available.
Please share how this access benefits you. Submit a story .

Accessibility

Essays on Global Sourcing, R&D, and Bank Credit

A dissertation presented

by

Yang Du

to

The Department of Economics

in partial fulfillment of the requirements

for the degree of

Doctor of Philosophy

in the subject of

Economics

Harvard University

Cambridge, Massachusetts

February 2016

© 2016 Yang Du

All rights reserved.

Dissertation Advisors:
Professor Pol Antras
Professor Marc Melitz

Author:
Yang Du

Essays on Global Sourcing, R&D, and Bank Credit

Abstract

This dissertation consists of three essays, two in the field of international economics and one in macroeconomics.

The first essay studies the interaction of manufacturing firms' sourcing decisions and their R&D investment. I propose a two-country model of sourcing where heterogeneous firms choose the sourcing destination as well as the extent to which they would like to engage in productivity-enhancing R&D investments. Firms self-select into different combinations of sourcing modes and R&D engagements based on their pre-R&D, or pure productivity level. This model generates novel predictions of sorting into four different sourcing/R&D combinations in the equilibrium. In contrast to canonical models of sourcing, this paper incorporates both extensive and intensive margins of R&D and shows the interaction of these choices with sourcing decisions through the cost function. The model suggests that foreign sourcing decision should be complementary to R&D investment both on the extensive margin and the intensive margin. I find empirical support for the model predictions using the ESEE data for Spanish manufacturing firms. Using an instrumental variable approach, I show that foreign sourcing is causally linked to an increase in a firm's propensity to engage in R&D extensively and the extent of the engagement intensively.

The second essay investigates manufacturing firms' decisions to employ multiple sourcing modes simultaneously and their relationship to productivity, firm size, and capital intensity in a heterogeneous firm framework. Using a simple extension of the Antras and Helpman (2004) model where each firm can produce differentiated goods by sourcing

from a multitude of suppliers, I show that more productive firms are able to use more varied sourcing modes, produce more products and shift a larger share of inputs away from the most basic form of sourcing into more advanced strategies. This is achieved by allowing supplier heterogeneity in the set of associated sourcing fixed costs. I show that the model predictions are consistent with stylized facts and empirical analysis with Spanish manufacturing firms. Using an instrumental analysis, the multiple sourcing patterns are found to be driven by firm-level productivity.

Finally, the third essay examines the propagation of monetary policy through the banking system in China in the context of a major banking reform in the 1990s. Using bank-level data for commercial banks over twenty years from 1986 to 2008, I examine the supply side of the narrow credit channel: loan level responses of commercial banks to monetary policy tools of the central bank. I find that banks have disparate but strong responses to different policy instruments depending on their type and level of capitalization. Moreover, the major banking reform in the 1990s has changed some characteristics of the bank-dependent propagation mechanism without diminishing its central role in monetary transmission.

Contents

List of Tables

List of Figures

Acknowledgments

This dissertation is a tribute to the invaluable inputs and continual support of my advisors on the dissertation committee, Pol Antràs, Marc Melitz and Emmanuel Farhi, from whom I have learned not only the useful tools of research, but also the steadfast approaches to problems in general. I am particularly grateful to Pol Antràs, whom I have worked for as a research assistant and were first introduced to the dataset that became the centerpiece for the first two chapters. In every stage of the dissertation, Pol has never ceased to ask the critical questions and push my thinking one step further, without which this work would not have been possible. I am deeply indebted to Marc for his insightful comments and vast patience in helping me formulate ideas and construct models for the chapters, which have pulled me through many trying times. I am grateful to Emmanuel for very helpful discussions that are more than constructive for the macroeconomic chapter.

I would like to thank the professors I have worked with over the years, Kenneth Kuttner, Ben Friedman, Alp Simsek, John Campbell and Diego Comin, for their mentorship, encouragement, and advice that, directly or indirectly, contributed to the completion of this work. I owe my gratitude to my colleagues in graduate school, from whom I have benefited tremendously both during numerous academic discussions and in endearing friendships. Special thanks go to Yao Zeng, Jing Xia, Oren Ziv, Lilei Xu, Mo Chen, Yin Chen, Gea Hyun Shin, Wentao Xiong, Stephanie Lo, just to name a few. For thoughtful comments and feedbacks in early stages of the projects, I would like to thank the international economics seminar and lunch participants.

Finally, I would like to express my wholehearted appreciation for the unconditional support from my family that made everything possible. My parents, despite being half a globe away for most of the times, have made boundless effort to encourage me in all my endeavors. My wife, Wei Luo, selflessly shares this journey - with all its arduousness, struggle, and euphoria - with me that she, being a Ph.D. candidate herself, only understands too well. Her devotion and company have molded me into a better person for which I cannot thank enough.

To my parents

Chapter 1

R&D Investment and Sourcing Choices[†]

1.1 Introduction

Productivity is at the core of the canonical heterogeneous firm models. Based on how productive they are, firms self-select into exporting or different sourcing modes (Melitz (2003), Antras and Helpman (2004)). Apart from the papers that laid out the theoretical underpinnings of trade patterns in heterogeneous firms, there is also a large and growing body of literature that documents empirical evidence (Defever and Toubal (2007), Farinas and Martín-Marcos (2010)) supporting the productivity sorting patterns. Technology innovation through R&D, on the other hand, does not receive as much attention in conjunction to the productivity sorting literature. In fact, the interaction of sourcing decisions and the choice of R&D investment by the firms is particularly interesting, as R&D directly enhances the

[†]The dataset used in this paper is the sole intellectual property of Fundacion SEPI. It was acquired originally by Professor Pol Antras for his project on the book manuscript *Global Production: Firms, Contracts and Trade Structure*. This paper is one of the related projects borne out of the research efforts while I was assisting Professor Antras in the manuscript. I draw many insights from the theoretical as well as empirical sections of the book. All errors are the sole responsibility of the author.

productivity of a firm and potentially enables the firms to self-select into different exporting or sourcing modes.

I incorporate R&D investment as another dimension of firm choices to study the 'productivity sorting' patterns. In a typical model, there are several productivity thresholds, by which firms are sorted into different sourcing categories. Less productive firms choose low fixed cost/high variable cost sourcing modes such as domestic sourcing while more productive firms will be able to make use of more advanced sourcing modes such as foreign sourcing, which incurs high fixed cost but reduces variable cost. This is because more productive firms will scale proportionately better with lower variable cost and generate enough profit to cover the high upfront cost. However, these models generally do not allow for productivity enhancing R&D investment. The categorization of firms is usually based on total factor productivity derived from the production function that already accounts for any contribution from R&D. Therefore, with R&D choices factored into firm's decision process, the productivity thresholds in the canonical models become less clear-cut. Initially less productive firms could invest more in R&D and increase its productivity past the threshold for more advanced sourcing modes. As I will show later empirically, there is indeed a significant number of firms that choose foreign sourcing while having lower productivity than many domestic sourcing firms - a scenario that is not possible in the canonical model. In the data, we also see that foreign sourcing firms on average are more productive than domestic sourcing firms (as predicted by the canonical models). At the same time, there is a clear complementarity between foreign sourcing and R&D at work. Foreign sourcing firms involve more heavily in R&D both extensively (a larger portion of all foreign sourcing firms conduct R&D) and intensively (among the firms investing in R&D, foreign sourcing ones spend more than domestic sourcing ones). Hence, the higher observed productivity among foreign sourcing firms may be a result of them pursuing productivity enhancing investments more aggressively. Naturally, one may ask: how do firms initially make sourcing decisions while taking into account the potential productivity improvement from their concurrent choices of R&D investment? My model will generate predictions that explain these empirical findings.

In this paper, the stages of the firm's decision game are as follows. In the first stage, after paying a fixed entry cost f_e to enter the market a la Melitz (2003), firms will be able to draw their productivity ψ from a distribution $G_1(\psi)$. Departing from the canonical model, this draw is the pre-R&D, or 'pure' productivity of the firm. Observing this measure, low productivity firms will exit the market. In stage 2, surviving firms then decide on whether to engage in R&D and whether to source domestically or abroad. The extensive margin R&D and sourcing decisions are made concurrently before production begins to reflect the fact that firms may find it difficult to change their R&D commitments as well as sourcing partners after production has taken place. To make the extensive margin decision, I introduce a notion of 'R&D potential', p_z, which the firm can learn by incurring a fixed cost f_p and draw from a distribution $G_2(p_z)$. The R&D potential can be thought of as the level of technology expertise of the firm, or the efficacy of R&D spending by the firm. The cost f_p can be perceived as the fixed entry cost for R&D, and in real life as the cost of conducting due diligence by the firm to find out the potential yield of its R&D spending. Therefore, at this stage, there are four potential modes a firm can commit to: domestic sourcing without R&D entry, domestic sourcing with R&D entry, foreign sourcing without R&D entry and foreign sourcing with R&D entry. Note that at this stage, paying the entry cost f_p does not guarantee that the firm will actually invest in R&D. In stage 3, firms that paid the entry R&D cost in the earlier stage observe its R&D potential, then decide on the intensive margin of R&D investment - the total spending on R&D. R&D cost again consists of two parts: a fixed cost of f_z and a variable cost $C(z)$. The fixed cost can be the overhead cost of setting up R&D facilities, hiring researchers or drawing up contracts with outside research institutes. The variable cost $C(z)$ will be convex in z by convention to reflect diminishing returns in R&D. The potential p_z as well as R&D investment level z will directly augment firms' productivity ψ in a multiplicative manner. In stage 4, after committing to both the sourcing modes and the extensive/intensive margins of R&D, production will start.

The key benefit of this model is the flexibility it offers in incorporating R&D, which allows analysis of both the extensive and the intensive margin. In stage 2 above, the entry cost involved in the draw for R&D potential will discourage low pure productivity firms from even considering R&D investment. For firms that have high enough pure productivity to enter the R&D potential draw, the realized potential will also affect the margins of R&D in stage 3. Specifically, firms with very low potential draws will forego the sunk entry cost f_p and not engage in R&D at all, because the presence of R&D fixed cost makes investing unfavorable. Therefore, even for those firms that paid the R&D entry cost f_p, not all of them will carry out investments in R&D. Similarly, high potential draws will incentivize firms to spend more on R&D.

The rationale behind introducing the R&D entry cost f_p is the following. Without the entry cost, a firm at stage 2 can perfectly foresee the returns on its R&D investment given the sourcing modes. Optimal R&D investment level will be an increasing function of firms' pure productivity as they reinforce each other's effect in reducing the marginal cost and increasing profit. R&D will also increase when firms switch from domestic sourcing to foreign sourcing, as higher sourcing capacity (Antras *et al.* (2014)) further boosts profit and improves the return on R&D. In this scenario, we should expect to see R&D investment increasing monotonically with productivity, and foreign sourcing firms will always have higher productivity and R&D spending than domestically sourcing ones. Furthermore, much in the spirit of Bustos (2011), with reasonable assumptions that will be elaborated in the model in detail later, there will only be three groups that exist in equilibrium: domestic sourcing firms with no R&D, domestic sourcing firms with R&D and foreign sourcing firms with R&D. In other words, foreign sourcing without R&D will always be dominated. However, the data (Table 1.1) shows not only a significant number of foreign sourcing firms do not engage in R&D at all [1], but the relationship between productivity and R&D spending is far from monotone.[2]

---

[1]In fact, close to half of the foreign sourcing firms do not engage in any R&D activities, while the number is around 78% for domestic sourcing firms

[2]The data further splits investment in R&D into 3 groups: external R&D only, internal R&D only and both types. An example of non-monotone relationship between R&D spending and productivity can be seen in Table 1.1, where domestic sourcing firms with both external and internal R&D spend more on R&D investment than

Table 1.1: *Manufacturing Firms by Sourcing Strategy and R&D Choice*

Modes	Domestic Sourcing Only				Foreign Sourcing			
	NO	Pct	Prod.	RD Intens.	NO	Pct	Prod.	RD Intens.
No R&D	593	41.1%	98.78	-	329	22.8%	100.08	-
With R&D	161	11.2%	100.81	0.015	360	24.9%	101.70	0.026
Ext. R&D Only	26	1.8%	100.82	0.013	51	3.5%	101.08	0.0098
Int. R&D Only	59	4.1%	100.31	0.017	108	7.5%	101.75	0.018
Both Ext. & Int.	76	5.3%	101.19	0.024	201	13.9%	101.83	0.034

Notes 1. Data is from ESEE Spanish Manufacturing Survey, year 2009.
2. Firms that do not source at all represent $< 5\%$ of the sample and are not included in the table.
3. Foreign sourcing firms import part or all of their inputs abroad, but may engage in domestic sourcing at the same time. In fact only $< 2\%$ of the sample firms source exclusively from abroad.
4. Productivity measure is Olley-Pakes relative productivity, where the industry average is 100.
5. R&D intensity is calculated as R&D spending divided by total sales.
6. External R&D, internal R&D and both types of R&D groups are mutually exclusive. 'With R&D' is the union of the three groups below.
7. Pct column shows the percentage of the type among all firms

This pattern that we observe in data can be reconciled with the addition of the R&D entry cost. In stage 2 before the firms draw their R&D potential, they will self-select into three distinct groups as in Bustos (2011): low pure productivity firms choose domestic sourcing and no R&D, medium pure productivity firms choose domestic sourcing with R&D, and high pure productivity firms choose foreign sourcing with R&D. However, in stage 3 after the potential has been realized, given the fixed cost in R&D, some firms with bad draws of R&D potential will forego the sunk entry cost and not invest in R&D at all, including firms that committed to foreign sourcing in stage 2. Therefore, we will see that some foreign sourcing firms do not invest in R&D given a bad draw, and some domestic sourcing firms invest heavily in R&D because of a good draw. Nonetheless, the threshold R&D potential below which a firm does not invest is higher in domestic sourcing firms than in foreign sourcing firms, as foreign sourcing implies higher pure productivity and lower marginal cost, rendering the firm easier to overcome the R&D fixed cost. This lower threshold produces the result of higher extensive and intensive margin of R&D among foreign sourcing firms, just as demonstrated in data.

foreign sourcing firms that only engage in internal R&D, but have lower overall productivity.

There are other potential ways to incorporate R&D into a heterogeneous firm model. A more intuitive approach would be to add the other dimension of heterogeneity, R&D potential, at the beginning. Firms only pay the market entry cost once and find out both their productivity and R&D potential at the same time. Their choices of sourcing destination and R&D will be based on these two parameters. It is straightforward to prove that the four combinations of sourcing/R&D couplets will all exist in equilibrium: firms with low productivity and low R&D potential choose domestic without R&D; firms with low productivity and high potential choose domestic with R&D; firms with high productivity and low potential choose foreign without R&D and firms with high productivity and high potential choose foreign with R&D. However, there is a huge caveat of using this approach compared to this paper. On average, one can prove that domestic firms without R&D have higher productivity than domestic firms without R&D. Foreign sourcing firms that do not engage in R&D will also have higher productivity than foreign sourcing firms with R&D. These implications of this approach are neither intuitive nor supported by data. In my two-stage setup, all firms have the same expectation of R&D potential draw at stage 1, and their sorting patterns are based on productivity alone. This way, in stage 2 after realizing the potential and making R&D choices, the firms still follow the empirical pattern where R&D firms are more productive (Ito and Tanaka (2013)). Therefore, I choose the two-stage setup in this paper as the theoretical basis of analysis. I will discuss the alternative set-up in detail in the next section.

The model in my paper builds on an extensive theoretical literature on international trade for heterogeneous firms. The mechanism for market entry works similarly as Antras and Helpman (2004) in that firms need to pay a fixed cost to start sourcing from abroad, which has the marginal cost advantage of lower labor cost per unit. The difference in this paper is that firms assemble an infinitely-dimensional bundle of inputs into differentiated final products. The model bears a resemblance to Eaton and Kortum (2002) and Tintelnot (2014) in that the location of each input is optimally chosen by a firm depending on the characteristics of different locations. Most notably, this paper draws on the insight of Antras *et al.* (2014) (AFT), where a firm's decision to source abroad increases its 'sourcing capacity' and positively impacts its revenue through the cost function. Given the data available, my paper simplifies the AFT model of multi-country sourcing into just two sourcing destinations: domestic and foreign. The main departure of my model is the inclusion of productivity enhancing R&D investment. With this additional dimension of choice by the firm, the overall productivity is no longer non-decreasing in the sourcing capacity - an important result in the AFT paper. However, I will show that the pre-R&D pure productivity behaves as the AFT model predicts and is increasing in sourcing capacity.

There is a large body of literature documenting the impact of technology on a firm's internationalization decisions. In Acemoglu *et al.* (2006), the proximity of firms to the technology frontier plays a crucial role, where the closer a firm is to the frontier, the stronger is the incentive to outsource production to concentrate on R&D. Naghavi and Ottaviano (2010) emphasizes on the complementarity between outsourcing and R&D. But this strand of literature is very different both in its model environment and goals. The closest papers that incorporate R&D in the heterogeneous firm model are Bustos (2011) and Ito and Tanaka (2013). However, technology in these papers is a simple binary choice: low vs. high technology in Bustos (2011), and internal vs. external R&D in Ito and Tanaka (2013). Although this simplification produces more tractable equilibrium results, the ability to analyze the intensive margin of R&D is compromised. Furthermore, these models cannot explain the counter-intuitive non-monotonous relationship between a firm's productivity and spending on R&D, as observed in data. Rodríguez-Clare (2010) also adopts the Eaton and Kortum (2002) model in analyzing offshoring and technology in a two-country world but has a very different definition of technology. To my knowledge, my model is the first to be flexible enough to accommodate both the intensive and extensive choices of R&D in a firm's internationalization decisions, and at the same time yield predictions that are testable in data.

Empirically, I test the model using the unbalanced panel survey data from ESEE on Spanish manufacturing firms. The data contains information on a firm's sourcing destinations: domestic, foreign, or both. It also has information on the firm's R&D activities. I first check whether the sorting pattern implied by the model is consistent with the data. The model predicts that firms sort into the following four groups that are increasing in pure productivity: domestic sourcing without R&D, domestic sourcing with R&D, foreign sourcing without R&D and foreign sourcing with R&D. I construct the pure productivity measure using an adjusted Olley-Pakes method that controls for R&D spending. By estimating productivity premia of different combinations of sourcing and R&D strategies, I show that the sorting pattern implied by the model is generally consistent with the empirical data. More importantly, the model produces clear predictions of complementarity between foreign sourcing and R&D: relative to domestic sourcing firms, there is a larger share of foreign sourcing firms that engage in R&D (the extensive margin); and among the R&D firms, foreign sourcing ones invest more heavily (the intensive margin). I test the complementarity between foreign sourcing and R&D using an instrumental variable approach. The results support complementarity between foreign sourcing and R&D on both the extensive and intensive margin, and the causality running from foreign sourcing to R&D can be established on both margins, although the extensive margin IV estimates are more significant.

The remainder of the paper is structured as follows. I describe the theoretical model in section 2 and derive testable predictions. In section 3 I describe the data set and initial statistics. Section 4 presents the empirical strategy. Section 5 concludes.

1.2 Model Framework

1.2.1 Preference and Technology

In a two-country world, domestic consumers have standard CES preferences over differentiated varieties:

$$U = \left(\int_{\iota \in \Omega_i} q(\iota)^{\frac{\sigma-1}{\sigma}} d\iota \right)^{\frac{\sigma}{\sigma-1}}, \quad \sigma > 1 \tag{1.1}$$

where Ω_i denotes the set of varieties available to consumers domestically. For simplicity, assume domestic firms (in country i) only serve domestic consumers, but can source their inputs from foreign suppliers (in country j). The preference yields the usual demand equation with aggregate spending on manufacturing goods E_i, price index P_i and price for variety $p_i(\iota)$:

$$q_i(\iota) = E_i P_i^{\sigma-1} p_i(\iota)^{-\sigma} \tag{1.2}$$

As I am only concerned with the domestic market for final goods, I will abuse the notation and skip the i subscript on domestic macro variables. Similar to Antras *et al.* (2014), domestic country i has a measure N of final good producers in a market characterized by monopolistic competition and free entry. Each firm/producer produces a single differentiated good variety. The final good is assembled from a measure 1 of intermediate inputs indexed by $\mu \in [0,1]$,which have to be sourced. The intermediate inputs are imperfectly substitutable with each other with a constant elasticity of substitution ρ. Each intermediate input is produced by the only production factor in the economy - labor, which has domestic wage w_i and foreign wage w_j.

Firms are characterized by their heterogeneous pure productivity ψ, which will be drawn from a cumulative distribution $G_1(\psi)$ a la Melitz (2003). They will need to pay a fixed cost f_e to learn their productivity draw, but will have full knowledge of their pure productivity levels when they make sourcing and R&D decisions. They have the option to participate in R&D after sinking a research cost, f_p, to find out their R&D potential p_z. If they decide to carry out R&D investment, the amount of R&D spending, z, will directly augment firm's productivity ψ, along with the potential p_z. Following Antras *et al.* (2014), a firm ψ will need $\kappa_k(\mu, \psi)$ units of labor to produce input μ in country k, where $\mu \in [0,1]$ and $k \in i, j$. The supplier market is competitive both domestically and foreign, so $\kappa_k(\mu, \psi) w_k$ is the unit cost of inputs paid for input μ in country k. An usual iceberg trade cost τ_k will be applied to the marginal cost as well, where $\tau_k = 1$ if $k = i$ and $\tau_k = \tau$ if $k = j$. The marginal cost function for a domestic firm is then given by

If there is R&D

$$c_z(\psi, k(\mu)) = \frac{1}{\psi p_z z}\left(\int_0^1 \left(\tau_k(\mu)\kappa_{k(\mu)}(\mu,\psi)w_{k(\mu)}\right)^{1-\rho} d\mu\right)^{1/(1-\rho)} \tag{1.3}$$

If there is no R&D

$$c_{-z}(\psi, k(\mu)) = \frac{1}{\psi}\left(\int_0^1 \left(\tau_k(\mu)\kappa_{k(\mu)}(\mu,\psi)w_{k(\mu)}\right)^{1-\rho} d\mu\right)^{1/(1-\rho)} \tag{1.4}$$

Following Eaton and Kortum (2002) and Antras, Fort and Tintelnot (2014), the intermediate input efficiencies $1/\kappa_k(\mu,\psi)$ are modeled as the realization of a random variable that is assumed to be independent across inputs and locations. In particular, for a domestic firm, the inverse of the unit labor requirement, $1/\kappa_k(\mu,\psi)$, is drawn from the extreme value Frechet distribution

$$G_3(\kappa_k) = Pr\Big(\kappa_k(\mu,\psi) \geq \kappa\Big) = e^{-T_k\kappa^\theta}, \quad T_k > 0 \tag{1.5}$$

T_k can be interpreted as the state of technology in country k where a higher T_k implies that the efficiency draws are likely to be better. θ denotes the degree of variability of draws, hence with lower θ, comparative advantage is stronger within the range of inputs across countries. Firms will learn the vector of input efficiencies for domestic sourcing, $\{\kappa_i(\mu,\psi)\}_{\mu=0}^{1}$, without incurring any cost. However, to learn this vector for foreign sourcing, $\{\kappa_j(\mu,\psi)\}_{\mu=0}^{1}$, a firm will need to pay a fixed cost f_j, which can be interpreted as the overhead research cost to learn about foreign suppliers and technology environment. This fixed cost structure is similar to the global sourcing literature as in Antras and Helpman (2004), but I am only concerned with differences caused by sourcing locations and do not consider different organizational forms at this point.

1.2.2 Sourcing and R&D Choices

I will first give a quick revision of the stages of firms' decision game as outlined in the introduction. In stage 1, given free entry, a firm can pay a fixed entry cost f_e to learn its pure pre-R&D productivity, ψ. Upon observing the pure productivity, low productivity firms choose to exit the market. In stage 2, surviving firms decide on whether to pay the entry cost f_p (in other words, the extensive margin of R&D) to learn its R&D potential, and also commit to a sourcing strategy between domestic or foreign. Note that the firms that chose foreign sourcing will also source domestically for a portion of the inputs. The share of foreign vs. domestically sourced inputs will depend on the parameters in the input efficiency distribution $G_3(\kappa_k)$, as well as the wages w_k and iceberg trade costs τ. Firms choosing to source from abroad will pay a one-time fixed cost f_j, and the commitment cannot be revoked in later stages. In stage 3, firms have already committed to a sourcing strategy and whether to learn its R&D potential. Those that paid the entry cost f_p will draw its potential p_z from distribution $G_2(p_z)$ with support in $(0, \infty)$. Observing this draw, low potential firms will not engage in R&D, and the entry cost is sunk. High potential firms engage in R&D by paying a fixed cost f_z, and a variable cost $C(z)$, which has the usual properties $C'(z) > 0$ and $C''(z) > 0$ (in other words, the intensive margin of R&D). In the last stage, production begins and profit is realized.

Given the above stages, firms' optimal problem can be solved backward. First, I derive a firm's intensive R&D choices conditional on a chosen sourcing strategy. Then, I analysis the optimal sourcing strategy and extensive R&D choices in stage 2.

Drawing on the results of Antras *et al.* (2014), consider a firm that has paid all relevant fixed costs and has access to intermediate inputs both domestically and foreign. For each input μ, the firm will choose between foreign and domestic that yields the lowest marginal cost. Or $k(\mu) \in \{i, j\}$ that solves $min\{\kappa_i(\mu, \psi)w_i, \kappa_j(\mu, \psi)w_j\tau\}$. The properties of Frechet distribution in equation (5) will allow us to solve for the share of inputs sourced from domestic and foreign suppliers. Specifically, the share of inputs purchased domestically is given by:

$$\chi_{ik}(\psi) = \frac{T_i w_i^{-\theta}}{\Theta_k(\psi)}, \quad k \in \{i, j\} \tag{1.6}$$

where

$$\Theta_i \equiv T_i w_i^{-\theta}, \quad \Theta_j \equiv T_i w_i^{-\theta} + \tau T_j w_j^{-\theta}, \ and \ \ T_k > 0, \ \ \theta > 1 \tag{1.7}$$

In the above expressions, the first subscript under χ refers to the country from which the share of inputs is sourced. The second subscript under χ denotes the overall sourcing strategy, where i means domestic sourcing and j foreign sourcing. Note that for a domestic sourcing firm, the share of domestic inputs purchased is naturally 1, or $\chi_{ii}(\psi) = 1$. Θ_k captures the sourcing capacity of a firm choosing sourcing location k. A foreign sourcing firm will also purchase a share of its inputs domestically, given by $\chi_{ij}(\psi)$. This is in accordance with what we observe in data, where most of the firms either only source domestically or source from both domestic and foreign suppliers. Firms that only source from abroad do not exist in our model framework, and they only represent a tiny portion ($< 2\%$) of all the firms in our sample. It is also clear from equation (7) that a foreign sourcing firm has larger sourcing capacities than a domestic sourcing one, or $\Theta_j > \Theta_i$.

Using the equations in (3) and (4), we can derive the overall cost function as

$$c_z(\psi, k) = \frac{1}{\psi p_z z}\Big(\gamma \Theta_k(\psi)\Big)^{-1/\theta} \tag{1.8}$$

$$c_{-z}(\psi, k) = \frac{1}{\psi}\Big(\gamma \Theta_k(\psi)\Big)^{-1/\theta} \tag{1.9}$$

with $\gamma = \left[\Gamma(\frac{\theta+1-\rho}{\theta})\right]^{\theta/(1-\rho)}$ and Γ the gamma function. Ignoring the fixed costs for now, we can combine the demand equation (2) with the cost functions above to express the variable profit function for a firm choosing sourcing strategy $\Theta_k(\psi)$ and R&D investment level z as

$$\pi_k(\psi, p_z) = \big(\psi p_z z\big)^{\sigma-1}\Big(\gamma \Theta_k(\psi)\Big)^{(\sigma-1)/\theta} B - w_i C(z) \tag{1.10}$$

where

$$B = \frac{1}{\sigma}\Big(\frac{\sigma}{\sigma-1}\Big)^{1-\sigma} E P^{\sigma-1} \tag{1.11}$$

Let $y = z^{\sigma-1}$ be a monotonic transformation of z and $C(y) = y^a$. I assume that a is sufficiently large that $a > 1$ and $(\sigma-1)a > 1$, so $C(z)$ and $C(y)$ both satisfy the usual properties of cost function $C' > 1$, & $C'' > 1$, i.e. increase marginal cost.[3] The optimal level of R&D investment can be solved by taking the FOC w.r.t. y as

$$y = \left(\frac{p_z^{\sigma-1} M_k(\psi)}{a w_i} \right)^{1/(\alpha-1)} \tag{1.12}$$

where

$$M_k(\psi) = \psi^{\sigma-1} \big(\gamma \Theta_k\big)^{(\sigma-1)/\theta} B \tag{1.13}$$

The subscript $k \in \{i, j\}$ denotes whether the firm is sourcing domestically or abroad. Substituting the expressions in (12) and (13) into (10) and after some manipulation, we have

$$\pi_k(\psi, p_z) = \big(a-1\big) \frac{1}{w_i^{1/(a-1)}} \left(\frac{p_z^{\sigma-1} M_k(\psi)}{a} \right)^{a/(a-1)} \tag{1.14}$$

1.2.3 Optimal R&D and Sourcing Strategy

Firms in stage 2 can observe their pure productivity, but is yet to learn their potential for R&D. At the same time, they need to decide whether to pay the fixed cost to source from abroad. Having full knowledge of future profitability for a given level of R&D potential as in equation (14), firms will compare the different combinations of sourcing mode with R&D choices and decide on the one that yields the highest overall profit. I will derive the four possible scenarios from which a firm can choose from.

First, a firm can choose to source only from domestic suppliers and not pay the entry cost for R&D. Using equations (9) and (10), the overall profit accounting for all fixed costs is

$$\Pi_{i,-p_z}(\psi) = M_i(\psi) = \psi^{\sigma-1} \Big(\gamma \Theta_i\Big)^{(\sigma-1)/\theta} B \tag{1.15}$$

Second, a firm can choose domestic sourcing while pay the entry cost to learn its potential for R&D. Using equation (14), the firm will deduce its profitability conditional on

[3]Without $a > 1$, as we shall see, the solution for the optimal profit function will be decreasing in productivity. This undesirable and unrealistic scenario is ruled out by this assumption.

a given draw of the potential. But as the potential is unrealized at this point, it will use expected profit for comparison as given below

$$
\begin{aligned}
&E\Big(\Pi_{i,p_z}(\psi)\Big) = E\Big(\pi_i(\psi, p_z) - w_i(f_p + f_z)\Big) \\
&= E\left(p_z^{(\sigma-1)a/(a-1)}(a-1)\frac{1}{w_i^{1/(a-1)}}\left(\frac{M_i(\psi)}{a}\right)^{a/(a-1)} - w_i(f_p + f_z)\right) \qquad (1.16)
\end{aligned}
$$

Foreign sourcing firms that choose not to learn its R&D potential will have their profit as the following expression, accounting for the fixed cost f_j to learn about the efficiency of foreign suppliers

$$
\Pi_{j,-p_z}(\psi) = M_j(\psi) - w_i f_j = \psi^{\sigma-1}\Big(\gamma\Theta_j\Big)^{(\sigma-1)/\theta} B - w_i f_j \qquad (1.17)
$$

Lastly, there are foreign sourcing firms that engage in R&D. Their profit is as follows

$$
\begin{aligned}
&E\Big(\Pi_{j,p_z}(\psi)\Big) = E\Big(\pi_j(\psi, p_z) - w_i(f_p + f_z + f_j)\Big) \\
&= E\left(p_z^{(\sigma-1)a/(a-1)}(a-1)\frac{1}{w_i^{1/(a-1)}}\left(\frac{M_j(\psi)}{a}\right)^{a/(a-1)} - w_i(f_p + f_z + f_j)\right) \qquad (1.18)
\end{aligned}
$$

At this stage, the characterization of the sorting pattern is reminiscent of that of Bustos (2011). The main difference in my model is the inclusion of intensive margin of R&D instead of the binary choice of low or high R&D. As a result, the profit graph of R&D firms will be a power function of $\psi^{\sigma-1}$ instead of a linear function as in Bustos (2011). Nevertheless, the main qualitative results do not change. To analyze the sorting patterns, it is useful to define the cut-off thresholds of different sourcing/R&D couplets that are available to firms. Using equations (15) - (18) above:

Let $\psi_{i,-p_z}^{j,-p_z}$ be the threshold at which a no R&D firm switches from domestic to foreign sourcing, or $\Pi_{i,-p_z}(\psi_{i,-p_z}^{j,-p_z}) = \Pi_{j,-p_z}(\psi_{i,-p_z}^{j,-p_z})$.

Let ψ_{i,p_z}^{j,p_z} be the threshold at which an R&D firm switches from domestic to foreign sourcing, or $E\Big(\Pi_{i,p_z}(\psi_{i,p_z}^{j,p_z})\Big) = E\Big(\Pi_{j,p_z}(\psi_{i,p_z}^{j,p_z})\Big)$.

Let $\psi_{i,-p_z}^{i,p_z}$ be the threshold at which a domestic firm switches from no R&D to R&D, or

$\Pi_{i,-p_z}(\psi^{i,p_z}_{i,-p_z}) = E\Big(\Pi_{i,p_z}(\psi^{i,p_z}_{i,-p_z})\Big)$.

Let $\psi^{j,p_z}_{j,-p_z}$ be the threshold at which a foreign sourcing firm switches from no R&D to R&D, or $\Pi_{j,-p_z}(\psi^{j,p_z}_{j,-p_z}) = E\Big(\Pi_{j,p_z}(\psi^{j,p_z}_{j,-p_z})\Big)$.

Some propositions can first be established that will help in characterizing the sorting pattern. Namely

Proposition 1. *The threshold of switching from domestic to foreign sourcing is higher for non-R&D firms than R&D firms, i.e.* $\psi^{j,-p_z}_{i,-p_z} > \psi^{j,p_z}_{i,p_z}$.[4] *The threshold of switching from non-R&D to R&D is higher for domestic sourcing firms than foreign sourcing firms, i. e.* $\psi^{i,p_z}_{i,-p_z} > \psi^{j,p_z}_{j,-p_z}$.

In the appendices I will give a brief proof of the above proposition. Note that at this stage, what I refer to as R&D firms are actually firms that choose to sink the entry cost and learn about their R&D potential. Intuitively, both R&D and foreign sourcing reduce a firm's variable cost by incurring a fixed cost. Firms that can better utilize lower marginal cost will be more likely to adopt R&D or start sourcing from abroad. A firm that already engages in R&D or a firm that already sources from abroad enjoys lower cost function as in (8). These firms benefit more from further strategies of cost-cutting, and will have lower productivity thresholds to switch to a more 'advanced' strategy. Using Proposition 1, we have the following related results.

Lemma 1. *For all firms with pure productivity* ψ*, 1) if* $\psi > \psi^{j,-p_z}_{i,-p_z}$*, foreign sourcing is always used; 2) if* $\psi < \psi^{j,p_z}_{i,p_z}$*, domestic sourcing is the only sourcing strategy; 3) if* $\psi > \psi^{i,p_z}_{i,-p_z}$*, R&D potential is always learnt; 4) if* $\psi < \psi^{j,p_z}_{j,-p_z}$*, R&D potential is never learnt.*

The proof is straightforward and will be omitted here. Armed with these results, we will be able to characterize the sorting patterns of the firms in the following proposition.

Proposition 2. *In stage 2, lowest* ψ *firms always sort into domestic sourcing and no R&D. Highest* ψ *firms always choose foreign sourcing and R&D. 1) If* $\psi^{j,p_z}_{i,p_z} > \psi^{i,p_z}_{i,-p_z}$*, medium* ψ *firms will choose*

[4] As the parameters in the equations are not yet calibrated, the inequality holds under reasonable restrictions, for example, when the assumption that foreign sourcing fixed cost is sufficiently high. This assumption will be further explained in the appendices

domestic sourcing and R&D; 2) If $\psi^{j,p_z}_{j,-p_z} > \psi^{j,-p_z}_{i,-p_z}$, medium ψ firms will choose foreign sourcing and no R&D; 3) for all other scenarios, only {domestic, no R&D} and {foreign, R&D} will remain in equilibrium. The 4 categories of sourcing/R&D couplets will never be all present in equilibrium.

I give a brief proof in the appendices. The main take away is that the neat hierarchical sorting pattern seeing in Antras and Helpman (2004) is not repeated here as at least one of the sourcing-R&D combination will be dominated in equilibrium. Given what we observe in data, I will assume $\psi^{j,p_z}_{i,p_z} > \psi^{i,p_z}_{i,-p_z}$ for this paper, i.e. the three categories firm sort into will be domestic sourcing without R&D, domestic sourcing with R&D and foreign sourcing with R&D. Intuitively, this scenario happens when it is easier for a domestic firm to switch from no R&D to R&D than for a R&D firm to switch from domestic sourcing to foreign sourcing. It is more likely to be true when the fixed cost of foreign sourcing is large relative to the fixed cost of learning R&D potential, which is a reasonable assumption. The equilibrium is presented graphically in Figure 1.1.

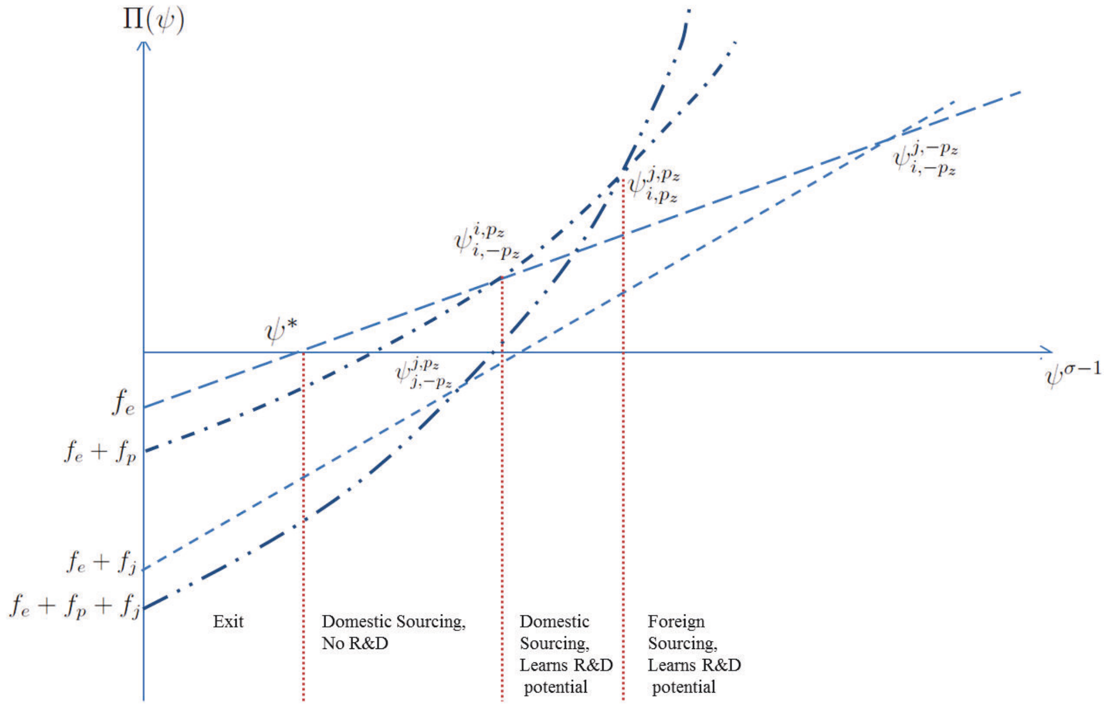


Figure 1.1: *Pure Productivity, Sourcing and R&D Choices*

Note that in Figure 1.1, f_j is significantly larger than f_p as assumed, which results in foreign sourcing and no R&D being dominated as in Proposition 2. At this stage, the firms sunk the relevant fixed costs and commit to a sourcing strategy. Nevertheless, they have another choice to make in the next stage which will determine the eventual R&D investment carried out by them.

In stage 3, for those firms that did not learn their R&D potential, they will stay on the strategy chosen in the last stage and start producing. For those that did learn their potential, they now decide if they would start investing in R&D, which will incur a fixed cost f_z as outlined before, as well as a variable cost $C(y),\ y = z^{\sigma-1}$ that is increasing marginally w.r.t. y. These firms will commit to the sourcing strategy, which can be interpreted as relationships fostered and contracts signed with suppliers in stage 2. But they can choose not to invest in R&D at all if their potential draw is too low to justify sinking the research fixed cost. Given realized potential, a firm that chose domestic sourcing and R&D in the last stage will start investing in R&D if

$$\Pi_{i,z}(\psi, p_z) > \Pi_{i,-z}(\psi)$$
$$\Rightarrow p_z^{(\sigma-1)a/(a-1)}(a-1)\frac{1}{w_i^{1/(a-1)}}\left(\frac{M_i(\psi)}{a}\right)^{a/(a-1)} - w_i f_z > M_i(\psi) \tag{1.19}$$

Note that there are two variables in equation (19), the potential p_z and the pure productivity ψ. As a result, the cut-off threshold to engage in R&D is not so straightforward. Firms with higher ψ will find the threshold lower, as p_z directly augments ψ in the cost function.

Let $p_i^*(\psi) = F_i(\psi)$ be the transformation of equality in (19) such that the threshold potential p_i^* - below which a domestic firm with sunk R&D entry cost will not engage in actual R&D - is a function of ψ. Using the distribution of p_z, the likelihood of a firm ψ in the range $[\psi_{i,-p_z}^{i,p_z}, \psi_{i,p_z}^{j,p_z}]$ to not engage in R&D is

$$Pr\Big(p_z(\psi) < p_i^*(\psi)\Big) = 1 - G_2\Big(F_i(\psi)\Big) \tag{1.20}$$

and the total share of firms in the same range not engaging in R&D is

$$\int_{\psi_{i,-p_z}^{i,p_z}}^{\psi_{i,p_z}^{j,p_z}} 1 - G_2\Big(F_i(\psi)\Big) dG_1(\psi) \tag{1.21}$$

Similarly, the total share of firms that chose foreign sourcing with R&D entry in stage 2 and switch to no R&D in stage 3 is

$$\int_{\psi_{i,p_z}^{j,p_z}}^{\infty} 1 - G_2\Big(F_j(\psi)\Big) dG_1(\psi) \tag{1.22}$$

where $p_j^*(\psi) = F_j(\psi)$ is the threshold potential draw that is a transformation of the equation

$$\Pi_{j,z}(\psi, p_z) > \Pi_{j,-z}(\psi)$$

$$\Rightarrow p_z^{(\sigma-1)a/(a-1)}(a-1)\frac{1}{w_i^{1/(a-1)}}\left(\frac{M_j(\psi)}{a}\right)^{a/(a-1)} - w_i f_z > M_j(\psi) \tag{1.23}$$

Proposition 3. *Foreign sourcing and R&D are complementary both on the extensive margin and the intensive margin. Specifically, on the extensive margin, a larger share of foreign sourcing firms engage in R&D than domestic sourcing ones. On the intensive margin, foreign sourcing firms spend more in R&D on average than domestic sourcing firms.*

A brief proof of the above proposition is as follows. Compare (19) and (23) together with the fact that $M_j(\psi) > M_i(\psi)$, we have $p_i^*(\psi) > p_j^*(\psi)$ for a given level of ψ. Also, the range of ψ is lower for $F_i(\psi)$ than that for $F_j(\psi)$ and F_i, F_j are both decreasing functions of ψ. It follows from equations (21) and (22) that the share of domestic firms that switch in stage 3 to no R&D is greater than the share of foreign firms that do so, for a reasonably shaped distribution of $G_1(\psi)$.[5] Furthermore, as firms in the range $\psi^* < \psi < \psi_{i,-p_z}^{i,p_z}$ are also domestic firms without R&D, the total share of domestic firms that engage in R&D is even smaller for domestic sourcing firms than foreign sourcing ones. Intuitively, firms that chose foreign sourcing in stage 2 already enjoy high pure productivity as well as a lower marginal cost from greater sourcing capacity, scaling up the benefit of investing in R&D. It is thus far

[5]The only scenario where this could be false is when the distribution $G_1(\psi)$ is highly skewed and concentrate around ψ_{i,p_z}^{j,p_z}, so that a high share of the foreign sourcing firms will switch to no R&D while a high share of domestic firms will stay in R&D. I omit this scenario in the analysis.

more likely for them to overcome the fixed cost of R&D compared to domestic firms.

The intensive margin advantage for foreign sourcing firms can be seen from equation (12), and is mostly driven by both greater sourcing capacity Θ_j and higher pure productivity ψ in $M_j(\psi)$.[6] Although for a domestic firm that draw a really high level of p_z compared to a foreign firm with a very bad draw, it is possible that the difference in p_z will more than offset lower ψ and sourcing capacity, inducing the domestic firm to invest more in R&D and have higher overall productivity, given by $\psi p_z z$.

1.2.4 General Equilibrium

To solve for the industry equilibrium, I will first lay out the exit condition and the free entry condition. Exit productivity is pinned down by the marginal firm at the cut-off between exiting production and domestic sourcing with no R&D.

$$\Pi_{i,-p_z}(\psi^*) = \psi^{*\sigma-1}\Big(\gamma\Theta_i\Big)^{(\sigma-1)/\theta} B = f_e \tag{1.24}$$

which will yield a solution for the exit productivity as a function of market demand: $\psi^*(B)$. The free entry condition requires that the final good producer only observes its pure productivity draw after incurring the fixed cost, so the entry cost must equal total expected profit. Note that it is more nuanced in this paper than the canonical model in that the draw for R&D potential is also unrealized, which must be taken in expectation. The potential draw, in turn, will affect if the firm decides to switch to no R&D. Given my previous analysis on the sorting patterns, the free entry condition can be expressed as

$$\int_{\psi^*}^{\psi^{i,p_z}_{i,-p_z}} \Big(\Pi_{i,-p_z}(\psi)\Big) dG_1(\psi) +$$

$$\int_{\psi^{i,p_z}_{i,-p_z}}^{\psi^{j,p_z}_{i,p_z}} \Bigg[\int_0^{p_i^*(\psi)} \Big(M_i(\psi) - w_i f_p\Big) dG_2(p_z) + \int_{p_i^*(\psi)}^{\infty} \Big(\pi_i(\psi, p_z) - w_i(f_p + f_z)\Big) dG_2(p_z)\Bigg] dG_1(\psi) +$$

[6] It is noteworthy, however, that since foreign sourcing firms have lower threshold p_z draw to invest in R&D, on average p_z can be lower for foreign firms than domestic firms. It is assumed that the negative effect coming from lower average p_z does not offset the positive effects from higher Π_j and higher ψ in general.

$$\int_{\psi_{i,p_z}^{j,p_z}}^{\infty} \left[\int_0^{p_j^*(\psi)} \Big(M_j(\psi) - w_i(f_p + f_j) \Big) dG_2(p_z) + \int_{p_j^*(\psi)}^{\infty} \Big(\pi_j(\psi, p_z) - w_i(f_p + f_z + f_j) \Big) dG_2(p_z) \right] dG_1(\psi) = w_i f_e \tag{1.25}$$

Combining the above expression with the definition for the terms in (13) - (18), one can pin down a unique solution of the market demand B.

To solve for the size of the final good producers N, one can follow Antras, Fort and Tintelnot (2014) in assuming a non-manufacturing sector that is perfectly competitive and large enough to pin down the wage w_i, and make use of the constant share of spending for manufacturing goods as well as CES properties in pricing. I will omit the derivations here.

1.2.5 Discussions of Alternative Model Set-ups

The model presented in the previous sections introduces a timing assumption that is novel in the literature. The mechanism breaks the R&D decision-making into two sequential steps: firms sink upfront due diligence costs to find out their research potential in the first step (stage 2 in the timing of events), then decide on the degree of involvement in R&D or even dropping out altogether in the second step (stage 3 in the timing of events). To better understand the contexts and motivations for using such a model set-up, it is informative to discuss alternative model mechanisms where the assumptions are relaxed.

First, consider a similar framework without the two-stage timing restriction. Firms are not heterogeneous in their research potential and after observing its productivity, given that it does not exit the market, decide at the same time their sourcing and R&D strategies. The mechanism works like the second stage of the model in this paper and is reminiscent of the Bustos (2011) set-up in the literature. The main drawback of relaxing the timing restriction can be best explained by Proposition 2 in the last section, i.e. the four sourcing/R&D combinations cannot co-exist in the equilibrium. Depending on fixed costs and other parameters, at most three combinations: domestic sourcing without R&D, foreign sourcing with R&D and either domestic sourcing with R&D or foreign sourcing without R&D will remain in equilibrium. As Table 1.1 demonstrates, this is counter-factual to empirical patterns in the data where each of the four types makes up a significant proportion of all firms. Furthermore, an important goal of this paper is to explore the complementarity between foreign sourcing and the extensive margin of R&D. If domestic sourcing with R&D is dominated in the equilibrium, the extensive margin of R&D for domestic sourcing firms becomes zero. On the other hand, if foreign sourcing without R&D is dominated in the equilibrium, the extensive margin of R&D for foreign sourcing firms becomes 100 percent. In both cases, the complementarity becomes trivial and leaves no room for testable predictions.

Let us then consider an alternative specification of the model that accommodates all four types of firms in the equilibrium but without relying on a timing restriction. I allow the firms to be heterogeneous in two dimensions: R&D potential and productivity. When firms pay the fixed entry cost, they learn their productivity and research potential at the same time. Observing these two parameters, firms then make sourcing and R&D decisions concurrently. In this specification, all four types of firms can co-exist in the equilibrium: low productivity/low potential firms choose domestic sourcing without R&D; low productivity/high potential firms choose domestic sourcing with R&D; high productivity/low potential firms choose foreign sourcing without R&D and high productivity/high potential firms choose foreign sourcing with R&D. To analyze the distribution of firms in detail, recall Lemma 1 in the last section shows that there exists a lower threshold in productivity below which only domestic sourcing will be used, as well as an upper threshold in productivity above which only foreign sourcing will be used. Similarly, there is a lower threshold in R&D potential below which R&D will never be chosen, and an upper threshold in potential above which R&D will always be chosen. Using the above properties, the distribution of firms along the productivity-potential space is presented in Figure 1.2.

As illustrated in the figure, $\psi_{i,-p_z}^{j,-p_z}$ and $\psi_{i,-p_z}^{j,-p_z}$ are the switching thresholds from domestic to foreign sourcing for non-R&D and R&D firms respectively. Proposition 1 establishes their relative positions on the graph. Similarly, $p_{i,-p_z}^{i,p_z}$ and $p_{j,-p_z}^{j,p_z}$ are the switching thresholds

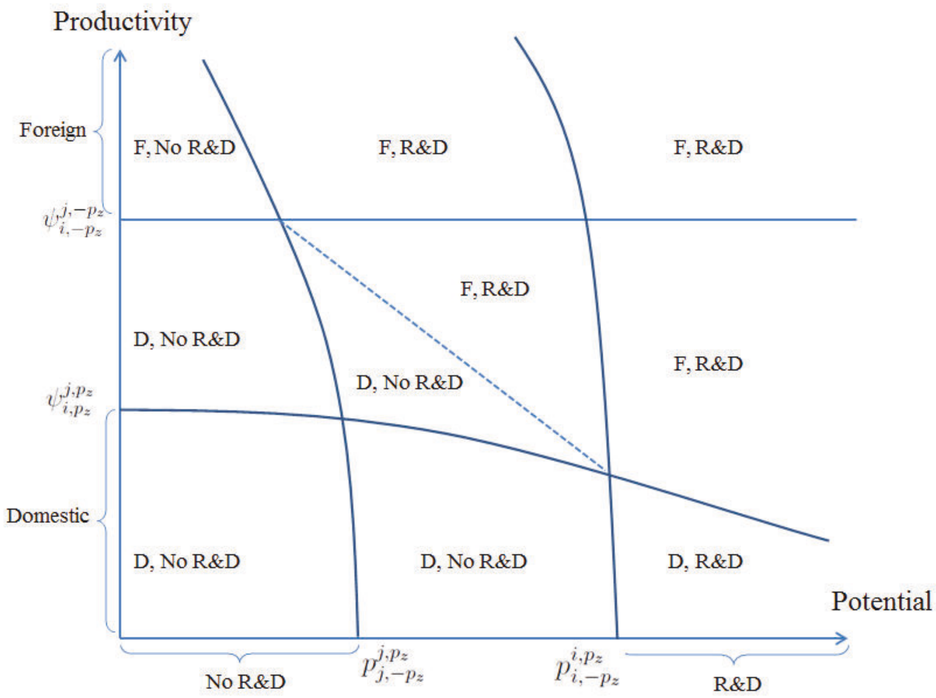


Figure 1.2: *Distribution of firms by Productivity and R&D Potential*

from non-R&D to R&D for domestic and foreign sourcing firms respectively.[7] Using the definition of the switching thresholds and results in Lemma 1, we can map the distribution of different sourcing/R&D types on the productivity-potential space.

It is immediately clear from Figure 1.2 that the equilibrium features all four sourcing/R&D combinations. However, there is a major drawback of using this framework. Assuming reasonable distributions of productivity and potential, Figure 1.2 demonstrates that among foreign sourcing firms, the ones that do not conduct R&D have higher productivity on average than the ones with R&D. The pattern is the same among domestic sourcing, where non-R&D firms on average are more productive than R&D firms. This implication of the model is again neither intuitive nor supported by data.

To understand the intuition behind this counter-factual model prediction, note that if a firm has an exceptionally good draw of R&D potential, R&D is so rewarding that it will

[7] $p^{i,p_z}_{i,-p_z}$ and $p^{j,p_z}_{j,-p_z}$ are simply the transformation of $\psi^{i,p_z}_{i,-p_z}$ and $\psi^{j,p_z}_{j,-p_z}$ from Proposition 1

want to invest in research. However, the same firm will need to have very low productivity to remain domestic, as with higher productivity, the mutually reinforcing effects of R&D and productivity will incentivize the firm to choose foreign sourcing instead. Similar logic applies to the foreign sourcing firms with no R&D - who has a really bad draw of research potential - and they need to have particularly high productivity to not choose domestic sourcing instead.

In summary, the main benefits of using the two-stage timing assumptions in this paper are threefold. First, it enables all four modes of sourcing/R&D combinations to exist in the equilibrium, which finds strong support in empirical data. Second, this set-up yields testable predictions of the complementarity between foreign sourcing and the extensive margin of R&D which is non-trivial compared to other model specifications. Third, the staggered timing of committing to discover R&D potential and committing to invest in R&D produces a productivity ranking of sourcing/R&D couplets that is consistent with both intuition and data.

1.3 Empirical Strategy

In this section, I test the predictions of the theoretical model above. First of all, The model yields a sorting pattern for firms based on their pure productivity and R&D potential as follows: the low productivity/low potential firms choose domestic sourcing without R&D; medium-low productivity/high potential firms choose domestic sourcing and R&D[8]; medium-high productivity/low potential firms sort into foreign sourcing without R&D[9]; high productivity/high potential firms choose foreign sourcing with R&D. Second, the model predicts that foreign sourcing firms are more likely to conduct R&D both on an

[8] While some of the firms paying for R&D entry cost in stage 1 end up dropping out in stage 2 given low potential draws, it is easy to see that the overall pure productivity is higher for domestic firms with R&D compared to those without.

[9] Again, these firms would have chosen to learn the R&D potential in stage 1, but drops out due to low potential draws. As pure productivity and potential reinforce each other in raising the profitability of a firm, on average these foreign sourcing firms without R&D have lower pure productivity than foreign firms with R&D at the end.

extensive margin (where a larger portion of foreign firms spend on R&D at all) and on an intensive margin (where among firms that spend on R&D, foreign sourcing ones spend relatively more than domestic ones). I test these predictions using firm-level data of Spanish manufacturing firms.

1.3.1 Data Description

For empirical analysis, I use the data from the annual business survey conducted by Fundacion SEPI. The survey ranges from 1992 to 2009 and covers about 2000 firms annually. All large firms (more than 200 employees) are invited to participate in the survey while about 5% of small firms (10-200 employees) are sampled randomly. This poses a clear caveat of over-representation of large firms, which I will try to control for in the empirical strategies.

Many previous studies have uncovered the link between sourcing strategies and productivity. Nunn and Trefler (2008) uses US firms' imports from foreign affiliates to test the predictions in Antras (2003) and Antras and Helpman (2004) and find that intra-firm trade increases in firms with more intensive headquarter services, or more skill and capital intensive. It is worth noting that using import data to proxy for sourcing could be imprecise as imports by a firm may not be used in intermediate production. Tomiura (2007) and Federico (2010) make use of similar survey data for Japanese and Italian firms, which precisely asks about firm's sourcing choices. They find that, indeed, more productive firms are more likely to source from abroad than domestically. There is also a growing literature emphasizing the relationship between R&D, productivity, and internationalization of firms. Ito and Tanaka (2013) uses Japanese survey data to show that higher productivity is associated with exporting as well as more R&D involvements. More notably, Bustos (2011) analyzes Argentina firm level survey data and constructed technology upgrading proxies based on spending in innovation-related activities. He shows that firms self-select into exporting and technology levels based on their productivity. There is, to the best of my knowledge, no previous studies analyzing the relationship between R&D and sourcing strategies, with particular emphasis on the intensive and extensive margins of R&D.

The main advantage of the data is its detailed firm-level information on sourcing decisions and research efforts, which are central to this paper. Firms participating in the survey answer direct questions on the type of sourcing they conduct. Not only do we have information on whether the inputs are sourced domestically or abroad, we also know if the inputs are procured from integrated upstream firms or through arms-length trade, much in the flavor of Antras and Helpman (2004). For my analysis, I will only focus on the domestic vs. foreign dimension of sourcing. A drawback of the data is that the sourcing information was only available from 2006 to 2009, rendering causal analysis using panel techniques difficult for such a short period. Nevertheless, the data from previous years could be used to construct productivity measures that take into consideration the entry and exit of firms a la Olley and Pakes (1996). Kohler and Smolka (2009) provide a detailed description of the data, emphasizing on the sourcing decisions of the firms.

The data set contains clear indicators of firms' R&D efforts. The notable ones are total staff employed in R&D and total expenditure in R&D on an annual basis. R&D expenditure is further split into external and internal R&D. Lai *et al.* (2009), Acemoglu *et al.* (2006), among many, explore the distinction between the two types of R&D and link them to firms' technology characteristics. For the major part of this paper, I do not differentiate between external and internal R&D. Instead, I focus on total R&D expenditure as the proxy for technology upgrading. The differentiation would provide an interesting area of extension nevertheless.

1.3.2 Pure Productivity Estimation and Summary Statistics

In the theoretical model, pure productivity is a key parameter assumed to be observed by the firm but is not directly observable by econometricians. As the sorting pattern depends crucially on pure productivity, I attempt to estimate the parameter with available data.

Given the detailed information on firm inputs and entry/exit choices, I use Olley and Pakes (1996) (OP) in constructing productivity measures that control for simultaneity bias and selection bias. However, using the canonical OP method comes with a caveat: the model is used to estimate total factor productivity in the absence of R&D. In order to obtain a proxy for the novel pure productivity measure, the contribution of R&D will need to be accounted for in the canonical estimation of total factor productivity. Representing the effect of R&D through a stock of knowledge capital accumulated over the years through R&D expenditure in the spirit of Griliches (1979), I estimate the following Cobb-Douglas production function:

$$\begin{aligned} y_{it} &= \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \beta_a a_{it} + \mu_{it} \\ \text{where} \quad \mu_{it} &= \omega_{it} + \epsilon_{it} \\ \text{and} \quad \omega_{it} &= \beta_r c_{it-1} + \psi_{it} \end{aligned} \tag{1.26}$$

where y_{it} is log output for firm i in period t; l_{it}, k_{it}, a_{it} and c_{it} are the log values of labor, capital, age and knowledge capital stock respectively; ω_{it} is the total factor productivity shock in the canonical OP framework, observed by the firm but not by the econometrician; ψ_{it} is the pure productivity of the firm and the interest of this paper.

Note that this specification is different from the original OP method in the incorporation of knowledge capital in total factor productivity. More importantly, I assume the following:

1. Capital investment by a firm, $i_{it} = f(k_{it}, a_{it}, \omega_{it})$ is a function of capital stock, age and total factor productivity, and is invertible in ω_{it}.

2. Total factor productivity is a function of pure productivity ψ_{it} and last period's knowledge capital c_{it-1}. It is assumed to take the form $\omega_{it} = \beta_r c_{it-1} + \psi_{it}$. This assumption could be relaxed to contain higher order terms of c_{it-1} too, as long as the knowledge capital stock is separable from core productivity.

3. Pure productivity ψ_{it} follows a first order Markov process.

The first assumption is the same as the original OP model, where Pakes (1994) provides an extensive proof. The second assumption provides the basis for this estimation method. The efficiency of a firm, or total factor productivity, takes a separable functional form over unobserved pure productivity and previous period's knowledge capital stock. In the production function, this is similar to having the stock of knowledge capital as one of the factors of production. However, given assumption 1, physical capital investment is still based on the overall efficiency, w_{it}, of the firm instead of the pure productivity. This also implies that pure productivity evolves independently from R&D and the stock of knowledge capital, which is quite strong. The third assumption departs from the original OP framework: instead of total factor productivity, it is the pure productivity that follows a stochastic process.

For the above-mentioned estimation to work, I need to first estimate the knowledge capital stock for each firm in the data set. Following the seminal Griliches (1979) paper, most studies in the literature use a simple perpetual inventory methodology to construct the knowledge capital stock from observed R&D expenditures. This method relies on at least two strong assumptions: the linearity of knowledge accumulation over the years, and the lack of complementarity between existing knowledge capital and R&D expenditure. As both assumptions are very strong, I instead use a variant of the knowledge capital model in assuming a law of motion of the Cobb-Douglas form $C_{it} = C_{it-1}^{\sigma}(1 + Z_{it-1})^{1-\sigma}$, where C_{it} is the knowledge capital stock for firm i in time t, and Z_{it} is the expenditure in R&D as before. In logarithm form, the law of motion becomes

$$c_{it} = \sigma c_{it-1} + (1 - \sigma) log(1 + Z_{it-1}) \tag{1.27}$$

As the data panel is unbalanced and there are gaps in firms' history of R&D expenditure when no R&D spending took place, the form $(1 + Z_{it})$ serves to ensure that the knowledge stock does not disappear after one year of zero spending. Note that the parameter σ effectively governs the depreciation of knowledge capital. Following Klette (1996), I use $\sigma = 0.8$ in this paper. With a constructed series of knowledge capital stock, the remaining steps in implementing this 'augmented' OP framework are detailed in the Appendices.

The results of pure productivity estimations and other summary statistics are presented in Table 1.2. I take relative pure productivity to industry average to facilitate comparison. Several observations are immediately noteworthy before further empirical analysis. For

Table 1.2: *Summary Statistics, Mean of Firms by Group*

Year	2007				2009			
Sourcing Modes	Domestic Only		Foreign Sourcing		Domestic Only		Foreign Sourcing	
R&D Choice	No RD	RD	No RD	RD	No RD	RD	No RD	RD
1. Number	440	149	278	374	268	121	203	307
2. % All Firms	35.5%	12.0%	22.4%	30.1%	29.8%	13.5%	22.6%	34.1%
3. Pure Prod.	95.95	100.90	100.38	105.09	95.21	100.15	100.41	104.55
4. R&D Intensity	-	0.017	-	0.019	-	0.021	-	0.024
5. Log(Size)	3.65	4.98	4.31	5.47	3.59	4.96	4.30	5.49
6. Log(Sales)	15.22	17.01	16.28	17.81	15.01	16.91	16.24	17.68
7. Elasticity σ	3.58	4.53	5.03	5.19	3.83	3.80	4.58	4.88

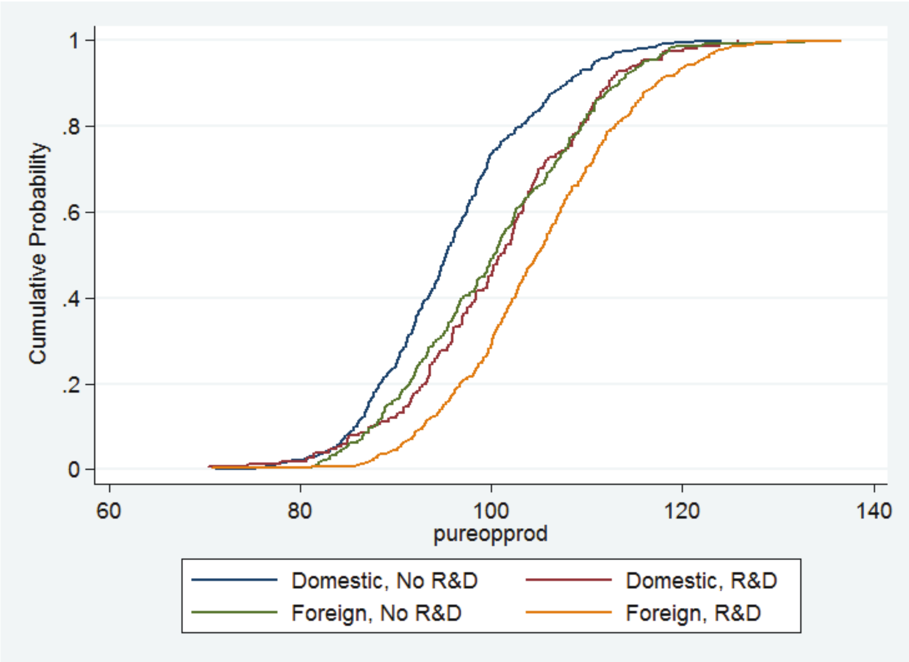
Notes 1. Firms that do not source at all represent $<$ 5% of the sample and are not included.
2. Foreign sourcing firms import part or all of their inputs abroad, but may engage in domestic sourcing at the same time. In fact only $<$ 2% of the sample firms source exclusively from abroad.
3. Productivity measures are Olley-Pakes relative pure productivity, where the industry average is 100.
4. R&D intensity is calculated as R&D spending divided by total sales.
5. Size refers to the total number of staff employed by the firm in the given year.
6. σ is calculated from price mark-up, and is restricted to firms with mark-up>1%.

example, in the year 2009 on line 2, it is clear that there are a much greater proportion of foreign sourcing firms engage in R&D (60.2%) than the proportion of domestic firms (31.1%), reaffirming the model prediction about the extensive margin of R&D. Line 4 shows that on average, the R&D intensity is higher for foreign sourcing firms (2.4% of sales) than domestic ones (2.1% of sales), echoing the model prediction about the intensive margin of R&D. Both results still hold rather emphatically for the year 2007 as well.

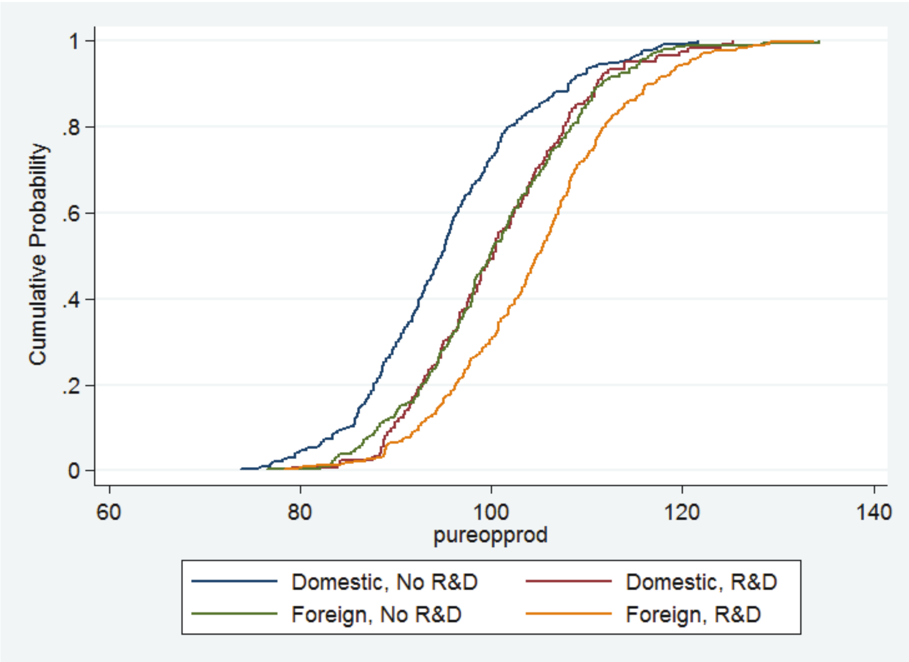
From line 3 we can see the emergence of a general sorting pattern. As the model predicted, R&D firms have higher pure productivity than non-R&D firms on average. The data in 2009 shows that this is true for both domestic sourcing firms (0.15% above industry average for R&D firms against 4.79% below for non-R&D firms) as well as foreign sourcing firms (4.55% above industry average for R&D firms against 0.41% above for non-R&D firms). Foreign sourcing firms also have higher pure productivity than their domestic sourcing counterparts. This again is true for non-R&D firms (0.41% above industry average for foreign sourcers against 4.79% below for domestic sourcers) and R&D firms (4.55% above industry average for foreign sourcers against 0.15% above for domestic sourcers). Again, the year 2007 yields similar qualitative results.

Figure 1.3 plots the cumulative distribution functions of the four groups to provide a graphical representation of a general comparison of pure productivity among groups. On the CDF graph, if the distribution plot for a group of firms is below that of another group, their pure productivities are more likely to be higher in general. As we expected, the pure productivity distribution of foreign firms with R&D is the lowest on the plot. It is also clear that for a given R&D strategy, foreign sourcing firms have higher pure productivity than domestic sourcing ones: the graph of foreign with R&D is lower than domestic with R&D, and the graph of foreign without R&D is lower than domestic without R&D. Similarly, for a given sourcing strategy, firms that conduct R&D have higher pure productivity than firms that do not. These observations originate from the model set-up where R&D, as well as foreign sourcing, are both complements to pure productivity and serve to lower the marginal cost of production. Therefore, firms with high pure productivity are more likely to adopt more advanced cost-cutting strategies.

The data does depart from model predictions in one aspect: the pure productivity of domestic firms conducting R&D (0.90% above industry) is higher than that of foreign firms without R&D (0.38% above industry) in 2007. In 2009, although domestic R&D firms have lower average pure productivity than foreign non-R&D ones, the difference is very small and insignificant. Recall that the model predicts all foreign sourcing firms should have strictly higher pure productivity than domestic sourcing ones, this empirical finding is concerning. In Figure 1.3, the CDF graph shows no immediately discernible difference between domestic R&D firms and foreign non-R&D firms in both 2007 and 2009. There could be a myriad of factors contributing to this observation. Given the contrast in the data for 2007 and 2009, during which period a global financial crisis swept the world, year fixed effects could be a huge factor. In addition, as Table 1.2 shows, domestic sourcers with R&D are both larger in size (measured by the number of employees) and larger in total sales than foreign sourcers without R&D. This could mean larger firms, in general, are associated with higher productivity. Nonetheless, this effect was at least partially accounted for in the OP method where firm size was one of the control variables.



(a) *Year: 2007*



(b) *Year: 2009*

Figure 1.3: *Pure Productivity Cumulative Distribution Functions of Different R&D - Sourcing Groups*

More interestingly, the elasticity of demand σ could play a huge role in firms' choices of R&D vs. foreign sourcing. There are two main channels through which σ affects the choices and profitability of the firm: a direct channel and an indirect channel. In the direct channel, equations (15) - (18) show that increasing sourcing capacity by importing from abroad becomes more profitable with higher σ. Firms thus are more likely to source abroad if they enjoy high elasticity of demand. In the indirect channel, σ affects complementarity between R&D and sourcing capacity. While R&D and sourcing capacity are complements in this paper and many others in the literature (Boler *et al.* (2014)), the degree of complementarity increases as σ increases. Antras *et al.* (2014) gave a detailed analysis of the complements case (where $(\sigma - 1)/\theta > 1$) and the substitutes case (where $(\sigma - 1)/\theta < 1$). From equations (15) - (18), the results in Antras, Fort and Tintelnot still holds: the marginal gain of firm profits is increasing in sourcing capacity if $(\sigma - 1)/\theta > 1$, or in the context of this paper, the marginal gain of profits is increasing if firms decide to source abroad. On the contrary, the marginal gain of firm profits is decreasing when the firm switches from domestic sourcing to foreign sourcing if $(\sigma - 1)/\theta < 1$. When σ decreases, the indirect channel discourages firms from conducting both R&D and foreign sourcing, while the direct channel discourages foreign sourcing alone. Therefore, if the elasticity of demand σ is low enough, firms with high research potential would prefer staying domestic and engage in R&D rather than sourcing abroad without R&D. In other words, we would expect the domestic R&D firms to have lower σ and higher potential than foreign firms without R&D (The prediction about potential is already confirmed in data as documented earlier).

I construct a measure of the elasticity σ under the assumption of CES preferences and monopolistic competition. In this framework, the firms will have a constant markup given by $\sigma/(\sigma - 1)$. I calculate the markups from the ESEE data as the ratio of sales to intermediate consumption by the firms - defined as the sum of purchases and external services minus the variation in the stock of the purchases. Care was taken to exclude outliers with negative mark-ups ($\sigma < 1$) or extreme values ($\sigma > 100$). The result is presented in line 7 of Table 1.2. As predicted, domestic firms with R&D has significantly lower elasticity (4.53 in 2007 and

3.80 in 2009) than foreign firms without R&D (5.03 in 2007 and 4.58 in 2009). In general, foreign sourcing firms also have higher σ than domestic sourcing ones, partially supporting the direct channel of elasticity discussed above.

1.3.3 Sorting Patterns

Instead of relying simply on the comparison of means between groups, I employ the non-parametric Kolmogorov-Smirnov (KS) test for a more rigorous examination of the sorting pattern. Using the concept of first order stochastic dominance, the KS test allows me to compare pure productivity distributions of firms with different R&D and sourcing combinations. For two distributions with cumulative function $F_1(\psi)$ and $F_2(\psi)$, first order stochastic dominance of $F_1(\psi)$ over $F_2(\psi)$ is defined as $F_1(\psi) - F_2(\psi) \leq 0 \ \forall \psi \in \Re$, with strict inequality for some ψ. Both one-sided and two-sided KS tests will be conducted on pairs of groups.

Specifically, the two-sided KS test examines the hypothesis that two distributions are identical. Its null hypothesis can be expressed as

$$H_0 : F_1(\psi) - F_2(\psi) = 0 \ \ \forall \psi \in \Re \ \ vs. \ H_1 : F_1(\psi) - F_2(\psi) \neq 0 \text{ for some } \theta \in \Re$$

The one-sided KS test examines if one distribution stochastically dominates another. Mathematically

$$H_0 : F_1(\psi) - F_2(\psi) \leq 0 \ \ \forall \psi \in \Re \ \ vs. \ H_1 : F_1(\psi) - F_2(\psi) > 0 \text{ for some } \theta \in \Re$$

As the test assumes independence across observations, I conduct separate tests for firms by year instead of pooled observations. If the null hypothesis of the two-sided test can be rejected while that of the one-sided test is not rejected, I reach the conclusion that $F_1(\psi)$ stochastically dominates $F_2(\psi)$. Following the predictions of the theoretical model, I compare the pure productivity distribution of firms across the four usual categories as defined at the beginning of the section. Additionally, I compare the R&D potential for domestic and foreign sourcing firms. The results are presented in Table 1.3.

Table 1.3: *Komorogov-Smirnov Test Statistics*

			2007		2009	
Test Variable	Group A	Group B	Two-sided H0: A = B	One-sided H0: A < B	Two-sided H0: A = B	One-sided H0: A < B
1. Pure Prod	Domestic, No R&D	Domestic, R&D	0.287 (0.000)	-0.013 (0.962)	0.273 (0.000)	-0.008 (0.989)
2. Pure Prod	Foreign, No R&D	Foreign, R&D	0.211 (0.000)	-0.002 (0.999)	0.225 (0.000)	-0.008 (0.984)
3. Pure Prod	Domestic, No R&D	Foreign, No R&D	0.252 (0.000)	-0.001 (0.999)	0.279 (0.000)	0.000 (1.000)
4. Pure Prod	Domestic, R&D	Foreign, R&D	0.200 (0.000)	0.000 (1.000)	0.228 (0.000)	0.000 (1.000)
5. Pure Prod	Foreign, No R&D	Domestic, R&D	0.044 (0.683)	-0.065 (0.439)	0.045 (0.735)	-0.067 (0.500)

Notes: The first row in the test statistics provides the maximum vertical distance between the two cumulative distribution functions. The second row provides P-value in brackets. Test for elasticity σ excludes outliers and is restricted to $\sigma > 1$ and $\sigma < 100$.

The KS test results are congruent to the simple summary statistics in the last section to a large extent. The first two lines compare firms with the same sourcing strategy and different R&D strategies. Firms that conduct R&D are found to be overwhelmingly more productive than firms with no R&D. Note that this is true for pure productivity that already discounts the effects of R&D. This is a result of the high initial fixed cost of engaging in innovation, and the complementary relationship between pure productivity and R&D in reducing the marginal cost of production as illustrated in the theoretical model. The third and fourth lines compare firms with the same R&D choices and different sourcing destinations. Again in both years, foreign sourcing firms dominate domestic firms conditional on R&D strategy as predicted by the model.

Overall, the KS tests lend more rigorous support of firms sorting into different R&D and sourcing strategies based on pure productivity. More productive firms are more likely to start sourcing from abroad, as well as engage in R&D innovation. The complementarity between pure productivity, R&D, and foreign sourcing through marginal cost function is apparent from this empirical exercise. Although the hierarchical ordering of firms for different combinations of strategies doesn't exactly coincide with model prediction, i.e. domestic R&D firms are found to be similar in pure productivity to foreign non-R&D

firms, if not more productive, such empirical discrepancies could be partially attributed to differences in firm sizes, elasticity of demand as well as year fixed effects.

1.3.4 Sourcing and R&D Premia Estimation

In this section, I use econometric analysis to establish the relationship between a firm's sourcing/R&D choices and its pure productivity. By estimating foreign sourcing premia and R&D premia on pure productivity, I will lend empirical support to the general pure productivity-based sorting pattern described in previous sections. The literature has established empirical evidence (Federico (2010), Kohler and Smolka (2011)) of productivity premia of foreign sourcing firms, but their specification has already taken into account any productivity-enhancing innovations. To my knowledge, there has not been a paper examining the sourcing premia of pre-R&D productivity, as well as the interaction between innovation and sourcing in that context.

The model in section 2 predicts that foreign sourcing will have higher premia than domestic sourcing while R&D firms have higher premia than non-R&D. This is derived from the model set-up where both foreign sourcing and R&D will complement firm's pure productivity in reducing marginal cost, and firms with higher pure productivity stand to benefit more from this complementarity, allowing them to overcome the associated fixed costs more easily and switch to advanced strategies. Following the literature on export premia (Bernard and Jensen (1999)) and sourcing premia (Kohler and Smolka (2011)), I estimate the R&D and foreign sourcing premia using sourcing and R&D dummies.

In constructing the dummy variables, I choose to exclude the firms that do not report any sourcing from the sample. The reason for ignoring the non-sourcing firms is twofold: first, in the theoretical model of section 2 as well as the classic literature on sourcing (Antras and Helpman (2004)), firms always need to source from another party, be it through arms-length trade or as an integrated subsidiary. In the model of this paper, sourcing is implicitly assumed to be the purchase of intermediate inputs. Firms that do not use inputs to produce are non-existent in the model. It is, therefore, more fitting to only consider the firms that report some form of sourcing activity. Second, those firms that do not source at all only comprise of $< 5\%$ of the entire sample, thereby excluding them would not affect the empirical results in any conceivable way.

1.3.4.1 Mutually Inclusive Sourcing and R&D Premia Estimation

I estimate the R&D and sourcing premia using two specifications. First, I construct dummy variables of sourcing and R&D activities respectively. Formally, the panel model to be estimated is as follows:

$$\psi_{ijt} = \beta_0 + \beta_1 Foreign_{ijt} + \beta_2 RD_{ijt} + \beta_3 Export_{ijt} + \beta_4 Age_{ijt} + \gamma_j + \gamma_t + \nu_{ijt} \tag{1.28}$$

where ψ_{ijt} is the pure productivity for firm i in industry j at time t; $Foreign_{ijt}$ is a dummy variable indicating whether the firm sources from abroad; RD_{ijt} is a dummy for whether the firm has any expenditure in R&D in the given year; $Export_{ijt}$ is a dummy of whether the firm exports its products; Age_{ijt} is the number of years since the firm was founded; γ_j and γ_t are industry and year fixed effects respectively; $\nu_{ijt} = \mu_i + \epsilon_{ijt}$ is a composite error term that consists of unobserved firm-level effect μ_i and idiosyncratic error ϵ_{ijt}.

The inclusion of export dummy follows from two considerations: firstly there is evidence for significant export premium in literature, e.g. Bernard and Jensen (1999) and Tomiura (2007); secondly, exporting firms may find it easier to cultivate relationships with foreign intermediate goods manufacturers, giving them readily access to foreign sourcing. The coefficient on export is expected to be positive. As knowledge is accumulated over time, and by construction R&D expenditure is complementary to the existing accumulation of knowledge, the age of a firm is expected to contribute positively to its pure productivity premium. In the global sourcing literature with incomplete contracts (Antras (2003), Antras and Helpman (2004)), firms' sourcing decisions are influenced by headquarter intensities which are usually assumed to vary on the industry level. In the model of this paper, there is no element of headquarter services or different organizational modes of sourcing, but headquarter intensity could certainly affect firms' sourcing and R&D strategies in the data. The elasticity of demand, σ, as described before is another industry-level variable that could potentially shape firm decisions. Therefore industry fixed effects are included in the estimation to account for these and other unobserved heterogeneity among industries. Lastly, following the convention in the literature on productivity premia, I include year fixed effects to account for time-specific shocks that affect the productivity of all firms in the sample. This is particularly important in light of the global financial crisis that occurred in the middle of our sample period of 2006-2009.

This model highlights the productivity premia associated with foreign sourcing and R&D separately. In this specification, I do not yet delve into the nuances involved in the interplay of sourcing and R&D choices. Rather, I show a general pattern of pure productivity premia that links to either sourcing or R&D. Note that in this case, the two dummy variables of interest are not mutually exclusive: a foreign R&D firm will code a value of 1 in both *Foreign* and *RD*. With this specification, I can directly compare the productivity premia associated with sourcing abroad to that of conducting R&D. While this comparison does not directly lay out the hierarchical structure of the sorting pattern, it does offer much insight into the propensity of firms to engage in different cost-cutting strategies.

I estimate the model first by simply pooling the data over the years in pooled OLS regression. Care is taken to account for serial correlation in the unobserved firm-level effect μ_i by computing robust clustered standard errors. I also estimate the between-estimator model as a comparison. The between-estimator applies OLS to the time average of variables in the model, therefore exploring variations only on the cross-section dimension. The estimation results are presented in Table 1.4. In this exercise, I do not claim any causal direction between productivity and sourcing/R&D choices, but rather explore the general pattern of within-industry firm heterogeneity in the aforementioned sorting pattern, much in the spirit of Kohler and Smolka (2011).

Several observations are immediately notable. First, we have solid evidence of the existence of pure productivity premia for foreign sourcing and R&D in all specifications.

Table 1.4: *Estimation of Premia by Mutually Inclusive Sourcing and R&D Strategies*

Dependent Variable: Olley-Pakes Pure Productivity						
	Pooled OLS			Between-Estimator		
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Foreign	0.585***	0.439***	0.401***	0.673***	0.503***	0.469***
	(0.055)	(0.055)	(0.053)	(0.068)	(0.068)	(0.066)
RD	0.744***	0.574***	0.490***	0.838***	0.644***	0.546***
	(0.064)	(0.065)	(0.064)	(0.069)	(0.071)	(0.069)
Export		0.658***	0.585***		0.647***	0.583***
		(0.067)	(0.066)		(0.072)	(0.070)
Age			0.0131***			0.0128***
			(0.0015)			(0.0012)
Constant	11.691***	11.349***	11.046***	11.471***	11.180***	10.884***
	(0.177)	(0.169)	(0.172)	(0.160)	(0.160)	(0.157)
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	No	No	No
Observations	4393	4393	4393	4393	4393	4393
R-squared	0.25	0.29	0.33	0.24	0.28	0.33

Notes Firms that do not source inputs are excluded. Parentheses show standard errors. Robust standard errors clustered by firm are computed for regressions (1) - (3). *Foreign*, *RD* and *Export* are dummy variables, *Age* is the total number of years since founding of the firm. * , ** and *** indicate significance at 10%, 5% and 1% respectively.

All of the regressions yield positive coefficients for both the foreign sourcing and R&D dummies, and the results are significant at 1%. For example, in column 3 after controlling for export status and firm age, foreign sourcing firms are found to be 49% more productive than domestic sourcing ones[10], while R&D firms are 63% more productive, even in pure productivity, than non-R&D firms.

Second, R&D premia are found to be universally higher than foreign sourcing premia. In all specifications, the coefficient on R&D dummy is at least 20% higher than that of the foreign sourcing dummy. It shows that as firms become more productive, they are more likely to engage in innovation investments than different sourcing strategies.

Third, the results are sensitive to other controls like an export dummy and firm age. Export premia are found to be both large in magnitude - commanding close to 80% higher productivity than non-exporters - and highly significant in regressions 3 and 6. However,

[10]The formula used to compute percentage difference in productivity between baseline and when dummy variable equals 1 is $(exp(\beta) - 1) * 100$.

including the export status in regressions 2 and 5 will cause the coefficients on foreign sourcing to decrease by about 25%, and the coefficients on R&D dummies by about 23% in both specifications. Nonetheless, both foreign and R&D dummies are still highly significant. This may be an indication of the correlation between exporting, sourcing and innovation that received much attention in the literature (Bernard and Jensen (1999), Guadalupe *et al.* (2012)). Firm age is also a significant contributing factor to pure productivity premium: the addition of one year of age is associated with 1.3% increase in pure productivity, which could become very impactful for a firm with a long history.

I do not control for firm size for the premia estimation. This is because firm size is an important component in estimating the dependent variable, pure productivity, that the inclusion of which may cause multicollinearity concerns. Indeed, the correlation between firm size and productivity premia seems so overwhelming, that the inclusion of this control would render the coefficients on other dummy independent variables insignificant. It is a similar result as Kohler and Smolka (2009) where firm size is found to be superior to all other sourcing and organization variables in explaining productivity premia. Apparently, the same is true regarding pure productivity premia.

1.3.4.2 Mutually Exclusive Sourcing and R&D Premia Estimation

After establishing the fact that both foreign sourcing and R&D contribute to pure productivity premia, I construct dummy variables of different sourcing and R&D combinations to examine the hierarchical structure. I aim to establish a ranking of the four combinations - domestic sourcing without R&D, domestic sourcing with R&D, foreign sourcing without R&D and foreign sourcing with R&D - that gives rise to premia in pure productivity. Formally, the panel model to be estimated is as follows:

$$\begin{aligned}\psi_{ijt} =& \beta_0 + \beta_1 ForeignRD_{ijt} + \beta_2 ForeignNoRD_{ijt} + \beta_3 DomesticRD_{ijt} + \\ & \beta_4 Export_{ijt} + \beta_5 Age_{ijt} + \gamma_j + \gamma_t + \nu_{ijt}\end{aligned} \tag{1.29}$$

where $ForeignRD_{ijt}$ is a dummy variable indicating whether the firm sources from abroad and invests in R&D; $ForeignNoRD_{ijt}$ is a dummy for whether the firm conducts foreign sourcing but no R&D; $DomesticRD_{ijt}$ is a dummy for whether the firm sources domestically with investments in R&D. The other variables are the same as before. Both industry and year fixed effects are included wherever possible to isolate the heterogeneity among different industries or different time periods.

Note that in this specification, the dummy variables for sourcing - R&D combinations are mutually exclusive: a firm will be coded with 1 in only one category. A regression of such will provide a more precise test for the theoretical model where a clear rank order emerges among the combinations. The group of firms in the lowest category - domestic sourcing without R&D - is used as a baseline in the regression. Thus, the coefficients on other dummies will indicate pure productivity premia in comparison with the domestic / no R&D firms. Again, I use both pooled OLS with robust clustered standard errors and between - estimator regressions to implement the panel model. Results are presented in Table 1.5.

The estimation results bear many resemblances to the first specification beforehand. For all specifications, there is overwhelming evidence of pure productivity premia for all of the more advanced strategies over the baseline group - domestic without R&D firms. The premia are not only highly significant statistically but also enormous economically as well. In column 3 for example, foreign R&D firms command a whopping 144% higher productivity (after log conversion) than domestic non-R&D firms, whereas the premium is 66% for domestic R&D firms and 45% for foreign non-R&D firms. As expected, export status and firm age clearly contribute to the premia as shown in columns 3 and 6. Adding the controls decreases the coefficient on the organizational mode dummies by about 50%, while not affecting their significance.

I conduct this exercise to examine the sorting pattern of firms based on pure productivity. The evidence so far firmly supports the prediction that domestic non-R&D firms is at the bottom of the sorting echelon and the most productive firms will sort into foreign R&D. The T-tests for coefficients further reinforce this finding, confidently rejecting the null hypothesis

Table 1.5: *Estimation of Premia by Mutually Exclusive Sourcing and R&D Strategies*

Dependent Variable: Olley-Pakes Pure Productivity						
	Pooled OLS			Between-Estimator		
Variables	(1)	(2)	(3)	(4)	(5)	(6)
ForeignRD β_1	1.328***	1.014***	0.891***	1.504***	1.148***	1.016***
	(0.073)	(0.078)	(0.076)	(0.082)	(0.089)	(0.087)
ForeignNoRD β_2	0.635***	0.445***	0.414***	0.703***	0.488***	0.468***
	(0.072)	(0.072)	(0.069)	(0.085)	(0.086)	(0.083)
DomesticRD β_3	0.816***	0.583***	0.508***	0.887***	0.621***	0.544***
	(0.089)	(0.090)	(0.088)	(0.107)	(0.109)	(0.105)
Export		0.657***	0.583***		0.649***	0.583***
		(0.067)	(0.066)		(0.072)	(0.070)
Age			0.0131***			0.0128***
			(0.0015)			(0.0012)
Constant	11.675***	11.347***	11.042***	11.463***	11.183***	10.884***
	(0.177)	(0.169)	(0.172)	(0.161)	(0.160)	(0.157)
$\beta_1 = \beta_3$	0.00	0.00	0.00	0.00	0.00	0.00
$\beta_1 = \beta_2$	0.00	0.00	0.00	0.00	0.00	0.00
$\beta_2 = \beta_3$	0.06	0.14	0.30	0.11	0.23	0.48
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	No	No	No
Observations	4393	4393	4393	4393	4393	4393
R-squared	0.25	0.29	0.33	0.25	0.28	0.33

Notes Firms that do not source inputs are excluded. Parentheses show standard errors. Robust standard errors clustered by firm are computed for regressions (1) - (3). *ForeignRD*, *ForeignNoRD*, *DomesticRD* and *Export* are dummy variables, *Age* is the number of years since the founding of the firm. * , ** and *** indicate significance at 10%, 5% and 1% respectively. Hypothesis testing performed on null hypothesis that coefficients are equal, the P-value results presented in lower panel.

when foreign R&D is compared to other categories. The result, however, does show that domestic R&D firms are not statistically differentiable from foreign non-R&D firms in pure productivity, despite having consistently higher coefficients. This result echoes that of the Kolmogorov-Smirnov tests from the last section.

Overall, the sorting of firms based on pure productivity obeys the following ranking: lowest pure productivity firms stay domestic and do not engage in R&D; medium pure productivity firms choose foreign sourcing without R&D or engage in R&D, but source domestically; most productive firms will be able to both foreign source and invest in R&D. The estimation result confirms most predictions of the theoretical model in section 2 with one discrepancy: domestic R&D firms are not inferior in pure productivity as predicted by the model. Recall that in the model, I made the assumption that in stage 1, foreign non-R&D

firms are dominated in equilibrium. The alternative possibility would be that domestic R&D firms are dominated in equilibrium. The type of equilibrium depends on many factors, but most ostensibly of all, the relative fixed costs of foreign sourcing vs. that of R&D. One could speculate that in reality, both types of equilibriums exist due to heterogeneous fixed cost structures among industries and firms, leading to the general sorting pattern not being as clear-cut as with just one equilibrium.

1.3.5 Complementarity between Foreign Sourcing and R&D

In this section, I will test another sharp prediction of the theoretical model in section 2, namely the complementarity of foreign sourcing and R&D. The model was set-up such that foreign sourcing and R&D will reinforce and multiply each other's impact on firm's total factor productivity. Intuitively, a foreign sourcing firm finds it more profitable to invest in R&D, because the increased marginal benefit brought by sourcing cheaper inputs abroad will be further magnified by the cost-cutting advantage of R&D. Conversely, for a firm already conducting R&D and reaping its benefit of lower marginal cost, it will find sourcing abroad an easier decision to make as the fixed cost of sourcing can be quickly overcome given increased profitability.

Existing literature such as Rodríguez-Clare (2010) and Bustos (2011) explore the link between internationalization and research efforts/technology upgrading by firms, but their focus was not on the complementarity between research and sourcing decisions. Boler *et al.* (2014) analyzes the relationship between R&D and foreign import of intermediates in a very similar fashion to this paper. They present both theoretical and empirical results supporting the existence of complementarity among Norwegian manufacturing firms. However, given the nature of their data, only 6.6% of all Norwegian manufacturing firms in their sample do not source abroad. It is very likely that many Norwegian firms rely on inputs that can only be imported from foreign countries, thus lacking the freedom to switching sourcing modes even if they would like to. In comparison, more than half (53%) of the Spanish firms in my sample are domestic sourcers. It will be interesting to test the complementarity in this case where firms are more likely to have a choice between domestic and foreign suppliers.

1.3.5.1 Instrumental Variable Approach

To establish complementarity between foreign sourcing and R&D, I regress separately firms' extensive and intensive R&D choices on a dummy of their foreign sourcing status in an attempt to estimate if a foreign sourcing firm has a higher propensity to engage in R&D. It is natural to control for the pure productivity of firms as it is the central parameter that directly impacts a firm's R&D involvement and sourcing strategy in the model. Foreign sourcing, however, is still susceptible to endogeneity concerns through reverse causality. By engaging in technology upgrading and thus raising its efficacy of using intermediate inputs, a firm could gain access to foreign suppliers they previous could not reach. Therefore, I propose to establish causality by instrumenting the foreign sourcing dummy with the industry average value share of foreign-sourced inputs.[11] The instrumental variable indicates an industry's propensity to source abroad, which is highly correlated with a firm's sourcing decisions within the same industry. In the estimations that follow, the first stage results of IV exercises positively reaffirm the high correlation between the instrument and instrumented variable. At the same time, the industry average propensity to source abroad does not conceivably impact a single firm's R&D choices directly.

1.3.5.2 Foreign Sourcing and Extensive Margin R&D

The theoretical model predicts that foreign sourcing firms are more involved in R&D activities both on the extensive margin and the intensive margin. On the extensive margin, foreign sourcing firms are more likely to engage in any R&D investment at all. On the intensive margin, among firms that conduct R&D, foreign sourcing ones, in general, spend more than domestic sourcing ones. I will test the complementarity on both margins separately. In estimating the extensive margin relationship, I use logit regression of firms'

[11]The formula for calculating the share is (share of imported inputs through foreign integration + share of imported inputs through foreign outsourcing)*total value of imports/(total value of imports + total value of domestic intermediate purchases) and averaged within an industry in a given year.

R&D status on their sourcing status. Formally, the equation to be estimated is:

$$
\begin{aligned}
logit(\pi_{ijt}) = log(\frac{\pi_{ijt}}{1-\pi_{ijt}}) = \beta_0 + \beta_1 Foreign_{ijt} + \beta_2 PureOPprod_{ijt} + \\
\beta_3 \sigma + \beta_4 Export_{ijt} + \beta_5 Age_{ijt} + \gamma_j + \gamma_t + \nu_{ijt} \\
where \;\; \pi_{ijt} = Pr(RD_{ijt} = 1|\mathbf{X}),
\end{aligned}
\tag{1.30}
$$

where the subscripts i, j, t denote firm, industry and time respectively as before. The dependent dummy variable RD, independent variables $Foreign$, $Export$ and Age are the same as before. $PureOPprod$ is the pure Olley-Pakes productivity of a firm and is a natural choice to be included as a control. In section 3.1, I discussed the elasticity of demand σ and its potential effect on firm's propensity towards different sourcing/R&D strategies, thus σ is included as a control in the estimation too. For the logit model, I implement three specifications: a pooled OLS with robust clustered standard errors, a population-average GEE model, and the instrumental variable model. Again, I control for industry and year fixed effects wherever possible.

Note that the conventional 2SLS IV approach is inconsistent in this framework with binary dependent variable and discrete (binary) endogenous regressor. Instead, I use bivariate probit model where the two binary outcomes - R&D dummy and foreign sourcing dummy - are jointly estimated in two probit models by maximum likelihood. For the maximum likelihood to provide consistent estimates, the endogenous regressor equation needs to be correctly specified and the errors of two stages are assumed to be jointly normal. The instrument is entered together with all other control variables as well as fixed effects in the probit model of foreign sourcing. Table 1.6 presents the estimation results of the specifications outlined above.

As results from Table 1.6 show, we have overwhelming evidence that foreign sourcing is complementary to a firm's extensive decision to engage in R&D, even after controlling for pure productivity, elasticity of demand, export status, and firm age. Pooled OLS regression (3) shows that a foreign sourcing firm has 87% higher odds to also engage in R&D than if it was purely domestic sourcing. The population average regression tells a similar story, where

Table 1.6: *R&D Extensive Margin Estimation*

Dependent Variable: R&D dummy in logistic regression							
	Pooled OLS Odds Ratio			Population Average Odds Ratio			IV Bi-Probit
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Foreign	2.331***	1.869***	1.865***	1.400***	1.345***	1.350***	1.463***
	(0.25)	(0.21)	(0.21)	(0.084)	(0.086)	(0.088)	(0.158)
PureOPprod	1.789***	1.586***	1.522***	1.402***	1.359***	1.317***	0.130***
	(0.10)	(0.094)	(0.092)	(0.048)	(0.048)	(0.048)	(0.038)
σ		0.993**	0.993**		0.998*	0.998	-0.00483***
		(0.0030)	(0.0031)		(0.0011)	(0.0012)	(0.0017)
Export		4.186***	4.080***		2.625***	2.578***	0.390***
		(0.65)	(0.63)		(0.26)	(0.26)	(0.11)
Age			1.008***			1.013***	0.00345**
			(0.0030)			(0.0026)	(0.0016)
Marg. Effect	0.161	0.111	0.110	0.070	0.058	0.058	0.477
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4393	4393	4393	4393	4393	4393	4393
Pseudo R-squared	0.22	0.26	0.26				

Notes Firms that do not source inputs are excluded. Parentheses show standard errors. Robust standard errors clustered by firm are computed. Average marginal effect is computed for Foreign dummy. Constant is used in regression but not reported. Coefficients in (1) - (6) are reported in odds ratio. * , ** and *** indicate significance at 10%, 5% and 1% respectively.

a foreign sourcing firm on average has 35% higher odds than an average domestic sourcing firm to invest in R&D in regression (6). More importantly, the IV regression (7) indicates a significant causal contribution of foreign sourcing on the propensity of a firm to engage in R&D, where the increase in likelihood is 46%. To facilitate comparison, I construct average marginal effects on the foreign sourcing dummy in all specifications. For non-instrumented OLS and PA models, by switching to foreign sourcing from domestic sourcing, the predicted probability of R&D increases by 11% and 5.8% respectively. Interestingly, the marginal effect of foreign sourcing rises more dramatically when IV is used: the predicted probability of R&D increases by 48% in the bi-probit specification. The IV exercise not only reaffirms the existence of highly significant directional links between foreign sourcing and R&D, but also demonstrates a much higher degree of complementarity compared to standard models.

As expected, pure productivity, export status, and age all have positive and highly significant impacts on the odds of R&D on the extensive margin. The impact of export status is found to be the greatest among all independent variables in the non-instrumented regressions (1) - (6). Once an instrumental variable is used, however, foreign sourcing dummy is found to contribute the most to the propensity of R&D. It is interesting to note that under IV, the elasticity of demand is highly significant in explaining the extensive margin of R&D, but an increase in σ actually decreases the odds of conducting technology innovation, if only slightly. It is possible, as discussed in section 3.2, that a high value of σ contributes more to a firm's foreign sourcing tendencies than its R&D inclination, that increasing σ could mean some firms switching to foreign sourcing without R&D from domestic R&D mode, thereby reducing the overall R&D propensity. This paper, however, does not give conclusive evidence on this hypothesis.

1.3.5.3 Foreign Sourcing and Intensive Margin R&D

To estimate the intensive margin - the amount of investment in technology upgrading conditional on engaging in R&D - I construct the natural log of total R&D expenditure by a firm in a given year and use it as a direct measure of the intensive margin. There is a caveat with using absolute R&D expenditure, as it will be highly correlated with the size of the firm, where larger firms have an overwhelming advantage in the pure amount they can afford to spend on R&D. It is thus necessary to control for firm size in the estimation.[12] Similar to the extensive margin, I estimate a pooled OLS, a population-average GEE and an instrumental variable model with the industry average share of foreign-sourced inputs as the instrument. As the dependent variable is continuous on the intensive margin, I use the standard two-step estimation with endogenous treatment to implement the IV. The estimation model is as follows:

[12] The reason I do not use R&D intensity as the dependent variable is that R&D effort by a firm does not scale proportionately with total sales. Many huge multinational firms in the sample, while outspending smaller firms in R&D by orders of magnitude, may still have smaller R&D intensity due to their sheer size. This phenomenon introduces a size bias to the estimation that is counter-intuitive. By using total R&D spending as the dependent variable and controlling for size in the estimation, this bias can be mitigated.

$$
\begin{aligned}
lnRDexp_{ijt} = \beta_0 + \beta_1 Foreign_{ijt} + \beta_2 PureOPprod_{ijt} + \\
+ \beta_3 \sigma + \beta_4 Export_{ijt} + \beta_5 Age_{ijt} + \beta_6 Size_{ijt} + \gamma_j + \gamma_t + \nu_{ijt}
\end{aligned}
\tag{1.31}
$$

where $lnRDexp_{ijt}$ denotes log total R&D spending for firm i of industry j in time t. $Size_{ijt}$ is the log of total employees of the firm and other variables are defined in the same way as before. The results are reported in Table 1.7 and suggest a similarly significant correlation between foreign sourcing and R&D. Foreign sourcing firms are found to invest more heavily in R&D than their domestic sourcing counterparts (columns (1) - (6)), which are highly significant for both pooled OLS and population average specifications. For example, after controlling for export status, elasticity of demand, firm size and age (column 3), if a firm sources abroad, it is expected to spend 171%[13] more in R&D compared to if it only sources domestically. In the population average specification (column 6), the magnitude of the coefficients decreases drastically but still maintaining significant qualitative interpretations: the expected increase in R&D spending is 54% higher for foreign sourcing firms compared to domestic sourcing. The IV estimates are not as significant as the extensive margin analysis, but 5% confidence is nonetheless a good indication of a causal link between foreign sourcing and the extent of R&D investment.

Nevertheless, it is important to keep in mind that the intensive margin estimation does not account for an essential unobservable parameter: firm R&D potential. The model predicts that foreign sourcing is complementary to the intensive margin of R&D *if* research potential is controlled for. In fact as equation (12) shows, if the potential is unobservable, average spending in R&D for foreign sourcing firms is ambiguous compared to that of domestic R&D firms. This is because the threshold potential for the extensive margin of R&D is lower for foreign sourcing firms (Proposition 3), resulting in a lower average potential of foreign R&D firms relative to domestic ones. With a good proxy of potential, the IV may yield sharper and more significant results.

The other variables behave as expected and echo that of the extensive margin estima-

[13] As the dependent variable is log expenditure, the percentage point is calculated using $exp(\beta_1) - 1$.

Table 1.7: *R&D Intensive Margin Estimation*

	Dependent Variable: log total expenditure in R&D						
	Pooled OLS			Population Average			IV
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Foreign	2.016***	1.426***	0.996***	0.754***	0.645***	0.431***	1.983**
	(0.27)	(0.27)	(0.25)	(0.13)	(0.13)	(0.13)	(0.91)
PureOPprod	1.614***	1.326***	-1.593***	0.787***	0.718***	-0.286***	-1.611***
	(0.12)	(0.12)	(0.20)	(0.069)	(0.070)	(0.084)	(0.20)
σ		-0.00602	-0.0135**		-0.00145	-0.00439**	-0.0143**
		(0.0042)	(0.0063)		(0.0018)	(0.0018)	(0.0062)
Export		2.879***	1.800***		1.856***	1.097***	1.538***
		(0.28)	(0.26)		(0.20)	(0.19)	(0.34)
Age			0.0109*			0.0109*	0.0103*
			(0.0061)			(0.0056)	(0.0061)
Size			3.250***			2.277***	3.194***
			(0.18)			(0.11)	(0.19)
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4393	4393	4393	4393	4393	4393	4393
Pseudo R-squared	0.32	0.35	0.46				

Notes Firms that do not source inputs are excluded. Parentheses show standard errors. Robust standard errors clustered by firm are computed. Constant is used in regression but not reported. * , ** and *** indicate significance at 10%, 5% and 1% respectively.

tions, with the exception of *PureOPprod*. It is interesting to see that the coefficients on pure productivity switch signs from positive to negative after controlling for firm size, and are highly significant in all specifications. Where the theoretical model predicts that more productive firms would spend more on R&D ceteris paribus, this result seems to point to an opposite interpretation. However, we should keep in mind that in the OP implementation, firm size was the central control variable used for the estimation of pure productivity. This sign switch could simply be caused by an extremely high correlation between the two variables that are both controlled for in this estimation.

Comparing the estimations in both Table 1.6 and 1.7, the evidence for complementarity between foreign sourcing and R&D is ample for both extensive and intensive margins, although I find more significant causal relationships for the extensive margin. More specifically, if firm size is not used as a control, both intensive and extensive margin estimations present reassuring evidence of complementarity. Controlling for firm size decreases the magnitude of foreign sourcing coefficients in the intensive margin estimations considerably (by more than 30%), but does not affect the foreign sourcing coefficients in the extensive margin results. More importantly, using an instrumental variable approach, the relationship between foreign sourcing and R&D is shown to be causal for both extensive and intensive margin, although the significance is only at 5% for the latter. Still, ample evidence can be drawn from the above exercises to support the model predictions on complementarity.

1.3.6 Robustness Check with Traditional Knowledge Capital Model

One of the central themes of this paper is to show that after controlling the effect of R&D, pure productivity can be used as a yardstick by firms to decide which sourcing/R&D modes to sort into. The method of estimating pure productivity from the production function is thus of paramount importance. In section 3.2, I outlined the Olley-Pakes framework (Olley and Pakes (1996)) while controlling for the effect of R&D as the implemented model. This method focuses on the accumulation of knowledge capital stock through R&D expenditure over time. I used a variant of the perpetual inventory method for accumulation of knowledge, allowing complementarity between R&D and existing stock of knowledge capital and breaking away from the linearity assumption.

However, the traditional perpetual inventory model is still the most used method for constructing a series of knowledge capital stock(Hall and Mairesse (1995)), which certainly merits consideration. In this section, I double check the empirical results using the original Griliches (1979) framework with simple perpetual inventory model. The law of motion for the knowledge stock C_{it} is given by:

$$C_{it} = (1-\delta)C_{it-1} + R_{it-1} \tag{1.32}$$

Where C_{it} is the level of capital stock for firm i in period t, and R_{it} is the level of R&D expenditure carried out by the said firm. The variable of interest, C_{it}, is assumed to accumulate each year by investing in R&D, much like the accumulation of physical capital. As pointed out in Doraszelski and Jaumandreu (2013), one of the major drawbacks in using this form is that the rate of depreciation δ is extremely difficult to estimate. Given that many firms have intermittent years without R&D spending, the knowledge capital would likely shrink over the years instead of growing. Bearing these concerns in mind, I follow Hall and Mairesse (1995) in assuming a depreciation rate $\delta = 0.15$. The estimated levels of knowledge capital stock will then be taken natural logarithm and used in the OP implementation outlined in Section 3.2.

Using the pure productivity measure obtained from this new specification, I test the estimation models (28) - (31) in the last section. This allows me to reaffirm the robustness of the sorting pattern and the complementarity between foreign sourcing and R&D (on both extensive and intensive margin). I report the results in Tables A.1 - A.4 in the appendices.

The sorting order estimation results in Tables A.1 and A.2 are qualitatively consistent with that under Cobb-Douglas knowledge accumulation in Section 3.4. More advanced sourcing/R&D combinations still have a clear pure productivity premia over the base group: domestic non-R&D firms. In fact, the only notable differences in Table 8 are that foreign sourcing now commands a smaller productivity premium than before, while R&D firms command a larger premium. Recall that while using the perpetual inventory model, complementarity between R&D expenditure and existing knowledge capital is shut down. This may result in under-estimation of firms' knowledge stock and cause R&D to yield a higher premium than otherwise. The same pattern can be seen in Table A.2 for the mutually exclusive strategies too. Compared to the baseline results in Section 3.4, domestic R&D firms now manifest a significantly higher productivity premia than foreign non-R&D firms. Hypothesis tests for the equality of coefficients, while in the baseline model show no statistical difference between the two modes, now reject the null hypothesis and differentiate the two modes at high significance level. These changes signify the importance of accounting for complementarity in the knowledge capital estimation.

In Tables A.3 and A.4, the complementarity estimations again yield very similar results as the baseline model, demonstrating evidence supporting complementarity between foreign sourcing and R&D. Again, I find that foreign sourcing is causally linked to both the extensive margin of R&D and the intensive margin, with the extensive margin estimates showing a higher level of confidence. The similarity with the main model is expected, as the only difference here is a different derivation of pure productivity that is just used as a control.

In summary, the long-term impacts of R&D prove to be highly significant and are accounted for in the traditional knowledge capital framework here. The results presented in the baseline models are found to be robust under this alternative specification for the accumulation of knowledge stock. Of course, there are many other ways to take into account the effects of R&D other than the OP method and the knowledge capital model. For example, Doraszelski and Jaumandreu (2013) develops a dynamic model of endogenous productivity change, which enables estimation of productivity accounting for uncertainty, nonlinearity and heterogeneity across firms in the interaction between R&D and productivity. This paper, in addition, adopts a framework that separates the effects of R&D from total factor productivity. Further tests of robustness using other estimation methods are ripe for future research.

1.4 Concluding Remarks

The literature has well-documented evidence of productivity sorting into different sourcing modes. However, there has not been much attention given to the interaction of sourcing and R&D, nor how a firm's innate pure productivity could be the basis of such interactions, giving rise to hierarchical sorting patterns. This paper attempts to formalize the idea in a simple model where foreign sourcing and R&D are interlinked through the marginal cost function. This gives rise to a sorting pattern of firms into different sourcing/R&D combinations based on pre-R&D pure productivity. The model is novel in that it captures both the extensive and intensive margins of R&D, and through the set-up of a two-stage decision process, yields a general equilibrium where all four combinations exist concurrently and in clearly defined pure productivity ranking. More importantly, the model predicts complementarity between foreign sourcing and R&D, both on the extensive margin and the intensive margin, that can be tested empirically. In the empirical section, I document the sorting pattern and estimate the productivity of firms in an Olley-Pakes framework, while separating the impacts of R&D from total factor productivity. Estimates of pure productivity premia for different sourcing/R&D combinations are found to support the general sorting pattern. Furthermore, the interaction between foreign sourcing and R&D is tested empirically to establish complementarity between foreign sourcing and R&D. The results indicate a highly significant correlation between foreign sourcing and R&D both on the extensive margin and the intensive margin. The complementarity on the extensive margin is especially strong even after taking into account other usual suspects like export status or firm age. The use of an instrumental variable suggests that the complementarity could be causal running from foreign sourcing to R&D on both extensive and intensive margins, although the extensive margin estimates are more significant. Therefore, foreign sourcing firms not only have a higher propensity to engage in R&D, but also spend more than their domestic sourcing counterparts on average, as predicted by the model.

There is still much work to be done to understand more thoroughly the mechanism of interaction. In this paper, I emphasize the marginal cost function as the source of interaction. There could be many other channels that contribute to the sorting pattern as well. For example, I do not differentiate organizational modes in sourcing, but rather just focus on the destination of suppliers. This could omit important mechanisms through bargaining and (incomplete) contracting with suppliers. The R&D impact on total factor productivity is also taken as a factor of production through the accumulated knowledge capital stock, while many studies have emphasized on the long-term dynamic effects of continued R&D and the uncertainties associated with the process. I believe the model and empirical findings of this paper can serve as a reference for much richer future explorations of the complex linkages between technology upgrading and internationalization decisions.

Chapter 2

Multiple Sourcing[†]

2.1 Introduction

The study of multinational firms has always been the focus of international trade literature. In more recent years, there is a subtle shift in emphasis from firms' export of final products to the intra-firm trade of intermediate inputs. The multinational firms are perfect candidates for the analysis of intra-firm trade, where close to 50% of all US total imports are accounted for by intra-firm imports (Bernard *et al.* (2010)) of MNCs. Research on the heterogeneity of firms lends support to further analysis of multifarious sourcing strategies adopted by multinational firms.

In this paper, my focus is on a particular empirical phenomenon on firm's sourcing strategy that surfaced after the proliferation of more firm-level empirical research: multiple sourcing. This means that firms adopt different sourcing strategies simultaneously with regard to the organizational mode and destination of the suppliers. It builds on the canonical model of global sourcing by Antras and Helpman (2004) that incorporates the property

[†]The dataset used in this paper is the sole intellectual property of Fundacion SEPI. It was acquired originally by Professor Pol Antras for his project on the book manuscript *Global Production: Firms, Contracts and Trade Structure*. This paper is one of the related projects borne out of the research efforts while I was assisting Professor Antras in the manuscript. I draw many insights from the theoretical as well as empirical sections of the book. All errors are the sole responsibility of the author.

rights approach (Grossman and Hart (1986), Hart and Moore (1990)). The different residual rights of control of inputs give rise to two organizational modes: outsourcing or integration, while different labor costs between countries give rise to two sourcing destinations: domestic or offshoring. Combining these two dimensions and the fact that each sourcing strategy entails a fixed cost, the global sourcing model produces sharp predictions about a sorting pattern where firms self-select into one of the four sourcing modes: domestic outsourcing (DO), foreign outsourcing (FO), domestic integration (DI) and foreign integration (FI). A firm in Antras and Helpman (2004), however, produces one differentiated product and is restricted to one supplier each, thus the sorting pattern will designate it to one sourcing mode. In reality, MNC firms usually produce multiple products (Bernard *et al.* (2010) and have more than a few suppliers. One does not need to look further than the household names such as GMC or Apple to see their vast catalog of product offerings and extensive supply chains spanning the globe. It is entirely possible that they would choose different strategies while sourcing from each supplier. I attempt to describe the pattern of firms using multiple sourcing in this paper and explore the relationship between productivity and different combinations of modes. At the same time, I look at how a multiple sourcing strategy could be linked to firm size, the number of products, as well as capital intensity.

This is not the first paper that documents multiple sourcing behaviors in firms. Empirically, Kohler and Smolka (2009) show that Spanish manufacturing firms use a multitude of combinations of sourcing modes. Multiple sourcing is in fact rather prevalent with close to half of the firms in the sample using more than one type of sourcing strategy. Similarly, Corcos *et al.* (2012) analyze French firms and show that intra-firm (integration) and arms-length (outsourcing) trades can co-exist. Similar 'hybrid sourcing' patterns are found to exist in Japanese firms as well (Tomiura (2007)) despite the much smaller proportion of internationalized firms in Japan compared to the EU countries. All the above-mentioned papers, however, focus on the productivity premia of specific sourcing strategies in a traditional comparison of export vs. non-export, outsourcing vs. integration, or domestic vs. offshoring. They remain largely silent on the relationship between productivity and the degree of variation in multiple sourcing strategies.

Theoretically, Schwarz and Suedekum (2014) model heterogeneous final good producers facing a measure of infinitesimal suppliers with whom a firm engages in multilateral bargaining for realized revenue. The paper yields a rich set of results regarding sourcing modes and complexity of inputs. It is possible for firms to adopt 'hybrid sourcing' in their model. However, productivity does not play a significant role and does not have a clear impact on multiple sourcing patterns. Grossman and Rossi-Hansberg (2006) model production as a range of tasks, part of which can be offshored to other countries. Antras and Chor (2013) enable simultaneous outsourcing and integration in a firm by arranging production vertically into a sequence of stages. The position of a supplier in the value chain plays a huge role in determining the organization of sourcing activity while headquarter intensity and elasticity of demand govern the overall pattern of multiple sourcing in the chain. Similarly, Costinot *et al.* (2013) also propose a sequential production structure in the global economy with many countries, allowing a firm to outsource to multiple destinations along the supply chain. Both Antras *et al.* (2014) and Tintelnot (2014) analyze the global sourcing decisions in a multi-country context, where firms choose an optimal set of countries (including the domestic country) to source from/set up production/export to. Although all these aforementioned papers provide theoretical foundations for a setting where multiple sourcing is possible, their emphases are vastly different from this paper. Existing literature usually focuses on one dimension of sourcing: either integration vs. outsourcing or domestic vs. foreign. Thus, almost all of these papers allow the co-existence of only two different sourcing modes, and the degree of variation in sourcing strategies usually refers to different countries to be added to potential sourcing locations. I would like to investigate the interaction between the two dimensions as in Antras and Helpman (2004), and unlock the relationship between the number of different sourcing modes (with a maximum of 4: DO, FO, DI, FI) and other firm-level characteristics like productivity, size, and capital intensity.

I propose a simple extension to the Antras and Helpman (2004) framework. Firms can now choose to produce a measure of products, but each of them needs to be manufactured separately by combining headquarter input with an intermediate input sourced from an associated supplier. There are a large number of suppliers both domestic and abroad which command different labor costs. A firm can also choose the organizational mode of sourcing, i.e. whether through arms-length trade or through intra-firm trade with an affiliated entity. In short, if a firm wishes to produce a new product, it will need to choose one of the four sourcing modes (DO, FO, DI, FI) for the supplier of that product. The suppliers for different products are heterogeneous in one dimension: the fixed cost of sourcing. As in the canonical model, I assume there is a ranking of fixed costs associated with the four modes. In fact, I will assume the simplest form of heterogeneity among suppliers without loss of generality: suppliers differ in their fixed costs by a multiplicative constant that is drawn from a distribution. This way, the ranking of the fixed costs for the four modes is preserved. In reality, this can be perceived as suppliers for different products have varying degrees of trade/transaction frictions, causing their fixed costs for all sourcing modes to rise or fall at the same time. The key to the model is that firms contract and produce each product independently from one another, thereby facing the same productivity sorting pattern as in Antras and Helpman (2004) for each supplier. Based on its productivity, a firm will then sort into different modes for its products, corresponding to suppliers of varying levels of fixed costs. For example, for a product where the supplier fixed cost is low, a firm may select foreign outsourcing as the optimal mode given its productivity. For another product where the supplier has higher fixed cost across the board, the firm may only be able to use a less expensive (but also less profitable) mode, e.g. domestic outsourcing. For yet a third supplier with very high fixed costs, if the firm's productivity level is too low to be profitable even under domestic outsourcing, it will drop out and choose not to produce the product at all. Under this setting, the number of sourcing modes, the number of products, as well as the size of the firm measured by either total sales or total number of employees are all increasing in the productivity of the firm, a pattern with solid empirical support in the literature. Headquarter intensity or capital intensity of the firm could affect the sourcing pattern by diminishing the possible number of modes a firm could employ as shown by

Antras and Helpman (2004). Therefore, it could also affect the number of sourcing modes indirectly with multiple heterogeneous suppliers.

Naturally, there are other ways to approach the problem of multiple suppliers. Schwarz and Suedekum (2014) models the single intermediate input in the production function as a CES aggregate of a continuum of components each provided by a supplier. The model is tractable with sharp predictions about firm complexity and sourcing patterns. However, the fact that the suppliers are interconnected through the production function requires a complicated Acemoglu *et al.* (2007) style multilateral contracting game. The suppliers are heterogeneous only to the extent that the firm chooses different sourcing modes for them. In fact, the firm decides the proportion of suppliers for each sourcing mode. It becomes extremely cumbersome to incorporate any other form of supplier heterogeneity within the Shapley value Nash bargaining game. Indeed, Schwarz and Suedekum (2014) find that hybrid sourcing is only possible with a small set of firms of very narrowly defined capital intensity and offshoring cost range. Even in the case of hybrid sourcing, only two types of sourcing modes are used simultaneously, contrasting the empirical findings. This paper abstracts away from complex multilateral bargaining by assuming a continuum of possible products and mutually independent production processes among suppliers. It simplifies the model considerably as when firms contract with one supplier, they do not need to take other suppliers' input into consideration. Furthermore, it allows the addition of more nuanced heterogeneity on the supplier side, giving rise to full-fledged multiple sourcing patterns.

Empirically, I test the model predictions with data on Spanish manufacturing firms. I find that firms indeed source from more modes as they become more productive, even after controlling for firm size and capital intensity. The result is robust to alternative measures of productivity and regression specifications. Using R&D expenditure as an instrumental variable, I show that productivity is indeed the main driver of multiple sourcing. Nevertheless, it is important to keep in mind that the total number of modes used by firms only describes a general pattern of increased sourcing variation. For example, firms that employ the same number of sourcing modes are not necessarily similar in productivity.

For example, a firm that does domestic and foreign outsourcing is found to be much less productive than a firm that does domestic and foreign integration, despite both using two sourcing modes. The more nuanced pattern appears when I examine the change in the share of sourced inputs by each mode. Unsurprisingly and consistent with the theoretical model, I find that firms tend to move a larger proportion of sourced inputs away from domestic sourcing and into foreign integration as they become more productive. The IV estimation again establishes a causal relationship between firm-level productivity and the change in shares of different modes. Another model prediction that could be empirically tested is a 'pecking order' of multiple sourcing strategies: when firms become productive enough to use multiple sourcing, they will add new sourcing modes following the same sequential order. It also means that the specific combinations of sourcing modes used by a firm with low productivity are a subset of the strategy sets of all firms with higher productivity. As a possible extension to the model, I discuss an alternative characterization of supplier heterogeneity and categorize multiple sourcing strategies into productivity-ranked groups predicted by the model. The available data is found to broadly support the ranking and patterns of sourcing.

The remainder of the paper is organized as follows. The next section outlines the model framework. Section 3 conducts empirical analyses of the multiple sourcing sorting patterns with alternative specifications and robustness checks. Section 4 concludes.

2.2 A Simple Model of Multiple Sourcing

2.2.1 Preferences and Demand

Consider the Melitz (2003) framework with heterogeneous firms, where the world consists of two countries, domestic and foreign, denoted by country 1 and 2 respectively. Domestic consumers have CES preference over a consumption composite of a continuum of industries j:

$$U_j = q_0 + \frac{1}{\mu} \sum_{j=1}^{J} Q_j^{\mu} dj, \quad 0 < \mu < 1 \tag{2.1}$$

where q_0 is the consumption of a homogeneous good. A firm chooses a measure of products $\kappa \in [0,1]$ to produce. Q_j is a composite of consumption in industry j over the aggregate of all products produced by firms in the industry, given by:

$$Q_j = \left[\int_{i \in \Omega} \int_0^{\kappa(i)} q_j(i,z)^{\alpha} dz di \right]^{\frac{1}{\alpha}} \tag{2.2}$$

α denotes the elasticity of substitution between different products. Note that the elasticity is the same both within a firm and between firms, which means every product, regardless of where it is produced, will be equally aggregated from a consumer's perspective. Similar to Tintelnot (2014), this assumption serves to simplify the pricing decision of the firm. We can solve for the familiar demand function for a product $q_j(i,z)$:

$$q_j(i,z) = A_j p_j(i,z)^{-\frac{1}{1-\alpha}} \tag{2.3}$$

where $A_j = Q_j^{\frac{\mu-\alpha}{1-\alpha}}$ is a measure of the industry level demand. Using equation (3) above, the revenue for firm i from selling product z is given by:

$$R_j(i,z) = A_j^{1-\alpha} q_j(i,z)^{\alpha} \tag{2.4}$$

2.2.2 Firm's Problem and Heterogeneity

Now I move on to the firm's problem. From here on I omit the industry subscript on all variables and assume that firms only sell to domestic customers with preferences and demand given above. Firms use labor as the only factor of production. To produce a product, a firm combines headquarter services h, which is produced in the home country with an intermediate input m that needs to be sourced from a supplier:

$$q(i,z) = \theta(i) \left(\frac{h(i,z)}{\eta} \right)^{\eta} \left(\frac{m(i,z)}{1-\eta} \right)^{1-\eta} \tag{2.5}$$

Following Antras and Helpman (2004), $\theta(i)$ is a firm-level measure of productivity, η is an industry-level measure of headquarter intensity and headquarter services can only be produced in the home country. Recall that a firm can produce a multitude of products using the production function above, but the intermediate inputs for each product need to be sourced separately from heterogeneous suppliers. As a product is associated with its intermediate good supplier, I can denote both the product and supplier by z. Therefore, it can be perceived as that a firm has a measure 1 of blueprints $z \in (0, 1)$ and faces a measure 1 of suppliers, each producing the intermediate input for a certain blueprint. The firm can freely approach any supplier to produce a new product, but it will eventually only choose a measure $\kappa(i) \in [0, 1]$ of suppliers. This is because the suppliers are heterogeneous in their sourcing fixed costs, rendering some too costly for a firm to source from.

It becomes clear that in this model setting a firm's sourcing decision with any supplier is completely independent of others. There are no cannibalization effects nor complementarity between products that are usually incorporated in other models in the literature. The independence assumption allows me to simplify the model tremendously without loss of generality, which facilitates the addition of supplier-side heterogeneity later on. Given the separable nature of each supplier, I shall lay out a firm's contracting environment with a single supplier before describing the heterogeneity in detail.

A firm decides simultaneously the location and organization of a supplier. The location could be either domestic or foreign, differing in their labor costs given by w_1 and w_2. On the organizational choices, the firm chooses if the supplier will be integrated as a subsidiary within the boundaries of the firm, or traded at arms-length through outsourcing. I follow the literature on property rights (Grossman and Hart (1986), Hart and Moore (1990)) in assuming that the contract is incomplete. This could be attributed to the fact that investment in inputs cannot be written into enforceable contracts, as they are impossible to be specified ex-ante and remain unverifiable ex-post. Furthermore, the parties cannot commit to not renegotiating the initial contract. Under this environment, a hold-up problem emerges and the firm needs to bargain with the supplier after their investments are sunk. As is common in the literature, the bargaining power of the firm depends on the organizational form it chooses for the supplier. I assume that the firm obtains a share $\beta^O \in [0,1]$ of the ex-post revenue from the relationship if the supplier is outsourced, and a share of $\beta^I \in [0,1]$ if the supplier is integrated. The supplier receives a fraction $1-\beta^O$ and $1-\beta^I$ respectively. It is assumed that $\beta^I > \beta^O$, as under integration the firm can threaten to seize a portion of the inputs provided by the supplier if bargaining breaks down, granting them higher bargaining power. In summary, the firm decides on one of the four sourcing modes, DO, FO, DI or FI, with its associated labor cost and revenue sharing plan for the supplier of every product.

I follow Antras and Helpman (2004) in assuming different fixed sourcing costs for the four sourcing modes from the supplier of each product, denoted by f^{DO}, f^{FO}, f^{DI} and f^{DI}. The exact ranking for these four fixed costs are:

$$f^{DO} < f^{FO} < f^{DI} < f^{FI} \tag{2.6}$$

The fact that foreign integration has the highest organizational fixed cost and domestic outsourcing is the lowest is conventional in the literature. However, I rank domestic integration above foreign outsourcing contrary to the set-up in Antras and Helpman (2004). This is because in the data I am using, domestic integration firms have slightly higher productivity than foreign outsourcers, as Kohler and Smolka (2009) has documented in their paper. The exact ordering of DI and FO firms is not essential to the qualitative and quantitative results of this paper.

I introduce heterogeneity to the suppliers by assuming varying degrees of sourcing friction resulting in different fixed costs for each supplier. This friction can be perceived, for example, as the heterogeneous nature of sophistication in producing new products causing varying degrees of sourcing difficulties. It is probably more appropriate to view this heterogeneity on the product level because there could be many suppliers competing for the contract for each product. The heterogeneity only exists between suppliers of different products, but not within a product. Nevertheless, as eventually only one supplier will win the contract and start producing, the heterogeneity is effectively transferred upon the suppliers and I shall carry on with the misnomer. The suppliers will each draw a sourcing friction parameter $n(z)$ from a distribution $G(n)$ with a lower bound on the support $n \geq 1$. Thus for supplier n, $(nf^{DO}, nf^{FO}, nf^{DI}, nf^{DI})$ is the menu of fixed costs corresponding to the four sourcing modes. Note that by applying a multiplicative constant to all costs, the exact ordering is preserved. This is both more realistic and allows for a more tractable analytical solution for the model.

2.2.3 Contracting Game

After establishing the heterogeneity among suppliers, I will next outline the structure of the game with the timing of events as follows:

- Firms pay a fixed cost f_e to enter the market. They draw a productivity from a distribution $F(\theta)$ a la Melitz (2003), usually assumed Pareto. After observing their draws, low productivity firms exit the market and do not produce. Remaining firms also observe the menu of fixed costs associated with the suppliers of the potential products $z \in (0, 1)$ they can produce.

- The firm decides simultaneously the number of products to produce and the sourcing mode for the supplier of each product. Specifically, a measure $\kappa \in (0, 1)$ of products will be chosen by the firm to start producing. For each product $z \in (0, \kappa)$, the firm posts a contract to potential suppliers specifying a lump-sum upfront transfer and an ex-post payment. The contract will also include the location and organizational mode of the supplier, which is decided by the firm based on the menu of fixed costs of the suppliers n.

- One supplier will be chosen for each product from the potential applicants. I assume that there are no outside opportunities for the suppliers, so they will accept the contract if the expected ex post payment plus the upfront transfer is at least equal to the cost of producing the intermediate input. Production will take place where the final good producer and suppliers independently decide on the input levels for $h(i, z)$

and $m(i,z)$ for each product z.

- After the investments are sunk, the parties bargain over the division of surplus from selling the products due to the incomplete nature of the contract. Again, for each supplier the relationship is product-specific, thus only the surplus from selling that one product (instead of the total surplus of the firm) can be bargained for. Rather than the multilateral bargaining game in Schwarz and Suedekum (2014) or Acemoglu *et al.* (2007), there will be separate mutually independent bargaining taking place for each supplier.

- The final goods are produced and the realized revenue distributed according to the bargaining agreement.

2.2.4 Solution and General Equilibrium

We can solve the above contracting game by backward induction. In the investment stage, both the firm and the suppliers make decisions taking into account their bargaining power in the later renegotiation, creating incentive compatible levels of headquarter and intermediate input investments. Foreseeing this behavior at the investment stage, the firm will optimally decide on the measure of products to produce and the sourcing mode assigned to each supplier. Note that in choosing the sourcing mode $l \in \{DO, FO, DI, FI\}$, the firm is effectively choosing the triplet $(\beta^l \in \{\beta^I, \beta^O\}, w^l \in \{w_1, w_2\}, f^l \in \{f^{DO}, f^{FO}, f^{DI}, f^{FI}\})$ that are final good producer's share of surplus, country-specific labor costs, and mode-specific sourcing fixed costs respectively. The overall program for firm i is:

$$\begin{aligned}
\max_{\kappa\in[0,1],l(z)} \pi(i,l,n,\theta) = \int_0^{\kappa} & R(i,z) - w_1 h(i,z) - w\big(l(z)\big)m(i,z) - w_1 n(z) f\big(l(z)\big)dz \\
s.t. \;\; h(i,z) &= argmax\big\{\beta^{l(z)}R(i,z) - w_1 h(i,z)\big\} \;\; \forall z \qquad \text{IC1} \\
m(i,z) &= argmax\big\{(1-\beta^{l(z)})R(i,z) - w_{l(z)} m(i,z)\big\} \;\; \forall z \qquad \text{IC2}
\end{aligned} \tag{2.7}$$

where IC1 and IC2 are incentive compatible constraints for the producer and supplier respectively. Note that the assumption of separability between products will simplify the solution considerably. As the above program shows, the total expected profit earned by a firm i is just the sum of expected profit from every product it decides to produce. Therefore, the solution is equivalent to solving all the single supplier problems separately. The firm will also have the incentive to produce as many products as possible without worrying about cannibalization, as long as the expected surplus from the relationship with the supplier is non-negative. Since the suppliers differ by their organizational fixed costs, the marginal supplier/product will have the sourcing friction n such that the ex-ante surplus from equation (7) just breaks even.

Because of the separability assumption, I can focus first on a single supplier with sourcing friction n below. Using the expression for $R(i,z)$ in equation (4) and solving the incentive constraints in (7), the solution for supplier n can be simplifed to:

$$\begin{aligned}\Pi(i,l,n,\theta) = \max_{l} \pi^{l}(i,n,\theta) &= Q^{\frac{\mu-\alpha}{1-\alpha}}(\theta\alpha)^{\frac{\alpha}{1-\alpha}}\psi^{l}(\eta) - w_1 n f^{l} \\ \text{where } \; \psi^{l}(\eta) &= \frac{1-\alpha\left[\beta^{l}\eta + (1-\beta^{l})(1-\eta)\right]}{\left[\left(\frac{w_1}{\beta^{l}}\right)^{\eta}\left(\frac{w^{l}}{1-\beta^{l}}\right)^{1-\eta}\right]^{\frac{\alpha}{1-\alpha}}}\end{aligned} \tag{2.8}$$

The result above is the same as in Antras and Helpman (2004). A sorting pattern thus emerges where low productivity firm is unprofitable and will not produce this product. There are clear-cut thresholds of productivity where firms will switch to more advanced sourcing mode with higher fixed cost and higher marginal returns. By the assumptions of this paper, if the wage differential between domestic and foreign isn't too large (so that we have $\psi^{DI} > \psi^{FO}$), the sorting productivity ordering will be domestic outsourcing $<$ foreign outsourcing $<$ domestic integration $<$ foreign integration. We can derive the threshold productivity of different sourcing modes as in the canonical models by solving:

$$\begin{aligned}\pi(i,DO,n,\theta_{EXIT}) &= 0 \\ \pi(i,DO,n,\theta_{DO}^{FO}) &= \Pi(i,FO,n,\theta_{DO}^{FO}) \\ \pi(i,FO,n,\theta_{FO}^{DI}) &= \Pi(i,DI,n,\theta_{FO}^{DI}) \\ \pi(i,DI,n,\theta_{DI}^{FI}) &= \Pi(i,FI,n,\theta_{DI}^{FI})\end{aligned} \tag{2.9}$$

At this point I am assuming the headquarter intensity η is high enough to warrant a sorting pattern of all four different sourcing modes. The case with low headquarter intensity and only outsourced suppliers will be discussed later. The results for solving the thresholds are:

$$
\begin{aligned}
\theta_{EXIT}(n) &= n^{\frac{(1-\alpha)}{\alpha}} Q^{\frac{\alpha-\mu}{\alpha}} \left(\frac{w_1 f^{DO}}{\psi^{DO}(\eta)} \right)^{\frac{(1-\alpha)}{\alpha}} \\
\theta_{DO}^{FO}(n) &= n^{\frac{(1-\alpha)}{\alpha}} Q^{\frac{\alpha-\mu}{\alpha}} \left(\frac{w_1 (f^{FO} - f^{DO})}{\psi^{FO}(\eta) - \psi^{DO}(\eta)} \right)^{\frac{(1-\alpha)}{\alpha}} \\
\theta_{FO}^{DI}(n) &= n^{\frac{(1-\alpha)}{\alpha}} Q^{\frac{\alpha-\mu}{\alpha}} \left(\frac{w_1 (f^{DI} - f^{FO})}{\psi^{DI}(\eta) - \psi^{FO}(\eta)} \right)^{\frac{(1-\alpha)}{\alpha}} \\
\theta_{DI}^{FI}(n) &= n^{\frac{(1-\alpha)}{\alpha}} Q^{\frac{\alpha-\mu}{\alpha}} \left(\frac{w_1 (f^{FI} - f^{DI})}{\psi^{FI}(\eta) - \psi^{DI}(\eta)} \right)^{\frac{(1-\alpha)}{\alpha}}
\end{aligned} \tag{2.10}
$$

It is clear that compared to the classical model, the addition of a constant multiplicative sourcing friction will eventually result in an increase of all the thresholds by a multiple of $n^{\frac{(1-\alpha)}{\alpha}}$. Intuitively, products that have greater n, or higher sourcing friction, will become more difficult for the producer to access. It will also be harder for the producer to use more advanced sourcing modes as the initial upfront requirements are higher.

Before solving for general equilibrium, we need to know how a firm chooses the measure z of products to produce and source. From the firm's problem in equation (7), it is straightforward to see that the firm would like to produce as many products as its productivity allow. In other words, a firm will keep adding new products to its catalog until all remaining potential products require a sourcing fixed cost too high to engage the supplier profitably. Using the distribution of the sourcing friction n, the measure κ chosen by a firm with productivity $\theta(i)$ is simply given by:

$$
\begin{aligned}
\kappa(\theta) &= \int_1^{n(i)} dG(n) \\
\text{where } n(i) &= \frac{\theta(i)^{\frac{\alpha}{1-\alpha}} \psi^{DO}(\eta)}{Q^{\frac{\alpha-\mu}{1-\alpha}} w_1 f^{DO}}
\end{aligned} \tag{2.11}
$$

Note that the expression for $n(i)$ is just the inverse of the exit threshold function in (10).

This is because the marginal supplier a firm can engage is the one with the level of sourcing friction n that just breaks even the total surplus of the relationship. All remaining suppliers will yield a negative profit if the product is to be produced.

Several comparative statics are immediately apparent from (11). κ is an increasing function of n, which is in turn increasing in θ, decreasing in w_1 and decreasing in α. However, the comparative static of headquarter intensity is more ambiguous. It has the same sign as the partial derivative of $\psi(\eta)$ on η as the expression below shows:

$$\frac{\partial \psi^{DO}}{\partial \eta} = \frac{-\alpha(2\beta^O - 1) - \left[1 - \alpha(\beta^O\eta + (1-\beta^O)(1-\eta))\right]\left(\frac{\alpha}{1-\alpha}\right)\left[ln\left(\frac{w_1}{\beta^O}\right) - ln\left(\frac{w_1}{1-\beta^O}\right)\right]}{\left[\left(\frac{w_1}{\beta^O}\right)^{\eta}\left(\frac{w_1}{1-\beta^O}\right)^{1-\eta}\right]^{\frac{\alpha}{1-\alpha}}} \tag{2.12}$$

which could take either sign depending on the values of β^O, η, α and w_1. It is interesting, however, to observe that when $\beta^O = 1/2$, the partial derivative is zero. Therefore, if under outsourcing the firm and supplier use a 50-50 Nash bargaining, the number of products do not depend on headquarter intensity at all. As the canonical model implies, if the firm increases β, it will enjoy a larger share of the surplus. But by giving the suppliers a small share, it disincentivizes the investment in intermediate good at the same time . Therefore, high headquarter intensity firms usually allocate a larger share towards the final good producer, while low headquarter intensity firms give more to the suppliers. In this case under 50-50 Nash bargaining, these two counteracting effects cancel out: headquarter intensity will not affect the profitability of the relationship, and thus the exit threshold for the firm.

Since each product will be equally received in the market by consumers, increasing the number of products always means larger sales and larger labor force needed for the firm. Summarizing the results above, the following prediction naturally follows:

Prediction 1. *Firm's size, measured either by total sales or total number of employees, is increasing in productivity, decreasing in domestic wage rate, and decreasing in the elasticity of substitution between products.*

These predictions should not come as surprises. As productivity increases or domestic wage decreases, a firm can access more suppliers with higher fixed costs and produce more. When α decreases, products are less substitutable and generate more profit for a firm, also allowing them to access suppliers that are previously too costly to source from. Note that the increase in sales and employees can be further decomposed into an *intensive margin* effect and an *extensive margin* effect. On the intensive margin, more productive firms will have a larger incentive to invest more in headquarter services and produce a larger amount of one product. One the extensive margin, more productive firms will be able to overcome the fixed cost requirements of more suppliers to produce more unique products.

To solve for the general equilibrium in this framework, I need to first define the free-entry condition which ensures that the expected operating profits of a potential entrant break even with the fixed entry costs. Given the heterogeneity among suppliers, a firm will need to exit the entire market and not produce a single product if its productivity level θ is below the exit threshold for the supplier with lowest fixed costs: $\theta_{EXIT}(n = 1)$. The free-entry condition can be expressed as:

$$\int_{\theta_{EXIT}(n=1)}^{\infty} \int_{0}^{\kappa(\theta)} \Pi(Q, n, \theta, \eta) dG(n) dF(\theta) = w_1 f_e \tag{2.13}$$

The above free-entry condition combined with the thresholds defined in (10) and the measure of products defined in (11) pin down an implicit solution of the industry level consumption demand Q_j, thereby solving the general equilibrium system.

2.2.5 Heterogeneity and Multiple Sourcing Decisions

Going back to the suppliers who are heterogeneous in n, the productivity thresholds will also differ for all suppliers. Firms will use different sourcing modes for the measure of suppliers they contract with. As the optimal mode of sourcing depends on firm-level productivity as well as the fixed costs of suppliers, multiple sourcing patterns naturally emerge. Figure 2.1 provides a graphical illustration of the multiple decision choices faced by firms.

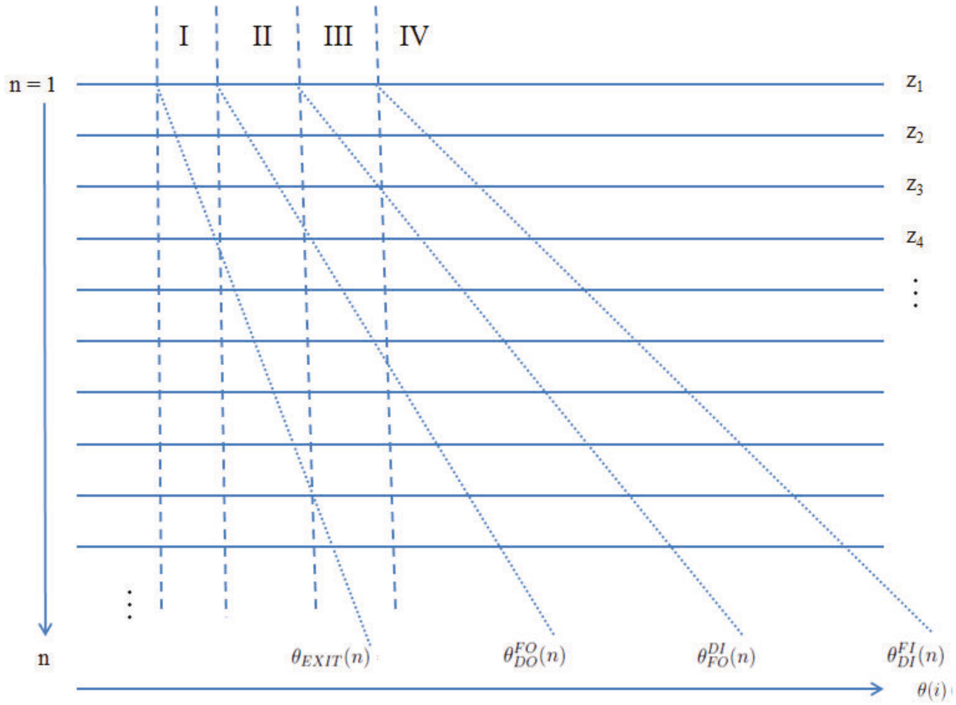


Figure 2.1: *Multiple Sourcing Choices by Firms*

It is clear from Figure 2.1 that under this simple assumption of heterogeneous sourcing friction, the number of sourcing modes used by firms is completely determined by its sourcing mode for the lowest-cost supplier with $n = 1$. This is because if the firm's productivity is high enough to switch to a more advanced organizational mode, the first switch will take place at the lowest-cost supplier. It also means that the sourcing mode used at the $n = 1$ supplier will be the most advanced in the firm's strategy set, together with all the modes that are less advanced. It then follows that the firm's sourcing choice {DO, FO, DI, FI} at $n = 1$ will correspond to {1, 2, 3, 4} as the total number of sourcing modes respectively. As the sourcing choice at lowest-cost supplier progresses when firm productivity increases, so is the number of sourcing modes. This model thus delivers a 'pecking order' in the multiple sourcing patterns: the sourcing strategy set of firms will always expand by using domestic outsourcing first, followed by foreign outsourcing, then domestic integration, and lastly foreign integration, in that exact order.

I will then discuss briefly the importance of industry level headquarter intensity. Figure 2.1 displays the sorting pattern with four distinct sourcing modes. Within this equilibrium, the effect of headquarter intensity on the number of modes used by firms is difficult to analyze. This is due to the profit function and thresholds also depend on the relationships between different fixed costs, wages rates, and bargaining power. But as Antras and Helpman (2004) demonstrates, the above scenario is only for the headquarter-intensive industry. When the headquarter intensity is below a certain threshold, i.e. in a component-intensive industry, all intermediate goods will be outsourced. All the results still hold in this context, except that now the maximum number of possible modes is two instead of four in a headquarter-intensive sector. Therefore, when we control for the industry, headquarter intensity could have very nuanced and indeterminate effects on the multiple sourcing choices. But economy-wise, the higher headquarter intensity would unlock domestic and foreign integration as new sourcing modes for high productivity firms. Figure 2.2 shows a plot of an average number of sourcing modes of different industries against their average capital intensity over the years. The support for a positive association between the two is evident.

Summarizing the results above, the next prediction immediately follows:

Prediction 2. *The number of sourcing modes used by a firm is increasing in its productivity, and generally increasing in headquarter intensity. Furthermore, the optimal sourcing strategy set $\mathcal{S}(\theta)$ for a firm with productivity θ follows a 'pecking order': it is always such that $\mathcal{S}(\theta_L) \subseteq \mathcal{S}(\theta_H)$ if $\theta_L < \theta_H$.*

Next, we can calculate the relative prevalence of the firms with different numbers of sourcing modes. It is very straightforward under this particular setting of the model. Since the number of sourcing modes corresponds to the type of organizational form at the $n = 1$ supplier, the composition can be calculated directly from the latter measure. In fact, the result will be the same as in Antras and Helpman (2004). Borrowing from their paper, I assume the productivity distribution to be Pareto with scale parameter b and shape parameter v:

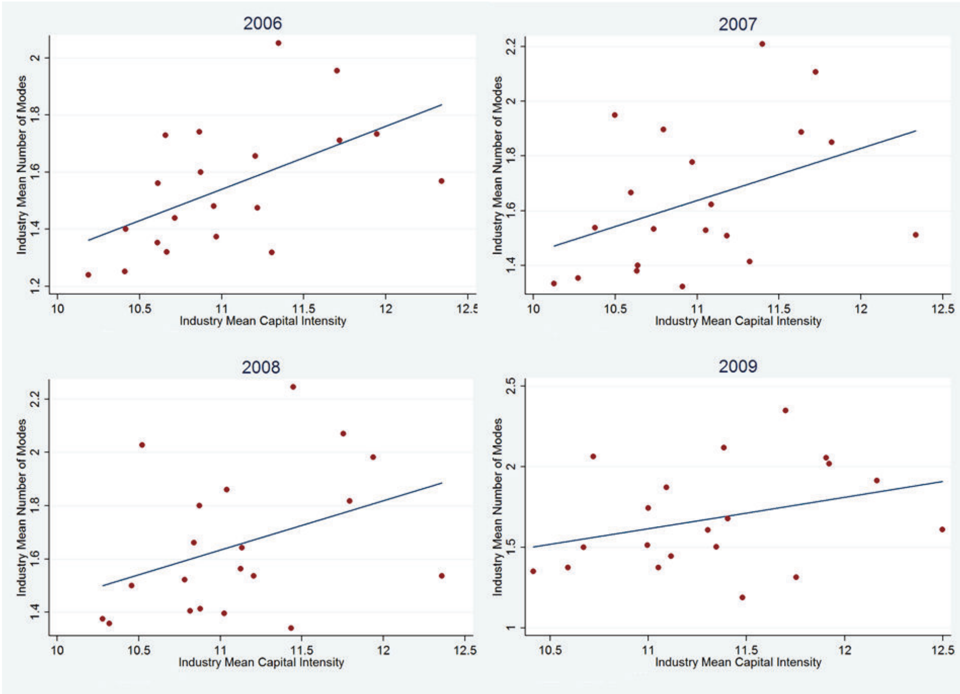


Figure 2.2: *Relationship between Multiple Sourcing and Industry Headquater Intensity*

$$F(\theta) = 1 - (\frac{b}{\theta})^{v} \quad \forall \theta > b > 0 \tag{2.14}$$

The threshold for adding new sourcing modes is the same as the threshold for switching to a more advanced sourcing mode at the $n = 1$ supplier. The total measure of active firms ranges from the exit threshold (which is also at $n = 1$) to infinity. Therefore, using (10) and (14) we can calculate the proportion of firms with different multiple sourcing strategies as follows:

$$
\begin{aligned}
s^1 &= \frac{F(\theta_{DO}^{FO}(1)) - F(\theta_{EXIT}(1))}{1 - F(\theta_{EXIT}(1))} = 1 - [\frac{\psi^{FO} - \psi^{DO}}{\psi^{DO}} \frac{f^{DO}}{f^{FO} - f^{DO}}]^{\frac{z(1-\alpha)}{\alpha}} \\
s^2 &= \frac{F(\theta_{FO}^{DI}(1)) - F(\theta_{DO}^{FO}(1))}{1 - F(\theta_{EXIT}(1))} = [\frac{\psi^{FO} - \psi^{DO}}{\psi^{DO}} \frac{f^{DO}}{f^{FO} - f^{DO}}]^{\frac{z(1-\alpha)}{\alpha}} - [\frac{\psi^{DI} - \psi^{FO}}{\psi^{DO}} \frac{f^{DO}}{f^{DI} - f^{FO}}]^{\frac{z(1-\alpha)}{\alpha}} \\
s^3 &= \frac{F(\theta_{DI}^{FI}(1)) - F(\theta_{FO}^{DI}(1))}{1 - F(\theta_{EXIT}(1))} = [\frac{\psi^{DI} - \psi^{FO}}{\psi^{DO}} \frac{f^{DO}}{f^{DI} - f^{FO}}]^{\frac{z(1-\alpha)}{\alpha}} - [\frac{\psi^{FI} - \psi^{DI}}{\psi^{DO}} \frac{f^{DO}}{f^{FI} - f^{DI}}]^{\frac{z(1-\alpha)}{\alpha}} \\
s^4 &= \frac{1 - F(\theta_{FO}^{DI}(1))}{1 - F(\theta_{EXIT}(1))} = [\frac{\psi^{FI} - \psi^{DI}}{\psi^{DO}} \frac{f^{DO}}{f^{FI} - f^{DI}}]^{\frac{z(1-\alpha)}{\alpha}}
\end{aligned}
\tag{2.15}
$$

where s^1, s^2, s^3, s^4 are the fractions of firms with 1, 2, 3, and 4 multiple sourcing modes respectively. Given the similar expressions above to the canonical model, the rich set of predictions for the prevalence of multiple sourcing strategies follows. Any variable that affects the profitability measure ψ, such as foreign wages, transportation costs, headquarter intensity, integration share to the producer, etc, will have an impact on the relative fraction of the multiple sourcing strategies. Antras and Helpman (2004) gives a detailed discussion of the different cases, which I do not delve into here.

2.2.6 Prevalence of Within Firm Sourcing Modes

When the firms have the ability to sourcing multiple modes simultaneously, it opens up a new dimension for analysis that is novel in the literature: the within firm composition of different sourcing modes. In order to quantify the fractions of different modes within a firm, I need to assign firms a functional form to the distribution of n, the heterogeneous sourcing friction among suppliers. As n is bounded below by 1 and unbounded above, it is natural to again use the Pareto distribution with a shape parameter ω and scale parameter 1:

$$G(n) = 1 - (\frac{1}{n})^{\omega} \quad \forall n > 1 \tag{2.16}$$

A firm will source the lowest n suppliers with the most advanced organizational mode it can achieve. From prediction 2 above we know that the firm will also use all the lesser advanced modes in its strategy set, as soon as the sourcing friction n surpasses a switching threshold. For further analysis recall the set of equations in (10), which was used to describe between-firm threshold productivities for a given supplier n. I transform these equations to represent the within-firm threshold sourcing frictions for a given productivity θ:

$$
\begin{aligned}
n_{EXIT}(\theta) &= \theta^{\frac{\alpha}{1-\alpha}} \frac{\psi^{DO}(\eta)}{Q^{\frac{\alpha-\mu}{1-\alpha}} w_1 f^{DO}} \\
n_{DO}^{FO}(\theta) &= \theta^{\frac{\alpha}{1-\alpha}} \frac{\psi^{FO}-\psi^{DO}}{Q^{\frac{\alpha-\mu}{1-\alpha}} w_1 (f^{FO}-f^{DO})} n_{FO}^{DI}(\theta) \quad = \theta^{\frac{\alpha}{1-\alpha}} \frac{\psi^{DI}-\psi^{FO}}{Q^{\frac{\alpha-\mu}{1-\alpha}} w_1 (f^{DI}-f^{FO})} \\
n_{DI}^{FI}(\theta) &= \theta^{\frac{\alpha}{1-\alpha}} \frac{\psi^{FI}-\psi^{DI}}{Q^{\frac{\alpha-\mu}{1-\alpha}} w_1 (f^{FI}-f^{DI})}
\end{aligned}
\tag{2.17}
$$

A firm will be able to domestically outsource from all suppliers with n smaller than $n_{EXIT}(\theta)$. If the firm's productivity exceeds $\theta_{DO}^{FO}(1)$, it will start using foreign outsourcing for suppliers with n smaller than $n_{EXIT}(\theta)$ but larger than $n_{DO}^{FO}(\theta)$. Similarly, as suppliers' n value crosses down the thresholds defined above, the firm will source them using a mode that is one notch more advanced. Figure 2.3 below demonstrates the sourcing pattern for a firm with three multiple sourcing modes.

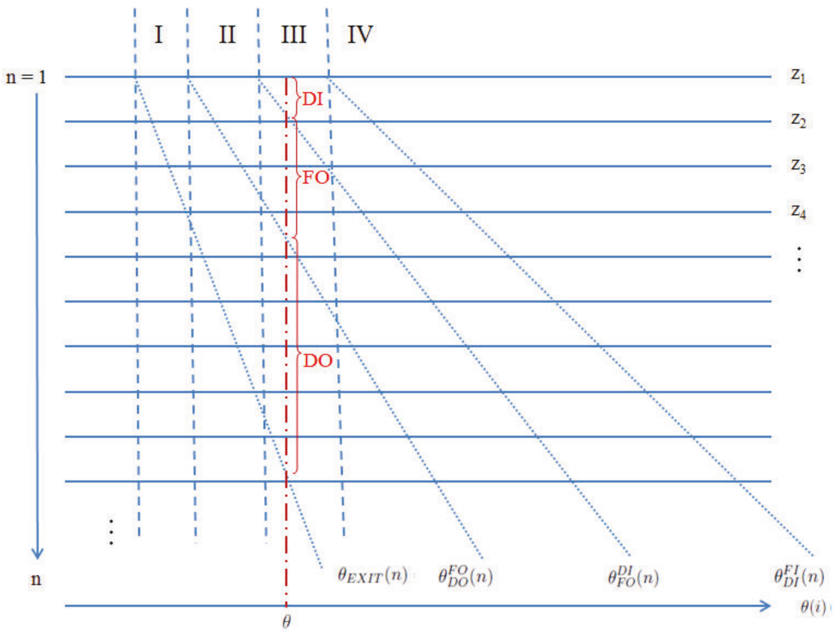


Figure 2.3: *Multiple Sourcing and the Composition of Modes within a Firm*

The fraction of different sourcing modes used by a firm can then be derived using the thresholds above and the distribution of n. I show the results below categorized by the number of simultaneous modes used:

$$\begin{aligned}
&\text{One mode, } \theta_{EXIT}(1) < \theta < \theta_{DO}^{FO}(1), \; s_1^{DO}(\theta) = \frac{G(n_{EXIT}(\theta))}{G(n_{EXIT}(\theta))} \\
&\text{Two modes, } \theta_{DO}^{FO}(1) < \theta < \theta_{FO}^{DI}(1), \; s_2^{DO}(\theta) = \frac{G(n_{EXIT}(\theta)) - G(n_{DO}^{FO}(\theta))}{G(n_{EXIT}(\theta))} \\
&\qquad s_2^{FO}(\theta) = \frac{G(n_{DO}^{FO}(\theta))}{G(n_{EXIT}(\theta))} \\
&\text{Three modes, } \theta_{FO}^{DI}(1) < \theta < \theta_{DI}^{FI}(1), \; s_3^{DO}(\theta) = \frac{G(n_{EXIT}(\theta)) - G(n_{DO}^{FO}(\theta))}{G(n_{EXIT}(\theta))} \\
&\qquad s_3^{FO}(\theta) = \frac{G(n_{DO}^{FO}(\theta)) - G(n_{FO}^{DI}(\theta))}{G(n_{EXIT}(\theta))} \\
&\qquad s_3^{DI}(\theta) = \frac{G(n_{FO}^{DI}(\theta))}{G(n_{EXIT}(\theta))} \\
&\text{Four modes, } \theta > \theta_{DI}^{FI}(1), \; s_4^{DO}(\theta) = \frac{G(n_{EXIT}(\theta)) - G(n_{DO}^{FO}(\theta))}{G(n_{EXIT}(\theta))} \\
&\qquad s_4^{FO}(\theta) = \frac{G(n_{DO}^{FO}(\theta)) - G(n_{FO}^{DI}(\theta))}{G(n_{EXIT}(\theta))} \\
&\qquad s_4^{DI}(\theta) = \frac{G(n_{FO}^{DI}(\theta)) - G(n_{DI}^{FI}(\theta))}{G(n_{EXIT}(\theta))} \\
&\qquad s_4^{FI}(\theta) = \frac{G(n_{DI}^{FI}(\theta))}{G(n_{EXIT}(\theta))}
\end{aligned} \tag{2.18}$$

These fractions depend on the values of the n thresholds for a given productivity. Given the expressions in (17), the fractions thus in turn depend on the domestic and foreign wage rates, sourcing fixed costs, bargaining power, etc. For this paper, I am interested in the relationship between productivity and the within-firm fractions for different sourcing modes.

Combining the expressions above and the functional form for $G(n)$, one can easily deduce that $G(n)$ is increasing in productivity. Hence, the absolute measure of suppliers for each sourcing mode always rises with productivity. This can be clearly seen from Figure 2.3 as well, where the vertical distances between the threshold lines - representing the measure of suppliers for that particular mode - are increasing in productivity. However, the effect of productivity on the fraction of a sourcing mode among all suppliers sourced turns out to be more nuanced:

Prediction 3. *For a firm with multiple sourcing strategies, the fraction of domestically sourced suppliers is always decreasing in productivity, while the fraction of foreign integrated suppliers is always increasing in productivity. For foreign outsourced and domestically integrated suppliers, the fraction will initially rise when the sourcing mode is the most advanced in the strategy set, but decrease when more advanced sourcing mode is added.*

I provide a brief proof of the above results in Appendix A. Intuitively, increasing productivity will allow firms to expand its product measure and at the same time utilize more advanced (high fixed cost, high marginal profit) sourcing modes. When a firm adds a new mode to the multiple sourcing strategy set, the relative proportion of suppliers that use the pre-existing modes will shrink to make way for the new mode, a cannibalization effect. The fraction of suppliers using a new mode will keep increasing as long as it is the most advanced sourcing strategy until another new mode is added and starts cannibalizing its share too. From the pecking order property of multiple sourcing, domestic outsourced suppliers are always at the lowest echelon and have their shares cannibalized from the beginning as productivity rises. Foreign integrated suppliers are always using the most advanced sourcing strategy and cannibalizing shares of other modes, thus their fraction will keep increasing with productivity. The medium modes, i.e. foreign outsourcing and domestic integration, will see their fractions increase as long as they are the in the highest echelon, and decrease as soon as they are overtaken by more advanced modes.

2.3 Empirical Strategies

2.3.1 Data Description

In this section, I test the predictions of the model in section 2. For empirical analysis, I use the data from the annual business survey conducted by Fundacion SEPI. The survey ranges from 1992 to 2009 and covers about 2000 firms annually. All large firms (more than 200 employees) are invited to take part in the survey while about 5% of small firms (10-200 employees) are sampled randomly.

The main advantage of the data is its detailed firm-level information on sourcing decisions that is crucial to this paper. Firms participating in the survey answer direct questions on the type of sourcing they conduct. Specifically, the responses of central interests are: (1) *Intermediate purchases to related firms in Spain*; (2) *Intermediate purchases to other (not related) firms in Spain*; (3) *Percentage of intermediate imports from other firms in the same group*; and (4) *Percentage of intermediate imports from other firms*. The records of above responses correspond directly to the sourcing mode DI, DO, FI and FO. In addition, the firms report *percentages* in value of a certain sourcing mode they conduct, allowing us to test the predictions on the within-firm fractions of different modes[1]. A major drawback of the data is that the sourcing information was only available from 2006 to 2009[2], rendering causal analysis using panel techniques difficult for such a short period. Nevertheless, the data from previous years contain other important firm-level variables such as entry/exit, capital stock, labor hired, and capital investment. This information could be used to construct productivity measures that mitigate selection bias and simultaneity bias a la Olley and Pakes (1996). Kohler and Smolka (2009) provides a detailed description of the data, emphasizing

---

[1]In fact, the raw data reports the percentages of intermediate purchases (domestic) that are outsourced or integrated; the percentages of intermediate imports (foreign) that are outsourced or integrated; and the values of intermediate purchases and imports. I construct the overall percentages as follows: pct of $DO = \frac{\text{pct of intermediate purchases outsourced} * \text{value of intermediate purchases}}{\text{value of intermediate purchases} + \text{value of imports}}$ and similarly for other sourcing modes.

[2]At the time when this paper is conceived, the data set only contains years up to 2009. It has since expanded the scope every year. By 2015, the data already contains information up to the year 2013 for most variables. However, this paper will focus on the original data set up till 2009.

on the sourcing decisions of the firms.

There is a vast literature investigating the relationship between sourcing strategies and productivity. Nunn and Trefler (2008) uses US firms' imports from foreign affiliates to test the predictions in Antras (2003) and Antras and Helpman (2004). They find that intra-firm trade increases in firms with more intensive headquarter services, or that are more skill- and capital-intensive. It is worth noting that using import data to proxy for sourcing could be imprecise as imports by a firm may not be used in intermediate production. Tomiura (2007) and Federico (2010) make use of similar survey data for Japanese and Italian firms, which precisely asks about firm's sourcing choices. They find that more productive firms are indeed more likely to source from abroad than domestically. More notably, Farinas and Martín-Marcos (2010) and Kohler and Smolka (2009) both use the same data set as this paper on Spanish manufacturing firms and set out to test the predictions of sourcing premia in productivity as laid out in Antras and Helpman (2004). Both employing the Kolmogorov-Smirnov test for first order stochastic dominance, they find that foreign sourcing has a significant productivity premia over domestic sourcing. However, despite acknowledging the existence of multiple sourcing in many of these papers, the relationship between multiple sourcing strategies and productivity has not been given much attention.

2.3.2 Summary Statistics

Before outlining the empirical framework, I first construct several crucial variables using the available panel data. First, productivity is the centerpiece of my analysis. The detailed firm-level information in the data allows me to follow Olley and Pakes (1996) to estimate the production function while controlling for potential simultaneity and selection bias. Second, firm size needs to be accounted for. This is both because it has been shown in the literature to be one of the most significant characteristics that affect firm decisions, as well as the fact that there is an oversampling of large firms (number of employee $>$ 200) in the data set. I use the natural log of total employees to proxy for the size of the firm. I follow Antras (2003) in using capital intensity as a proxy for headquarter intensity of a firm, which is defined as the log ratio of total capital stock over total employees. Note that while the model assumes that capital intensity is an industry-level variable, the same result on the firm-level holds even if we allow for varying intensity within an industry. Thus, I construct the capital intensity measure for each firm and year. From Predictions 1 and 2, we would expect a strong positive association between a firm's number of sourcing modes, its productivity, firm size as well as capital intensity.

Table 2.1 provides a snapshot summary of the sample data in the year 2008. Note that the O-P productivity measure has been transformed to relative productivity on the industry level, where the industry average is normalized to 100. This transformation serves to isolate the industry specific effects on productivity that might bias the statistics to high value-added industries. The summary is split into two parts: first, in Table 2.1.1 I categorize firms by the number of distinct sourcing modes they simultaneously employ. The table intends to display the general pattern of multiple sourcing by simply comparing the degree of variation in sourcing strategies. Second, in Table 2.1.2 I examine in depth the type of sourcing modes used by multiple sourcing firms. The modes and combinations of modes in this table are mutually exclusive, which paints a detailed picture of the evolution of multiple sourcing strategies when the productivity or other characteristics of firms change. Given the presupposed ranking of sourcing modes in the model, the table aims demonstrate in general if the 'pecking order' of multiple sourcing in Predictions 2 holds.

The results presented in Table 2.1.1 strongly supports our hypothesis. The relative productivity of firms is increasing throughout as the number of modes increases: from 0.82% below the industry average for a single sourcing firm to 1.57% above the industry average in a quadruple sourcing firm. Figure 2.4 plots the probability density of firms with a different number of sources on the productivity scale. The probability density graphs noticeably shifts to the right as the number of modes increases, giving a graphical representation of the above observation.

Recall that in the model, as a firm becomes more productive, it will be able to overcome the higher fixed costs of suppliers and engage in the production of more products. Firm

Table 2.1: *Summary Statistics by Multiple Sourcing modes, 2008*

Table 2.1.1	Number of Multiple Sourcing Modes				
	1	2	3	4	Total
Number	813	544	212	55	1624
Percentage	50.1%	33.5%	13.1%	3.4%	100%
Relative Prod.	99.18	100.67	101.30	101.57	100
Cap. Intensity	10.78	11.29	11.62	11.74	11.09
Log Firm Size	3.56	4.49	5.62	6.10	4.23

Table 2.1.2	Mutually Exclusive Multiple Sourcing Strategies							
	DO	FO	DI	FI	DOFO	DODI	DOFI	FODI
Number	765	29	17	2	443	76	14	3
Percentage	47.1%	1.8%	1.0%	0.1%	27.3%	4.7%	0.9%	0.2%
Productivity	99.09	100.37	100.16	107.31	100.43	101.35	103.50	101.71
Cap. Intens.	10.75	11.19	11.21	11.98	11.19	11.82	11.35	11.68
Firm Size	3.49	4.44	5.05	5.58	4.32	5.18	5.42	5.51
	FOFI	DIFI	DOFODI	DOFOFI	DODIFI	FODIFI	DOFODIFI	
Number	7	1	104	98	7	3	55	
Percentage	0.4%	0.1%	6.4%	6.0%	0.4%	0.2%	3.4%	
Productivity	102.00	105.31	100.77	101.54	104.75	103.31	101.57	
Cap. Intens.	11.70	12.62	11.68	11.62	11.27	10.39	11.74	
Firm Size	5.14	5.52	5.48	5.68	6.61	6.26	6.10	

Notes: Productivity is relative to industry average of 100. Non-sourcing firms excluded from sample. Capital intensity is the log ratio of total capital over total employment. Firm size is the log of total employment.

size, on the other hand, is directly determined by the measure of products a firm chooses to produce, thereby also increasing in productivity. For headquarter intensity, the model predicts a cut-off threshold above which a firm can use all four sourcing modes simultaneous, and below which the firm outsources all its products, thereby using a maximum of two modes. Both hypotheses find convincing evidence in Table 2.1.1, where firm size and capital intensity are monotonically increasing in the number of sourcing modes. Unsurprisingly, single sourcing is the most prevalent form, comprising half of all Spanish firms. As we will see next, a predominant fraction (around 95%) of the single sourcing firms uses domestic outsourcing. Since it is the cheapest and most accessible organizational form, this prevalence is to be expected if we have a highly skewed distribution of θ in the economy, such as the Pareto distribution assumed.

Table 2.1.2 takes a closer look at the exact multiple sourcing strategies of firms. The key pattern to look for here is the 'pecking order' hypothesis from the theoretical section: that if

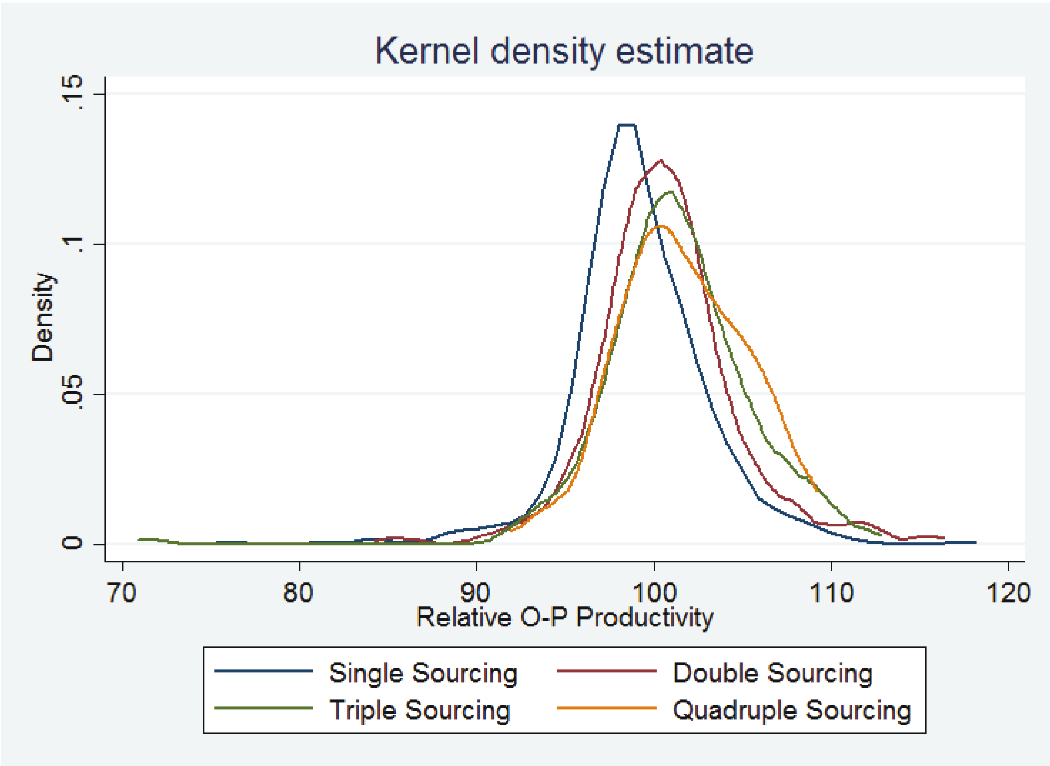


Figure 2.4: *PDF of Firms by Multiple Sourcing Modes*

firm A has less sourcing modes than firm B, the multiple sourcing strategy set of A is a subset of that of B. In other words, when firms add new sourcing mode to their strategy set, they always follow a sequential ordering (DO $\rightarrow$ FO $\rightarrow$ DI $\rightarrow$ FI) where the less advanced mode is added first. It immediately follows that the model predicts multiple sourcing strategies of only the following combinations: DO, DOFO, DOFODI, and DOFODIFI. Indeed, DO, DOFO, and DOFODI are the most prevalent forms of multiple sourcing in Table 2.1.2, and naturally the most prevalent among peers with the same number of modes. Among the single sourcing firms, DO is more than 25 times more prevalent than the second highest, FO. Among the double sourcing firms, DOFO is more than 5 times more prevalent than DODI which comes second. The triple sourcing strategy is less clear-cut: DOFOFI trails closely behind DOFODI. While the results shown lends rather strong support to the 'pecking order' theory, it is interesting to note that the multiple sourcing strategy becomes more varied as the number of modes increases. This could be explained by the increased firm size and productivity with firms using more sourcing modes, so they have more resources/networks to choose different combinations of modes that do not obey the usual pecking order. In fact, the outliers in Table 2.1.2 with only single digit firms such as FI, DOFI, DIFI, DODIFI or FODIFI all have disproportionately high levels of productivity compared to their peers.

2.3.3 Impact of Productivity on the Number of Modes

In this section, I estimate a regression framework to quantify the impact of productivity on firm's multiple sourcing choices. Note that in this case the dependent variable is the number of modes, which only takes on values from 1 to 4. As the number itself only represent a level increase in the complexity of sourcing strategy and does not carry much quantitative meaning, I use the ordered logit framework to estimate the following model:

$$
\begin{aligned}
\text{o.logit}(Modes_{ijt}) &= \beta_0 + \beta_1 OPprod_{ijt} + \beta_2 OPprod_{ij,t-1} + \beta_3 Age_{ijt} + \beta_4 TradeIntensity_{ijt} \\
&\quad + \beta_5 ForeignCap_{ijt} + \beta_6 Size_{ijt} + \beta_7 CapIntensity_{ijt} \\
&\quad + \lambda_j + \lambda_t + \epsilon_{ijt} \\
&\text{where} \\
TradeIntensity_{ijt} &= \frac{TotalImport_{ijt} + TotalExport_{ijt}}{TotalSales_{ijt}} \\
CapIntensity_{ijt} &= \log\left(\frac{TotalCapital_{ijt}}{TotalEmployment_{ijt}}\right)
\end{aligned} \tag{2.19}
$$

where *Modes* is the number of simultaneous sourcing modes, *OPprod* is the O-P productivity measure, *Age* is the years since the firm is founded, *TradeIntensity* is a measure of total value of foreign trade (both import and export) normalized by sales, *ForeignCap* is the percentage of firm capitalization that is controlled by a foreign entity, *Size* is the log of total employees, *CapIntensity* is the log ratio of capital over employment, and lastly, λ_j and λ_t are industry and year fixed effects respectively.

The coefficient of interest is β_1, the contemporary effect of productivity on the multiple sourcing decision. In reality, however, productivity usually has longer term impacts on firm's decision-making, and sourcing choices may very well be determined before the current period. Therefore, a one period lagged productivity variable is included. Following the theoretical model predictions, I expect firm size as well as capital intensity to have positive effects on the number of modes. To minimize the effect of serial correlation within the firm, I calculate robust standard errors clustered at the firm level. Year and industry dummies are controlled for wherever possible to isolate specific effects corresponding to particular industries or time.

There is certainly a concern for endogeneity between productivity and the number of sourcing modes. For instance, the different sourcing modes may have a complementary effect on each other, facilitating knowledge spillover or lowering sourcing frictions across the board. Thus using multiple sourcing strategies could reversely cause a firm to have higher productivity. I use an instrumental variable approach to establish the direction of causality. The instrument used is logged expenditure on R&D, which should positively impact a firm's productivity but have no discernible effect on the sourcing modes. Note that I only instrument the current period productivity measure in the estimation, as the lagged productivity is less susceptible to endogeneity concerns described above. The IV will be implemented using ordered probit. As an additional check, I also implement the model using a GEE population average model. The results of both specifications are reported in Table 2.2.

Columns (1) and (5) in Table 2.2 impose no controls and can be perceived as the econometric counterpart of Figure 2.4, except with the addition of a lagged productivity variable. In columns (2) and (6), I include all the 'usual suspects' in trade literature that could potentially affect sourcing behavior: firm age, trade intensity and foreign control of firm capital. In columns (3) and (7), I include the two variables, firm size and capital intensity, that will also impact multiple sourcing modes as predicted by the theoretical model in this paper. The IV estimation includes all control variables as in (3).

The regression outcome reiterates that of Prediction 2, where increasing productivity

Table 2.2: *Estimation of Productivity Impact on Sourcing Modes: Olley-Pakes*

	Dependent Variable: Number of Simultaneous Sourcing Modes						
	Ordered Logit: Odds Ratio			IV	Population Average		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Prod.	1.411***	1.369***	1.251***	0.118**	0.0764***	0.0513***	0.0328**
	(0.083)	(0.098)	(0.091)	(0.051)	(0.015)	(0.015)	(0.015)
Prod.(-1)	1.371***	1.288***	1.097	0.0610	0.0813***	0.0466***	0.0177
	(0.086)	(0.098)	(0.080)	(0.040)	(0.014)	(0.015)	(0.014)
Age		0.993**	0.991***	-0.005***		0.00059	-0.0018*
		(0.0033)	(0.0033)	(0.002)		(0.001)	(0.001)
Trade Intens.		5.433***	2.641***	0.536***		0.493***	0.291***
		(0.879)	(0.447)	(0.094)		(0.056)	(0.053)
Foreign Cap.		1.012***	1.007***	0.003***		0.00515***	0.0032***
		(0.0017)	(0.002)	(0.001)		(0.001)	(0.001)
Size			1.723***	0.322***			0.200***
			(0.073)	(0.024)			(0.014)
Capital Intens.			1.222***	0.114***			0.0417***
			(0.065)	(0.029)			(0.125)
Marg. Effect	0.0001	0.0002	0.0025	0.0014			
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4434	4434	4434	4434	4238	4238	4238
Pseudo R^2	0.07	0.14	0.19				

Notes: Firms that do not source inputs are excluded. Average Marginal Effect is calculated for productivity at number of modes = 3. Constant is not reported. Marginal effect is at Modes = 3. Parentheses show standard errors. Robust standard errors clustered by firm are computed for regressions (1) - (3). * , ** and *** indicate significance at 10%, 5% and 1% respectively.

should correspond to an increase in sourcing modes. Even after accounting for firm size, capital intensity, and various other controls in column (3), a one unit increase in productivity is expected to increase the odds of adding a new mode by 25.1%. This effect is also found to be contemporary, as the lagged productivity coefficient becomes insignificant after controlling for size and capital intensity. On the other hand, firm size and capital intensity all have the expected positive sign and at the same time are highly significant. The IV results echo that of column (3), with the only exception being that the instrumented productivity coefficient is now significant at 5% level. For better interpretation and comparison between different specifications, I calculate marginal effects for the ordered logit and IV estimations in columns (1) - (4) where the number of sourcing modes equal 3. In column (3), an increase of 1 unit in productivity is found to increase the probability of employing 3 sourcing modes by 0.25%. Its IV counterpart in column (4) shows a slightly smaller increase of 0.14% in probability. The percentages may seem small, but keeping in mind that 3 sourcing modes are quite rare in the data (13% of all firms), the result is economically quite significant. The results under the GEE population average model is consistent with the ordered logit specification, which means that the same positive correlation between productivity and number of modes still holds for an average firm in the economy.

Table 2.3: *Estimation of Productivity Impact on Sourcing Modes: Per Capita Real Value-added*

	Dependent Variable: Number of Simultaneous Sourcing Modes						
	Ordered Logit: Odds Ratio			IV	Population Average		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Prod.	1.672***	1.444***	1.231***	0.107**	0.089***	0.0647***	0.0328**
	(0.125)	(0.107)	(0.088)	(0.050)	(0.017)	(0.016)	(0.015)
Prod.(-1)	1.181***	1.447***	1.133*	0.0803**	0.098***	0.0624***	0.0196
	(0.140)	(0.113)	(0.084)	(0.041)	(0.015)	(0.015)	(0.014)
Age		1.003	0.997	-0.001		0.00236***	-0.0007
		(0.002)	(0.002)	(0.001)		(0.001)	(0.001)
Trade Intens.		4.716***	2.629***	0.533***		0.474***	0.290***
		(0.766)	(0.444)	(0.094)		(0.056)	(0.053)
Foreign Cap.		1.012***	1.007***	0.004***		0.00506***	0.0032***
		(0.002)	(0.002)	(0.001)		(0.001)	(0.001)
Size			1.723***	0.323***			0.200***
			(0.073)	(0.024)			(0.014)
Capital Intens.			1.138**	0.0740**			0.0319**
			(0.064)	(0.031)			(0.127)
Marg. Effect	0.0002	0.0009	0.0039	0.0032			
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4467	4444	4435	4435	4273	4250	4239
Pseudo R^2	0.09	0.19	0.19				

Notes: Firms that do not source inputs are excluded. Marginal effect is calculated at number of modes = 3. Constant is not reported. Parentheses show standard errors. Marginal effect is at Modes = 3. Robust standard errors clustered by firm are computed for regressions (1) - (3). * , ** and *** indicate significance at 10%, 5% and 1% respectively.

For the purpose of robustness, I re-estimate the model in (19) using a different specification of firm productivity. The new productivity measure is calculated by taking the log ratio of real value-added over total employees, or the per capita real value-added of a firm. The regression results are displayed in Table 2.3. As we can see, outcomes of the two estimations with different productivity measures are broadly consistent with each other. In fact, the only notable difference is that capital intensity becomes less significant at 5% level under labor real value-added productivity, compared to 1% significance under O-P productivity. The IV results are still robust, with productivity coefficient significant at 5% level. In summary, there is rather convincing evidence that increasing productivity at the firm level will cause firms to simultaneously employing more sourcing strategies for the suppliers.

2.3.4 Impact of Productivity on the Composition of Different Modes

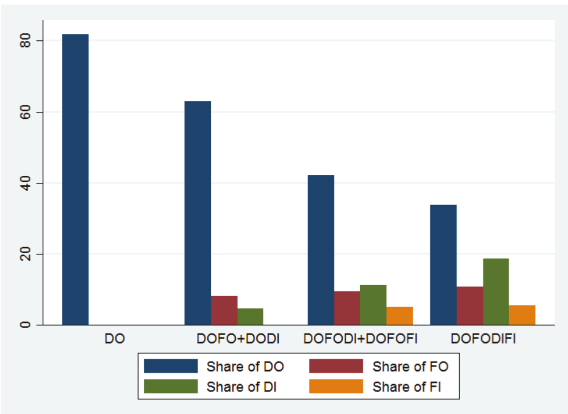
Prediction 3 states that the value share of domestically outsourced inputs should be monotonically non-increasing in productivity (monotonically decreasing if DO is not the only sourcing mode); the value share of foreign integrated inputs should be monotonically increasing in productivity; while foreign outsourcing and domestic integration shares will rise initially and decline afterward. Table 2.4 gives an overview of the descriptive statistics of the composition of sourcing modes within a firm.

Table 2.4: *Summary Statistics: Within-Firm Composition of Sourcing Modes, 2008*

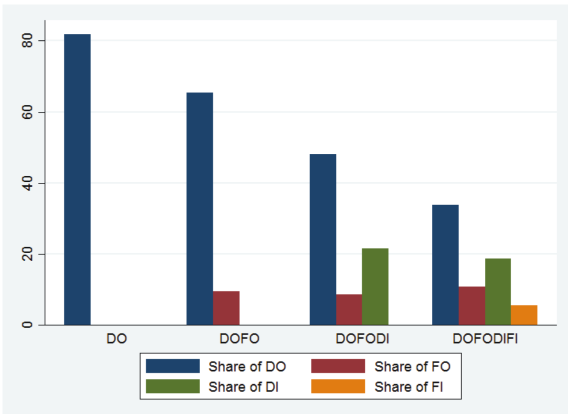
	Percentage of Intermediate Inputs Value by Sourcing Mode							
	DO		FO		DI		FI	
	All	Non-zero	All	Non-zero	All	Non-zero	All	Non-zero
Number	1649	1586	1651	757	1649	273	1651	190
Mean	65.4	68.0	4.4	9.6	4.3	25.7	1.2	10.1
Median	75.5	77.4	0	6.4	0	13.8	0	6.4
Min	0	0.6	0	0.001	0	0.6	0	0.04
Max	100	100	45.4	45.4	100	100	43.2	43.2
Std. Dev.	32.5	30.3	8.0	9.5	14.5	27.0	4.9	10.7

Under each sourcing mode in Table 2.4, the first column presents statistics of all firms. The overall prevalence is immediately obvious, echoing the pattern in Table 2.1: domestic outsourcing is the most used mode of sourcing not just between firms, but within the firm as well. The share of a firm's intermediate inputs that is sourced by DO is 65.4% on average, compared with 4.4% of the next highest mode, FO. In fact, because a large portion of the firms does not use sourcing modes other than DO at all, the average shares for other modes are severely downward biased: the median for FO, DI and FI are all zeros. The second column under each mode presents a more useful construction, which summarizes the modes conditional on it having non-zero within firm shares. The results reveal that the share of DO (68.0%) is still the predominant form of sourcing conditional on being used by a firm. Interestingly, the conditional share of FO (9.6%) is lower than that of DI (25.7%) and FI (10.1%), while its unconditional share (4.4%) is slightly higher than DI (4.3%) and FI (1.2%). It implies that FO is more prevalent between-firm, but less prevalent within-firm. In the model framework, this implies different shapes of the distribution function for between firm productivity $F(\theta)$ and within firm sourcing friction $G(n)$.

Coming back to the model prediction, recall that the shares of each mode change with productivity, thus also change with multiple sourcing choices. Figure 2.5 plots the average share of a mode within groups of firms with the same multiple sourcing strategies. To eliminate the effect of outliers, I only keep strategies (as shown in Table 2.1.2) that represent more than 2% of all firms. In panel (a), I categorize by the number of sourcing modes: under single sourcing there is only DO firms; under double sourcing are DOFO and DODI; under triple sourcing are DOFODI and DOFOFI; and all four modes under quadruple sourcing. Note that this characterization does not obey the exact 'pecking order' hypothesized by the model, which is plotted in panel (b).



(a) *Category: Number of Modes*



(b) *Category: Pecking Order Strategies*

Figure 2.5: *Composition of Sourcing Modes by Multiple Sourcing Strategies*

We can see a clear downtrend of domestic outsourcing share in both (a) and (b) as the number of modes increases. At the same time, all three other sourcing modes see an upward trend in their shares in panel (a). This is a strong indication that firms shift a greater share of their sourcing activities towards more advanced mode when their productivity increases. However, the 'pecking order' theory would predict that shares of modes decrease when a more advanced mode is added. Indeed, in panel (b) the share of DI decreases moving from DOFODI to DOFODIFI, and the share of FO decreases moving from DOFO to DOFODI, broadly consistent with the model prediction. There is, however, an increase of FO shares in the quadruple sourcing case that contradicts the 'pecking order'. This could very likely be caused by the high correlation between FO and FI. When FI is used as a sourcing mode, the firm is likely to have very large import values relative to domestic intermediate purchases, therefore boosting the value share of FO compared to the triple sourcing case.

Having found support of model predictions in the general pattern of sourcing composition, I next test the results using a regression framework given below:

$$\begin{aligned} Share^{l}_{ijt} &= \beta_0 + \beta_1 OPprod_{ijt} + \beta_2 TradeIntensity_{ijt} + \beta_3 Age_{ijt} + \beta_4 ForeignCap_{ijt} \\ &\quad + \beta_5 CapIntensity_{ijt} + \beta_6 Size_{ijt} + \lambda_j + \lambda_t + \epsilon_{ijt} \end{aligned} \tag{2.20}$$

where $Share^{l}$ is the fraction of total intermediate input value sourced using $l \in \{DO, FO, DI, FI\}$. I use the same set of controls as before with both industry and year fixed effects. As before, productivity is instrumented with log total expenditure in R&D to mitigate the concerns for reverse causation. Table 2.5 presents the regression results.

As expected, domestic outsourcing share displays a significant downward trend as productivity increases: 1 unit increase in log productivity measure is correlated with a 2.14 percentage drop in the share of domestic outsourcing in column (1). The IV result is less significant at 10% level with the same negative sign. Foreign integration, on the other hand, is positively correlated with productivity: 1 unit increase in log productivity corresponds to 0.59 percentage point increase in the shares of foreign integration with pooled OLS and

Table 2.5: *Estimation of Productivity Impact on the Composition of Multiple Sourcing*

	Dependent Variable: Share in Total Intermediate Inputs Value							
	DO		FO		DI		FI	
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Prod.	-2.14***	-1.68*	0.499**	0.484***	0.146	0.022	0.590***	0.414***
	(0.74)	(0.93)	(0.20)	0.20)	(0.47)	(0.59)	(0.14)	(0.13)
Trade Intens.	-29.5***	-29.5***	9.31***	9.31***	-4.29***	-4.29***	2.58***	2.57***
	(2.23)	(2.23)	(0.76)	0.75)	(1.23)	(1.23)	(0.45)	(0.45)
Age	0.055*	0.044	-0.023**	-0.023**	-0.036*	-0.033	-0.015***	-0.011*
	(0.032)	(0.035)	(0.009)	(0.009)	(0.020)	(0.022)	(0.006)	(0.006)
Foreign Cap.	-0.112***	-0.113***	-0.008	-0.008	-0.021**	-0.021**	0.049***	0.049***
	(0.019)	(0.019)	(0.0061)	(0.0061)	(0.010)	(0.010)	(0.0050)	(0.0050)
Capital Intens.	-1.28**	-1.26**	0.463***	0.462***	0.736*	0.732*	-0.165**	0.172**
	(0.576)	(0.575)	(0.13)	(0.13)	(0.43)	(0.43)	(0.076)	(0.075)
Firm Size	-3.773***	-3.822***	0.385**	0.386***	2.422***	2.435***	-0.0823	-0.0637
	(0.53)	(0.53)	(0.15)	(0.15)	(0.33)	(0.33)	(0.094)	(0.093)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6416	6416	6419	6419	6417	6417	6415	6415
Pseudo R^2	0.28		0.22		0.06		0.24	

Notes: Productivity is constructed using Olley-Pakes method. Firms that do not source inputs are excluded. Constant is not reported. Parentheses show standard errors. Robust standard errors clustered by firm. * , ** and *** indicate significance at 10%, 5% and 1% respectively.

0.41 percentage point increase with IV. Both of these estimates are significant at 1% too. Given that the DO share is on average more than six times larger than the FI share in a firm (Table 2.4), the positive impact of productivity on FI share is even more spectacular than its negative impact on DO share. Again, both of these findings are perfectly in sync with the implications of the theory. The model also predicts that FO and DI would rise first before falling, which means in a regression setting the coefficient should have a vague sign. Indeed, DI's coefficient lost its significance in both pooled OLS and IV. FO, on the other hand, has a positive coefficient that is still at 5% significance in OLS and at 1% in IV, suggesting a very convincing positive causal impact of productivity on foreign outsourcing shares. This could be due to high prevalence of DOFO strategy - where FO shares experience the initial rise in shares as productivity goes up - among all firms that adopt FO that outweighs the effect of other much less prevalent strategies where FO eventually falls off. Overall, the regression analysis and IV estimations provide overwhelming support that the shift of shares of inputs from basic sourcing modes to more advanced ones is driven by increases in productivity.

The shift is especially prominent in the most basic form, DO, and the most advanced form, FI.

I again conduct two robustness checks for the above result. First, I use a GEE population average model to see if the findings are true for an average firm in the economy. Second, I use the alternative productivity measure, i.e. real value added per capita, to estimate equation (20) again. The outcome of the robustness checks are presented in Table B.1 and B.2 in the Appendices. Under the population average model, the correlation between shares of FO/DI and productivity has completely disappeared. The sign for the productivity coefficient is still negative for DI, but the significance is lost when capital intensity and firm size are controlled for. This could be caused by the predominance of single sourcing DO firms, where the share of DO remains high if not 100%, that dilutes the response of an average firm. The alternative productivity measure regressions yield largely consistent results w.r.t. the effect of productivity. It is unsurprising that the coefficients on some controls that were used in the Olley-Pakes method, such as firm size and age, lost their significance, as their marginal effects are partially absorbed into the new productivity measure.

2.4 Discussion of Alternative Supplier Fixed Cost Specification

The model in section 2 provides a rich set of testable predictions on firm's multiple sourcing behaviors. However, the particular nature of supplier heterogeneity creates an environment where only four strategies are possible: DO, DOFO, DOFODI and DOFODIFI, which forms a pecking order of sourcing. In Table 2.1 we have seen that there are firms in the data that prefer using other strategies not following the pecking order. In particular, some firms opt for other sourcing modes and do not use DO at all, which is the most accessible mode and should be in every firm's strategy set. I discuss a slight change in the heterogeneity structure that accommodates this observation.

The source of the heterogeneity, sourcing friction n, follows a standard Pareto distribution with no upper bound. Therefore, there are always suppliers with fixed costs high enough that a firm cannot source from, no matter how productive it is. In reality, sourcing frictions will likely have an upper bound so that all suppliers are accessible to a highly productive firm. Keeping this possibility in mind, I use upper-truncated Pareto distribution as an alternative function for $G(n)$. The CDF is given by:

$$G(n) = \frac{1 - n^{-\omega}}{1 - (\frac{1}{b})^{\omega}} \tag{2.21}$$

where ω is still the shape parameter, the function features 1 as the lower limit as before and b as the upper limit. Thus, the supplier with the highest sourcing friction will have $(bf^{DO}, bf^{FO}, bf^{DI}, bf^{FI})$ as the menu if his fixed costs. I further assume that

$$\begin{aligned}
&\theta_{DO}^{FO}(b) > \theta_{DI}^{FI}(1) \\
\Rightarrow &b^{\frac{(1-\alpha)}{\alpha}} Q^{\frac{\alpha-\mu}{\alpha}} \left(\frac{w_1(f^{FO} - f^{DO})}{\psi^{FO}(\eta) - \psi^{DO}(\eta)}\right)^{\frac{(1-\alpha)}{\alpha}} > Q^{\frac{\alpha-\mu}{\alpha}} \left(\frac{w_1(f^{FI} - f^{DI})}{\psi^{FI}(\eta) - \psi^{DI}(\eta)}\right)^{\frac{(1-\alpha)}{\alpha}} \\
\Rightarrow &b > \frac{(f^{FI} - f^{DI})(\psi^{FO}(\eta) - \psi^{DO}(\eta))}{(f^{FO} - f^{DO})(\psi^{FI}(\eta) - \psi^{DI}(\eta))}
\end{aligned} \tag{2.22}$$

where the expressions are defined in (10). Recall that $\theta_{DO}^{FO}(b)$ is the threshold of switching from DO to FO for supplier b. The assumption serves to ensure that the first firm to switch from DI to FI for supplier 1 does not yet switch from DO to FO for supplier b so that there are firms using all four sourcing modes in the equilibrium. With a finite measure of suppliers, all firms with productivity $\theta > \theta_{EXIT}(b)$ will be able to source from all suppliers. Beyond this threshold, the measure of products stops growing as firm productivity increases, because all the blueprints have found a unique supplier to source from. However, the revenue and size (employee count) of the firms will still increase with productivity because more investments will be made to produce headquarter services, generating higher revenue. In other words, the extensive margin effect of productivity on revenues and size has disappeared, leaving only the intensive margin effect at work.

More interestingly, as firms saturate the possible suppliers to source from and continue to increase in productivity, they will eventually find more basic sourcing modes less cost-effective and drop them all together. The sourcing choices at supplier b, the last supplier with highest fixed costs, will determine the sequential elimination of less advanced modes, just like the sourcing choices at supplier 1 determines the addition of more advanced modes. Specifically, firms with $\theta > \theta_{DO}^{FO}(b)$ will stop using DO; firms with $\theta > \theta_{FO}^{DI}(b)$ will stop using FO; firms with $\theta > \theta_{DI}^{FI}(b)$ will stop using DI. The new multiple sourcing patterns can be seen graphically in Figure 2.6:

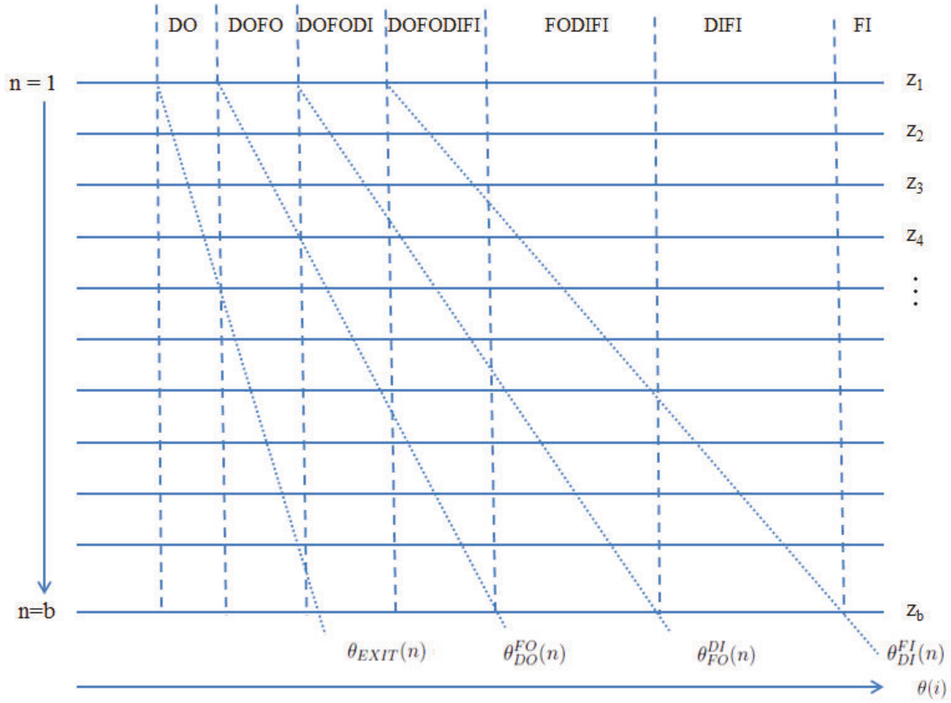


Figure 2.6: *Multiple Sourcing Choices by Firms with Bounded Supplier Heterogeneity*

In this scenario, the number of sourcing modes used by a firm is no longer strictly increasing in its productivity. The new ranking for multiple sourcing strategies is now $DO < DOFO < DOFODI < DOFODIFI < FODIFI < DIFI < FI$, with the single-sourcing foreign integration firms being the most productive. I plot the average productivity across groups of this new order in Figure 2.7 below:

The radii of the circles in Figure 2.7 represent the relative number of firms using a given strategy. It is to be expected that firms using multiple sourcing strategy at an even higher echelon than quadruple sourcing will be very scarce in the data set. Because those firms will have extremely high productivity, this is also consistent with the distributional assumptions

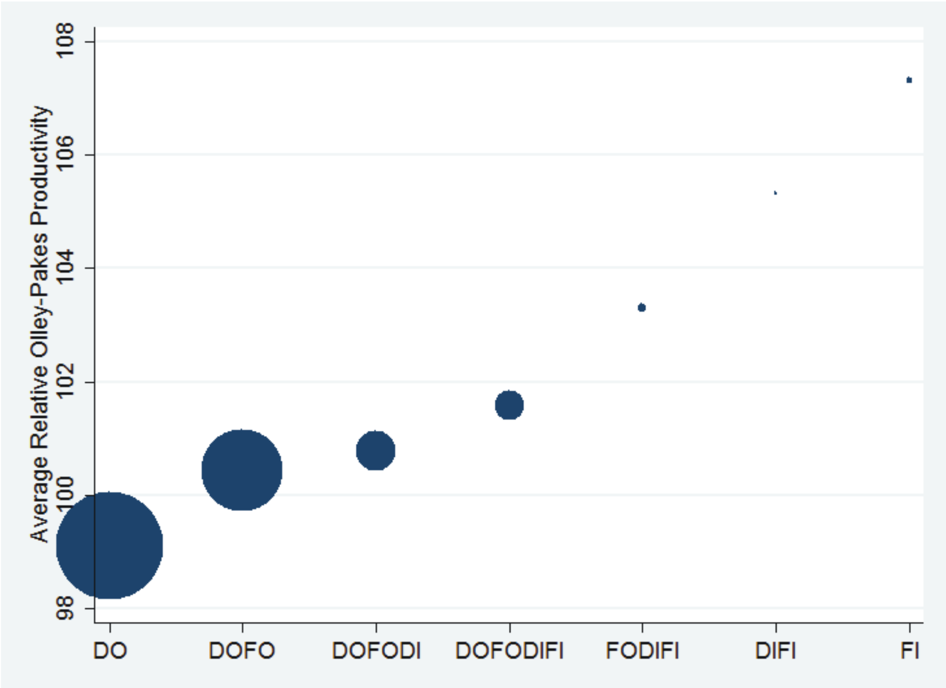


Figure 2.7: *Average Productivity across Multiple Sourcing Strategies*

of θ. Although there are only a handful of firms that use more advanced sourcing strategies than quadruple sourcing, Figure 2.7 shows that their productivities follow the exact order predicted by the model under alternative heterogeneity specification, lending support to its validity. Because of the scarcity of data points beyond quadruple sourcing, regression analyses like the ones in section 3 will yield practically identical results as before. It would be a potential avenue for future research when we have more data available on firms using those highly unconventional sourcing strategies.

2.5 Conclusion

In this paper, I develop an extension to the Antras and Helpman (2004) framework to analyze the patterns of multiple sourcing. I incorporate supplier heterogeneity of fixed costs into the canonical model so that firms need to contract and source from different suppliers separately to produce associated new products. The model generates a rich set of novel predictions on the relationship between a firm's productivity and its sourcing behavior. First, as productivity increases, firm size (measured by total sales or total employees) increases as well. This impact can be decomposed into the intensive and the extensive margins: firms invest more and generate higher revenue for each product it produces as higher productivity increases expected profit, and firms create more products as higher productivity enables them to access previously unprofitable suppliers with high fixed costs. Second, the number of simultaneous sourcing modes used by a firm is increasing in productivity and headquarter intensity. Intuitively, increasing productivity allows a firm to start using more advanced sourcing mode for a portion of its suppliers with lowest fixed costs, and increasing headquarter intensity unlocks new organizational modes (domestic and foreign integration) that would be dominated in a low headquarter intensity environment. Third, the composition of different sourcing modes within a firm will experience a shift from more basic modes to more advanced modes as productivity rises. More specifically, the fraction of suppliers sourced by domestic outsourcing monotonically decreases with productivity, while that of foreign integration monotonically increases. Foreign outsourcing and domestic integration, being at the middle of the fixed cost ranking, will initially increase and eventually decrease with increasing productivity. An important result that is borne out of the model set-up is a 'pecking order' of multiple sourcing strategy, where the multiple sourcing strategy set of a less productive firm is a subset of the strategies used by all firms with higher productivity.

Using a firm-level unbalanced panel data set for Spanish manufacturing firms, I test the theoretical model with regression analysis and find convincing support for all the predictions. The results are robust to different model specifications or alternative measures of firm productivity. Using an instrumental variable approach, there is ample evidence that productivity is the driving force behind firms' adopting of more sourcing modes, as well as the within-firm shift in the composition of modes described above. I then use a different distributional assumption for the supplier heterogeneity and show that the pecking order equilibrium could be modified to include firms that only uses advanced sourcing modes, while dropping the basic ones like domestic outsourcing altogether. Given the scarcity of data on those highly productive firms, I only show a graphical representation that supports the new ranking without deploying extensive econometric analysis.

The way supplier heterogeneity is modeled in this paper is uncomplicated, aiming to provide a parsimonious extension of the canonical model to yield the desired qualitative results. This opens the possibility for many model assumptions to be challenged. For example, assuming that the ranking of fixed costs for different sourcing modes is preserved for all heterogeneous suppliers is hardly innocuous. It is entirely possible, for instance, that suppliers from a foreign country enjoy preferential government policies aimed at FDI (foreign integration), but arms-length trade incurs high tariffs. The pattern becomes much more complex and harder to characterize if we allow fixed cost heterogeneity to be less uniform. There are also other channels of heterogeneity among suppliers which can potentially yield similar results. For example, in Antras and Chor (2013) suppliers at different positions along a sequential value chain will vary in their organizational mode of sourcing. Costinot *et al.* (2013) assumes suppliers along the supply chain have a different propensity to making mistakes, compromising their effective contribution. It will be interesting to theoretically incorporate other forms of heterogeneity into the global sourcing framework and empirically establish evidence of new patterns in multiple sourcing.

Chapter 3

Banking Reform, Monetary Instruments and Loan Supply in China

3.1 Introduction

During the episode of global financial crisis in 2008, the People's Bank of China (PBC)[1] announced a 586 billion USD stimulus plan. In the year that followed, the banking sector saw its total credit exploding with more new loans extended in the first four months of 2009 than in all of 2008[2]. Intriguingly, neither the require reserve ratio nor the centrally administered loan and deposit interest rates has changed significantly during that period, at least not nearly as enough to prompt such a garguantuan scale of lending frenzy from a profit maximizing standpoint. This is but one of the many baffling scenarios where the conventional framework for market economies like the US does not seem to explain the behavior of Chinese banks under a command economy. So how are monetary policies implemented in China and what are the commercial banks' reactions in the form of loan

[1]The People's Bank of China has assumed the role of Central Bank since 1984.

[2]Source: "Chinese Banks Lend Now, May Pay Later", The Wall Street Journals, May 2009

supply?

This paper sets out to address these puzzles by investigating the response of bank lending to monetary policies in the context of China. In other words, I explore the effectiveness of the narrow credit channel in translating monetary policies to changes in bank loan supply. As pointed out by Agénor and Montiel (2008), the credit channel is of paramount significance in a vast majority of developing countries that lack mature securities markets and whose financial systems are dominated by mega state banks. The relative importance of the credit channel among all transmission mechanisms in China has also been established inXie (2004), Zhou and Li (2006) and Park and Sehrt (2001). The propagation of China's monetary policy through the credit channel is unique from many other countries in two aspects: the Chinese central bank has frequently made use of a heterodox combination of monetary instruments such as excess reserve interest rate, required reserve ratio and window guidance, and the experience of a major banking reform in mid-1990s that have potentially huge impact on the conduct of monetary policies. However, the existing literature has not delved into the responses of different types of banks to each monetary instrument and the impact of the reform on these nuances. The focus of this paper is to provide an analysis of the effectiveness of monetary policy tools on the loan supply of major commercial banks. I assess the relative responsiveness of the banks both cross-sectionally between large and small banks, as well as intertemporally spanning 10 years before and after the on-set of the reform. Understanding the implications of monetary policy for different banks will allow the central bank to design more effective monetary policies and by analyzing the impact of the reform, the groundwork can be laid out for the optimal path of future reform agenda.

First, I briefly explain the essense of the narrow credit channel, which has been discussed at length in the context of the United States by Romer and Romer (1993), Kashyap and Stein (1994) and Kishan and Opiela (2000). The classical bank lending channel consists of mainly four stages. The first stage links the central bank and the monetary base through monetary policies like open market operations. Changes in monetary base then transform into changes in banks' deposit holdings through the constraint of required reserves. In the next stage, deposit fluctuations cause loan supply to vary accordingly, assuming banks cannot costlessly substitute between loans and other forms of securities. Lastly, total investment is affected by the fluctuations in loans available, especially for small and medium sized enterprises that rely heavily on bank loans for external finance.

In the context of China, the credit channel plays a pivotal role. The People's Bank of China wields a heterodox combination of monetary policy instruments that influence deposits and loans directly, such as credit quota[3], window guidance[4], benchmark loan and deposit rates, rediscount rate and required reserve ratio. In mid-1990s, the central bank started a major overhaul of the banking sector which changed the way monetary policies were crafted and transmitted. Given the existence of a oligopolistic group of State-owned Commercial Banks, the implication of the reform on the effectiveness of the credit channel for different banks is particularly intriguing. I find that distinctions in responses of different types of banks to monetary policy instruments do exist and some of these disparities can be attributed to the characteristics of the Chinese banking system. The reform has transformed the functions of some policy instruments such as the relending rate, and changed the way banks react to some others such as the loan interest rate or the required reserve ratio.

The remainder of the paper is organized as follows. In section 2, I provide some background information on China's financial intermediation. In section 3, relevant literature is discussed. Section 4 establishes a model based on profit maximization behavior of banks tailored to the context of China. Section 5 outlines the specifications of the data. The empirical analysis, interpretation of results as well as a brief discussion of limitations are presented in section 6. Section 7 concludes.

---

[3]The credit quota under China's context is a directional credit target which dictates the amount and the direction (to which sector or which area) of loans a bank has to extend in a given year.

[4]Window Guidance is often termed 'moral suasion', it has been used to persuade banks and other financial institutions to keep to official guidelines. The 'moral' aspect comes from the pressure for 'moral responsibility' to operate in a way that is consistent with furthering the good of the economy.

3.2 Background

The People's Bank of China (PBC), the Chinese central bank, possesses a variety of monetary policy instruments which could be used to provide stabilization of the economy through the banking sector. The direct quantitative instruments, mainly credit plans, direct PBC lending and window guidance, stem from the legacies of a centrally planned economy before the 1980s. The PBC also has at its disposal the indirect instruments, the most influential of which are required reserve ratios, a full set of heavily regulated interest rates and open market operations. To adjust to a new financial and economic environment in preparation for deeper integration into the global market, the tools and implementation of monetary policies in China have undergone many changes over the last twenty years, with the most fundamental reforms taking place in mid 1990s. During this "reform era", the PBC's aimed at transforming the financial framework from one in which direct quantitative control was predominant to a more market-oriented structure. Figure 3.1 summarizes the movements of major PBC policy instruments[5].

3.2.1 Characteristics of China's Banking System

In analyzing the monetary policy instruments in China, it is important to acknowledge China's unique financial environment. First, similar to many developing countries, China's financial market has been dominated by four large State-Owned Commercial Banks (SOCBs): Industrial and Commercial Bank of China, Agricultural Bank of China, Bank of China and China Construction Bank. The "Big Four" possess more than 80 percent of the entire banking sector's assets, absorb around 70 percent of the total deposit and extend over 80 percent of the total lending (Geiger (2008)). The SOCBs do not face much competition from

[5]Several characteristics of the graph is worth noting: 1. Instead of adjusting just one policy instrument at a time, the PBC tend to move a combination of policy levers simultaneously; 2. The required reserve ratio has stayed constant before 1998 and has been used most frequently in recent years; 3. The law of No Arbitrage failed in early 1987 and mid 1993 when the excess reserve interest rate exceeded the relending rate. The banks could in theory borrow indefinitely from the PBC and deposit the borrowed fund as excess reserve in the PBC again and make an arbitrage profit. This indicates that there are other non-pecuniary costs or constraints that prevented the banks from borrowing excessively from the central bank.

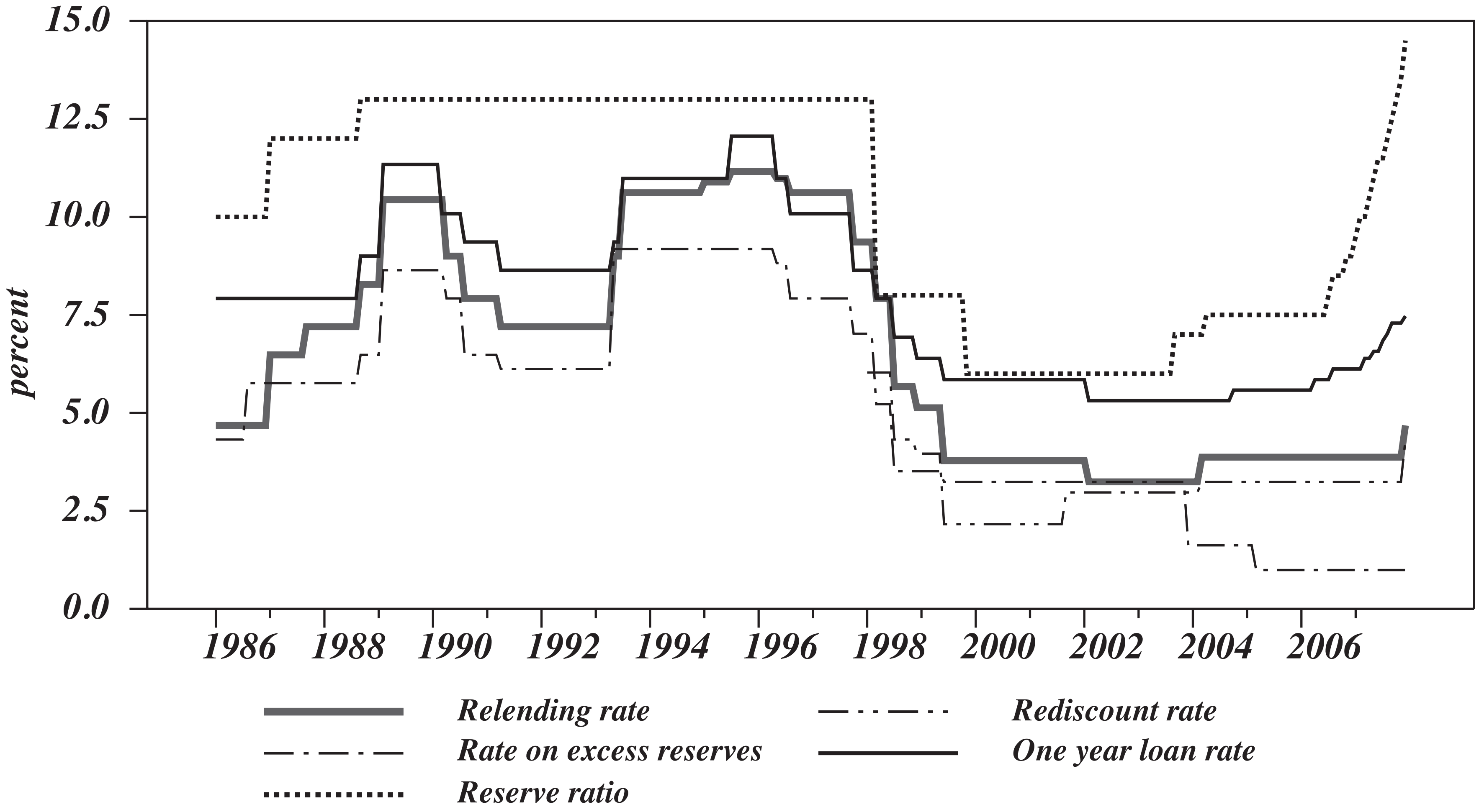
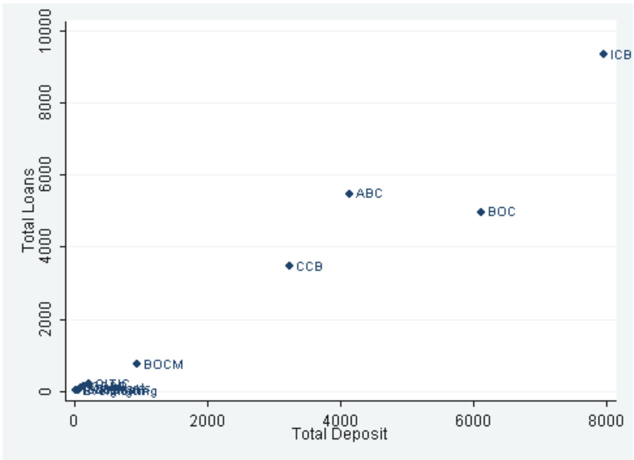
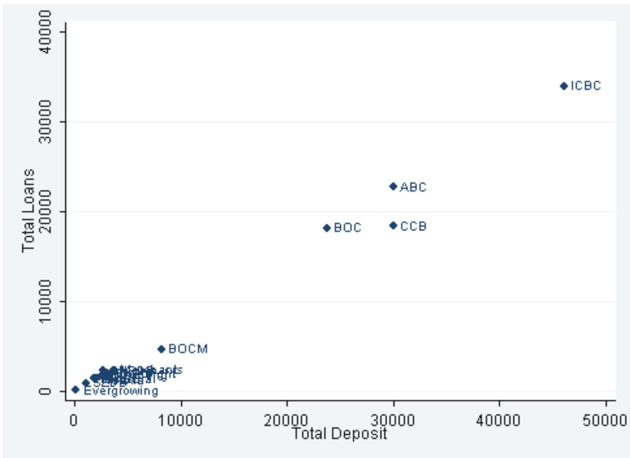


Figure 3.1: *Monetary Policy Indicators*

the smaller banks, thus forming a de-facto oligopoly. Furthermore, given their segregated lending targets conveyed partly in their names, the four banks do not compete against each other in all businesses. The scatter plots in Figure 3.2 of banks in two representative years illustrate the dominant position of the four SOCBs described above.



(a) *Major banks in 1992 (Pre-reform)*



(b) *Major banks in 2003 (Post-reform)*

Figure 3.2: *Plots of Banks' Total Loans versus Total Deposits (Unit: 100 Million Yuan)*

Second, the balance sheets of Chinese banks consist mainly of loans on the asset side (more than 60 percent in 2002) and deposits on the liability side (around 90 percent in 2002 for the SOCBs)[6]. The dependency on deposits as source of funding indicates that Chinese banks do not have means of large-scale external finance from foreign capital markets.

Third, the asset quality of Chinese banks has been historically lower than their foreign counterparts (Barnett (2004)). An unhealthy level of non-performing loans (NPL) persists within the banking system. For example, the share of NPL in total loans for SOCBs in 2004 was 19.15 percent[7]. Moreover, the ratio was much higher before the banking reform, when the majority of bank lending took place as preferential policy lending to specific industries/areas supported by the government.

Fourth, as the Central Bank Law states "The People's Bank of China shall, under the leadership of the State Council, formulate and implement monetary policies", government intervention is still prevalent despite the reform efforts to steer away from direct control. Before 1990, the captivity of the central bank is most conspicuously manifested in the "credit plans" that enforced commercial banks to allocate preferential policy loans to industries the government wished to support. Although the use of credit plans has been discontinued after reforms, interest rates are still heavily regulated by the authorities despite slow progress made towards liberalization. Window guidance, which was modeled from Japan's experience, has also played an important role.

Fifth, the banks keep a high ratio of excess reserves, which was well above 10 percent in the 1990s and only gradually dropped to around 5 percent after 2003. Unlike central banks in the developed world, the PBC pays exorbitant interest rates on reserves as well as excess reserves. In mid 1990s, the excess reserve interest rate was at one time as high as 9 percent[8]. Such high rates on excess reserves predictably dampened the response of financial intermediations to other interest rate fluctuations when banks had the option of using excess reserves as a risk-free investment. Nevertheless, it also played its unique role

[6]Both figures are author's calculation from PBC official statistics at *www.pbc.gov.cn*.

[7]China Banking Regulatory Commission (CBRC) Statistics

[8]This is in relative terms to the international standard. For example, the Federal Reserve paid zero interest on excess reserves before 2008 (banks did not keep any excess balance anyways) and is now paying only 0.25% on the nearly 1 trillion excess reserves in the banking system.

in that the Central Bank was able to use excess reserve interest rate as an active policy tool.

3.2.2 Reforms of China's Monetary Policy

Before a series of reforms that took place in mid 1990s, China's monetary policy makers aimed for the total credit as the intermediate target, exhibiting the characteristics of a centrally planned economy. PBC and government agencies were the only sources of funding available besides deposits. The common monetary tools used then included credit plans, relending policies and administered interest rates.

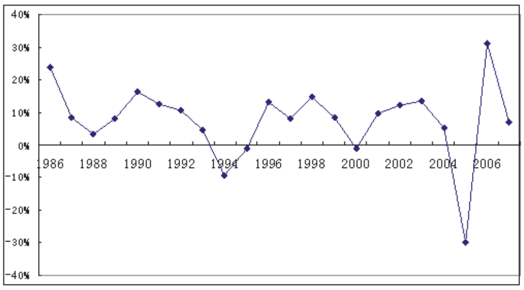
Credit plans were used extensively in the 80s and 90s, where the central bank designed and dictated the quantity and direction of loans extended by banks according to its policy objectives. The World Bank has estimated that 60% to 80% of the bank lending went to policy loans (Dickinson and Jia (2007)). Relending policies of the central bank reflect such plans. As was usually the case, large gaps existed between the available funding of the SOCBs through deposit and their assigned loan quota. PBC therefore extended direct lending to the banks through a process called "relending". The relending rate was the interest rate earmarked for funds provided to SOCBs for policy purposes in the case of deposit shortfalls (Park and Sehrt (2001)). In 1993, PBC refinanced about 40% of the loans from SOCBs. The smaller, non-state-owned commercial banks did not have to shoulder such heavy policy lending responsibilities to state-owned enterprises. Therefore they either did not have to use the PBC relending facility, or could not access central bank funds as easily as the SOCBs[9].

Despite having a large proportion of lending directed towards policy loans, banks still had some flexibility in allocating loans. The relending rate as the price of funds from the central bank was the marginal cost of supplying loans. This means that before the reforms, relending policies could have the potential to affect bank's credit decisions.

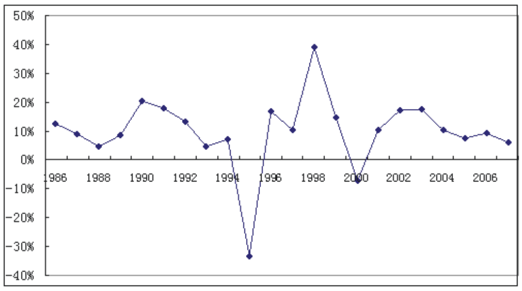
Before the 1990s, massive government intervention, low asset quality and low capitalization characterized the Chinese banking system (García-Herrero *et al.* (2006)). The first

[9]The balance sheet data of non-SOCBs demonstrates that they did not borrow from the PBC at all besides for emergency cash clearing purposes which only amounted to a miniscule portion of their liabilities.

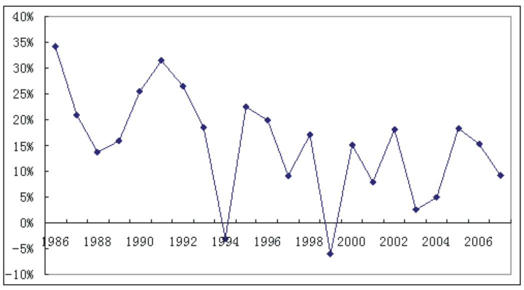
wave of reforms took place in 1994-1995 and the notable changes include: relaxation of binding credit plans; adoption of a new Commercial Bank Law to improve managerial incentives and prudential financial regulation; establishment of policy banks to separate policy from commercial lending[10] (Figure 3.3); as well as the establishment of a national, unified interbank market. The purpose of the reform was to converge to the global standard and steer the banks to becoming more commercially oriented.



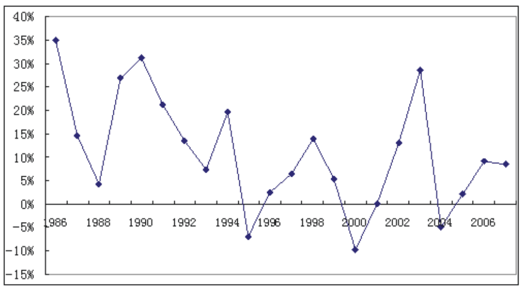
(a) *Industrial and Commercial Bank of China*



(b) *Agricultural Bank of China*



(c) *China Construction Bank*



(d) *Bank of China*

Figure 3.3: *Real Loan Growth of SOCBs*

In 1998, explicit credit quotas were eliminated once and for all. In its place, PBC started to adopt a policy of "window guidance", compelling banks to stick to official guidelines (Geiger (2008)). Also since 1998, the required reserve ratio started to assume its importance as a monetary policy instrument and was used frequently in the following years.

Before mid 90s, PBC relending was the main channel of monetary control. After the

[10]The large drop in SOCBs' loan growth demonstrated in Figure 3.3 around 1994-1995 was justified by the purpose of the policy banks that took over some policy loan responsibilities.

reforms, open market operations (OMO) were used as the primary tool to manage monetary base (Bennett and Dixon (2001)). Since 2000, however, as increasing volume of capital inflows rushed into China, OMOs were used mainly to withdraw liquidity from the financial system and maintain the de facto peg of the RMB[11]-dollar exchange rate(Xie (2004)). Until late 2005 when the peg was relaxed into a crawling peg, repurchase operations (repos)[12] remained an important sterilization tool. The OMOs have a special implication for loan supply and the credit channel. In order to cope with an increasing pressure from the foreign exchange market, the PBC started issuing Central Bank Bills since the 90s. Although commercial banks acquire such bills at a discount rate through price bidding, some large commercial banks are subjected to directional issurance. That is, they were required to acquire a certain amount of Central Bank Bills by PBC mandate. The acquisition of the bills directly removes excess liquidity from banks and reduces their ability to make loans. The interest rate paid on the short-term Central Bank Bills thus establishes a floor for the rediscount rate.

After the discontinuation of direct central bank lending in 1994 (Geiger (2008)), central bank loans were transformed from a main source of funds for SOCBs' policy loans to a lender of last resort and a subsidy for policy-oriented activities (Xie (2004)). The reserve requirement that stayed at 13 percent from 1988 to 1998 started to be seen as an effective and direct instrument to manage the liquidity level in the banking system. It has become one of the active tools of monetary adjustments, together with open market operations, rediscount rate and benchmark interest rates.

3.2.3 Monetary Transmission Channels in China

Given the predominance of finance by bank loans in China, it is natural to analyze the effects of monetary policies within the context of the bank lending channel of monetary transmissions. The PBC explicitly states that quantitative credit planning, along with

[11]The Renminbi (RMB), or the Yuan, is China's currency which is traded with the US dollar at 6.8 to 1 exchange rate at the moment.

[12]Repo operation is an important arsenal of the PBC which usually consists of the PBC raising yields on its bills and draining liquidity by selling more bonds.

monetary policies, is an important component of its macroeconomic management[13]. As a means to “fine tune” financial structure, credit policies in China are closely connected with monetary policies and mainly carried out in the following forms: (1) setting aggregate growth targets of credit in the economy (credit quota); (2) directing preferential credit to areas and industries that are in need of development and supported by government policies (policy lending); (3) limiting excess commitment of credit to certain industries through “window guidance”; (4) establishing laws and regulations to promote financial reform and innovation, as well as minimizing potential credit risk. Bank lending as the sole carrier of credit policies becomes all-important.

For the bank lending channel to work effectively, the following premises need to be satisfied. First, banks cannot costlessly substitute loans with securities and other types of asset on their balance sheet. This condition is generally true in China for the past twenty years with loans consisting of a large portion of China banks’ assets, approaching 65% in the year 2002, while bonds only made up about 7% of the balance sheet[14]. Second, firms depend predominantly on loans as a source of fund. In 2004, bank loans represented 83 percent of the total fund raised by non-financial sector, while stocks were 5 percent and bonds 12 percent (García-Herrero *et al.* (2006)). This is again confirmed in Pan and Tao (1995), where the authors find bank loans took up 80.2% of the total financial resources in 2006. In short, I am well-grounded to hypothesize that the bank lending channel plays the predominant role in China’s monetary policy transmission.

The interest rate channel has gained importance as China’s financial reform deepens. Despite the progress made in interest rate liberalization, however, the current set of price-based instruments are still subject to heavy government intervention. All benchmark interest rates are still monitored by the central bank and only allowed to fluctuate in a narrow band. The channel of monetary transmission thus deviates greatly from the textbook interest

[13]PBC Homepage, *www.pbc.gov.cn*, Credit Policy, Mission Statements

[14]A significant portion of banks’ securities holding is Central Bank bills which cannot be easily substituted even at the margin. PBC Statistics, Aggregate Data for Year 2003

rate model. Furthermore, the effectiveness of the interest rate channel anchors on the responsiveness of the firms and households' consumption level to interest rate fluctuations. Given the lack of alternative investment options and a historically high propensity to save, most household consumers are insensitive to benchmark interest rates. While firms are expected to react to changes in loan rate, if the loan market is supply constrained as I will illustrate later, the aggregate level of investment depends more on the availability of bank loans through the credit channel.

China has maintained a de facto peg of the nominal exchange rate of RMB to the dollar for two decades, only after 2005 was the regime changed to a crawling peg. Therefore, the classical exchange rate channel has been virtually blocked. Zhang and Clovis (2009) provides further analysis into the impact of changes in effective exchange rate. By adopting a VAR model, he finds that the movements of the real effective exchange rate[15] do not influence the output in a statistically significant way, but the sign of the coefficient is in agreement with the arguments of the exchange rate channel, i.e. a decrease in the effective exchange rate causes a corresponding increase in output.

China is in the league of a vast majority of developing countries characterized by the lack of a well-functioning capital market (Agénor and Montiel (2008)). As discussed above, Chinese firms depend predominantly on bank loans for external finance, while Chinese customers are more accustomed to holding deposit in banks rather than equities or securities (although in the developed world, similar examples do exist as in the case of Japan). A policy-induced change in asset prices is incapable of significantly affecting the value of a firm's collateral or the wealth of a typical household. The effect of wealth channel and the balance sheet channel are thus severely undermined.

---

[15]The real effective exchange rate is the weighted average of a country's currency relative to an index or basket of other major currencies adjusted for the effects of inflation. The weights are determined by comparing the relative trade balances, in terms of one country's currency, with each other country within the index. Source: *Investopedia*

3.3 Overview of Existing Literature

3.3.1 Different Channels of Transmission Mechanisms

Studies on monetary policy transmission have seen most progress in the 80s and 90s, with the emergence of influential literature establishing the different channels of the monetary transmission mechanism. Ireland (2005) gives a succinct overview of the notable research on this topic. I provide a brief summary below.

The most basic interest rate channel originates from the core of the Keynesian IS curve, although the response of consumption and investment that is markedly larger than estimated interest rate elasticity suggests that other mechanisms besides the narrow interest rate channel might be at work (Kuttner and Mosser (2002), Bernanke and Gertler (1995)). The empirical study of Bernanke and Blinder (1992) has not only validated the existence of the interest rate channel but also asserted that it is the major monetary transmission mechanism in the US. In an open economy, the exchange rate channel works through the uncovered interest rate parity (Mishkin (1995), Kuttner and Mosser (2002)). Monetary policy can also propagate through asset prices via two channels. The monetarist channel illustrated by Meltzer (1995) focuses on relative asset prices. According to Meltzer, the importance of the interest rate channel established in earlier works (Bernanke and Blinder (1992), Friedman and Kuttner (1992)) can also be interpreted as the cyclic change of relative asset prices. It is notable that Meltzer argues that the monetarist channel is operative even if a country does not have an effective financial market, as in the case of China. The wealth channel, on the other hand, stems from Ando and Modigliani (1963) consumption and saving life-cycle hypothesis illustrated in standard macroeconomics textbooks. The broad credit channel, or the balance sheet channel, emphasizes the role of borrowers instead of banks (Bernanke and Gertler (1989), Bernanke and Gertler (1995)). Monetary policy that affects the net worth of firms and their cash flow is capable of influencing investment spending due to adverse selection and moral hazard issues.

The focus of this paper, however, will be the narrow credit channel, or the bank lending channel. Bernanke and Blinder (1988) extended the traditional IS/LM model with the integration of bank lending into the LM curve, allowing the roles of both money and "credit". In their paper, Bernanke and Blinder replace the IS curve with a CC curve, denoting the clearance of both the credit and commodity markets. In this model, investment is determined by interest rates of both non-risky bonds and bank loans. It is important to note the assumption that these two sources of funds are not perfect substitutes, so that borrowers cannot costlessly switch away from their dependence on bank loans due to external finance premium (Pan and Tao (1995)). Therefore, the model encapsulates three kinds of financial instruments: money, bonds and bank loans. A simple illustration of the transmission mechanism goes as such: contractionary monetary policy reduces reserves; banks constrained by required reserve ratio will see their deposit level drop; banks face constraints of their balance sheet and their ability to make loans decreases; firms are unable to obtain bank loans or have to pay higher interest on loans, investment is cut back, which reduces total output.

Pan and Tao (1995) conclude in their paper that the Chinese monetary transmission is typically a "credit channel", but also acknowledge its limitations: constraints in open market operations due to large volumes of foreign exchange swap; oligopolistic competition pattern formed by the SOCBs; abuses of window guidance that causes fluctuations in loan supply and the disproportionately large impact of the credit channel on small and medium sized enterprises. They describe the mechanism through which different monetary tools affect bank lending, but fails to account for the strategic usage of a combination of tools by the PBC.

The transmission mechanisms have been discussed at length in many Chinese studies. However, most of the empirical papers make use of simplistic models, rendering their results unconvincing. Gao-qi (2005) make use of only the aggregate GDP, loans and M2 figures. By conducting Granger causality test and regressing GDP on both loans and M2, they conclude that the credit channel is more prevalent than the monetarist channel in China, where changes in total loans represent the credit channel and money base represents the monetarist channel. It is premature to arrive at the conclusion so casually with such limited empirical evidence. Zhou and Li (2006) conduct similar research with a few more variables such as price, industrial output, M1 and interest rate. Their analysis, however, includes only the Granger causality test. Besides the gross generalization of a transmission channel to one aggregate variable, most Chinese papers fail to distinguish between loan demand versus loan supply which both drive changes in aggregate loans. The demand and supply side each encompass the interest rate channel and the credit channel respectively. Such identification of supply and demand sides is crucial if we hope to understand the working of various transmission channels, especially in an economic framework as complex and nebulous as China's.

3.3.2 China's Banking System and Reforms

The existing western literature has mainly taken interest in the financial reforms of the 90s and their impact on the effectiveness of monetary policies. Geiger (2008) notes that the intermediate target of the PBC has shifted from total credit to money supply after the reform, which is echoed in Pan and Tao (1995). The paper also makes an attempt at investigating the PBC's usage of multiple monetary policy instruments simultaneously. By analyzing the actual and targeted level of credit, money supply, inflation and economic growth, Geiger finds that the application of a heterodox mixture of monetary policies has allowed China to reach its final target of price stability and economic growth, even though the intermediate targets were consistently missed. Using two or more instruments concurrently creates various distortions that prevent the interest rate channel of monetary transmission from functioning effectively. Geiger thus proposes a sudden change that suspends all quantity-based instruments like credit quotas, window guidance and capital controls in order to achieve the original goal of the reforms, that is, restructuring the financial system anchored around interest rates and other market-based instruments.

García-Herrero *et al.* (2006) identify three centerpieces of China's reform effort: bank restructuring, mainly aiming at the SOCBs and cleaning their unsustainable level of NPLs;

financial liberalization, where credit plans and direct controls of interest rates should be gradually relaxed; and strengthening of supervision and regulation. Similar to Geiger (2008), they also point out that the progress of reforms, albeit commendable, is not fast enough and more radical changes need to take place. Barnett (2004), on the other hand, holds back on his evaluation of the reforms and notes that its full impact will only become clear in a few years. Nonetheless, Barnett supports improvement in banking regulation and transparency.

3.3.3 Bank Behavior Models in Developing Countries

Agénor and Montiel (2008) analyze the framework of monetary policy in small open economies where bank loans are the only source of external finance. The paper acknowledges that in many developing countries with an immature securities market, the credit channel becomes all-important. This analysis is relevant for China where firms (especially small and medium enterprises) do resort to bank loans as their main source of funds. The paper proposes a macroeconomic model involving equilibrium in both the financial and goods market, with firms, households, commercial banks and central banks as players. The part of the analysis of commercial banks is of particular interest to my paper. In their model, banks are assumed to have two assets: lending and required reserves; and two liabilities: central bank borrowing and deposits. Borrowing from the central bank is perfectly elastic at the official refinance rate (the relending rate in China's context), and banks choose the level of deposit and loan interest rate to maximize their profit subject to balance sheet constraint.

While Agenor & Montiel's model puts forth a basic framework in analyzing bank behavior in developing countries, we have to be aware of some caveats before applying it to China's case. *First*, Chinese banks hold a large amount of excess reserves. Even in recent years after a decade's reform, SOCBs still hold around 3 percent excess reserves for which the PBC pays interest. It is an important source of income that affects banks' lending decisions. *Second*, I need to take into account the constraint of credit plans in the pre-reform era, which were usually binding for the banks. With the credit quotas to meet, banks were not simply maximizing their profit based on interest rates. *Third*, the most distinct departure of the Chinese banking system from that in Agenor & Montiel's model is that all benchmark interest rates, including the central bank relending rate and loan/deposit interest rates, are actively administered by the central government. Banks thus cannot use interest rates as a tool to adjust their balance sheets. Instead Chinese banks choose the level of borrowing, loans and excess reserves at the exogenously determined rates.

Another notable paper on behaviors of Chinese banks is Park and Sehrt (2001). It argues that the importance of policy lending by Chinese state banks did not fall after the reform and that lending by financial institutions did not respond to economic fundamentals such as sector output and output growth rate. The innovation of their work lies in the development of a bank intermediation model that attempts to incorporate policy lending. The bank intermediation model developed in their paper provides great insight into the behavior of Chinese banks. The incorporation of policy lending into bank's objective functions implies the existence of window guidance.

Although the paper has shown commendable promise under the constraint of data to model policy lending, it still falls short in several aspects. *First*, banks should not be able to choose the level of policy lending before the reforms. As discussed earlier, strict lending quotas in the form of credit plans dominated the pre-reform banking system in China. Banks usually were given no alternative but to meet the lending targets, even if it meant borrowing directly from the PBC. Even after reform where window guidance, or moral suasion, replaced credit quotas, it is hard to fathom that banks had much freedom in choosing whether to obey the official guidelines. The legacy of centrally planned economy would have incurred too high a non-pecuniary cost on banks to not abide by the PBC ruling. Indeed more often than not, as demonstrated in Pan and Tao (1995), banks acted according to window guidance in the special period but reversed their actions as soon as window guidance expired, creating undesirable fluctuations in the financial system. *Second*, the three policy variables in the regression: grain production (GRAIN), state-owned enterprise output (SOEY) and state-owned enterprise profit (SOEP) are insufficient to capture the entire objective function of the PBC in designing the optimal monetary policy or credit targets.

Production of different commodities is highly specialized in China. For example, southern China has much higher grain production due to its geographic and climate advantages, while northern China produces more steel. Other factors such as efficiency of transportation in the form of railroads or highways will perceivably also affect the amount of policy lending. *Third*, it is rather simplistic to infer government's policy lending objectives from policy variables alone. Besides industrial and area considerations, unobservable factors such as environmental changes and government tastes will all have an impact on the allocation of preferential policy loans.

3.4 A simple model for Chinese banks

The banking reform in the mid 1990s has profound implications on the behavior of Chinese commercial banks. Before the reform, the PBC set explicit credit plans and banks were subject to loan quotas. There were large volumes of direct lending from the PBC to the SOCBs, implying that the credit quota was binding for banks that resorted to the PBC for funding. A functional interbank market did not exist and banks held large amounts of excess reserves (more than 10 percent).

After the reform, explicit credit quotas were lifted by the PBC. An interbank market was set up where banks could borrow or lend at the interbank offer rate. Although implicit window guidance took place of the credit plans, it was no longer as binding. This is partly because deposit growth has outstripped loan growth in the 1990s for all the SOCBs[16] and banks were flooded with liquidity. Direct borrowing from the PBC discontinued. The banks, however, continued to hold high levels of excess reserves relative to the international norm, exceeding 5 percent entering the year 2000[17]. Therefore I propose separate bank profit maximization models before and after the reform.

There is immense challenge in modeling the financial sector in China, especially for the

[16] See Appendices, Figure C.2.

[17] PBC Homepage, *www.pbc.gov.cn*, Aggregate Statistics of 2001, author's calculation

era before the modernization of the banking sector. There are many unobserved factors - implicit or explicit quota requirements, policy mandates, etc - that affect banks' decision making much more than one usually assumes for the western banks. Another major obstacle to using a fully fledged general equilibrium model is the key difference in the mechanism of interest rates. While in almost all models of banking literature, interest rates are pinned down by the equilibrium in the money market and serve to balance the credit supply and demand. In China, however, interest rates - from the benchmark overnight lending rate to deposit and loan rates - are large exogenously determined by the policymakers. The supply and demand of credit is also not necessarily balanced. Therefore, in this section I only use a barebone partial equilibrium model to illustrate the comparative statics of the banks responding to changes in policy interest rates, without delving deep into the general equilibrium that may quickly fall out of context.

3.4.1 A Bank Model for the Pre-reform Era, 1986-1997

Bank's liability side consists of deposit, D, and borrowing from the central bank, B. Deposit is assumed to be exogenous. The asset side consists of loans, L, required reserves, αD where α is the required reserve ratio determined by the central bank, and excess reserves, E. As the level of required reserves is exogenous, I can assume no interest rate paid on them without compromising the analysis of the model. Therefore the balance sheet constraint is

$$E + L + \alpha D \leq D + B \quad \text{or } E + L \leq (1 - \alpha)D + B$$

Naturally, the level of excess reserves cannot be negative, neither is the level of borrowing from the PBC. Banks face the set of exogenous interest rates that is centrally administered and a credit quota L^* imposed by the PBC. They can choose the levels of L, B, and E to maximize their objective function U subject to the balance sheet constraint:

$$\max_{L,B,E} U = r_L(L, i_L)L + r_E(E, i_E)E - r_D D - r_B(B, i_B)B$$

$$\text{s.t. } E + L \leq (1 - \alpha)D + B$$

$$E \geq 0, B \geq 0, L \geq L^*$$

where: $r_L(\overset{-}{L}, \overset{+}{i_L})$ is the return on loans that depends negatively on L and positively on i_L, the loan interest rate. The negative partial derivative on L captures the fact that risk assessment becomes more difficult and the ratio of NPLs tend to become higher the larger amount of loans a bank extends (Stiglitz & Weiss, 1981).

$r_E(\overset{-}{E}, \overset{+}{i_E})$ is the return on excess reserves that depends positively on the excess reserve interest rate, i_E. The non-pecuniary return of holding excess reserves also captures the 'safety factor' a bank gains so that they are less likely to face a liquidity crisis. The more excess reserves, the less marginal 'safety' it offers the bank[18]. Hence r_E depends negatively on E.

$r_D = i_D$ is the cost of holding deposits which is assumed to be equal to the deposit interest rate and exogenously determined.

$r_B(\overset{+}{B}, \overset{+}{i_B})$ is the cost of borrowing from the PBC. First it depends positively with the relending rate, i_B. We would also expect greater non-pecuniary cost incurred on a bank the more it tries to borrow from the central bank. Such costs can take the forms of, for example, ceding more of the bank's autonomy to the PBC in order to obtain loans. Therefore r_B is positively correlated with B.

From the set up it is clear I have assumed that banks are not "pure" profit maximizers because returns on assets and costs on liabilities are not completely pecuniary. Solving the first-order conditions in this case requires us to invoke the Kuhn-Tucker conditions for the nonnegativity constraints. The cases where E, B are binding will yield rather uninteresting results. Also in reality, excess reserves and direct borrowing from PBC were definitely not zero before the reforms. I only consider the case where neither E or B is binding.

If L^* is non-binding, first-order conditions yield:

$$MRL = r_L' L + r_L = \lambda$$

[18] Banks that fail to meet the reserve requirement after running out of excess reserves usually face hefty fines. The PBC can, for example, force the bank to acquire central bank bills at a below-market interest rate.

$$MCB = r'_B B + r_B = \lambda$$

$$MRE = r'_E E + r_E = \lambda$$

where

$$\lambda = \frac{r_D}{1-\alpha}, r'_L = \frac{\partial r_L}{\partial L} < 0, r'_B = \frac{\partial r_B}{\partial B} > 0, r'_E = \frac{\partial r_E}{\partial E} < 0$$

In short, $MRL = r'_L L + r_L$ is the marginal return of loans, $MCB = r'_B B + r_B$ is the marginal cost of borrowing from the PBC and $MRE = r'_E E + E$ is the marginal return of holding excess reserves. Therefore the first-order conditions require $MRL = MRE = MCB$ and all of them pinned down by $\frac{r_D}{1-\alpha}$. In the equilibrium, at least one of the non-negativity constraints needs to bind.

Consider first the scenario where the credit quota L^* is non-binding, excess reserve E non-binding and borrowing B is binding. Figure 3.4 for a simple graphical illustration.

$r_B(0) = i_B$ is the marginal cost of borrowing when banks just start to borrow and it equals the relending rate. $r_E(0)$, on the other hand, is the marginal return of excess reserves when $E = 0$. It is higher than the excess reserve interest rate i_E because the non-pecuniary 'safety factor' is the highest when $E = 0$. The negative slope of MRE is steeper than that of MRL because otherwise banks will start holding excess reserves as soon as $MRL = r_E(0)$. In the above graph, I assume that the level where $MRL = MRE$ is lower than $r_B(0)$. Therefore B becomes binding and the bank splits its resources $(1-\alpha)D$ between loans and excess reserves, extending loans up to the point where the marginal return of holding excess reserve becomes higher. The levels of L and E are shown in the graph.

Under this scenario, an increase in the loan interest rate i_L shifts MRL upwards, raising the level of loans and decreasing excess reserves provided B is still binding. Decreasing the excess reserve interest i_E shifts the MRE curve down and produces the same effect. If B remains binding, the relending rate that changes the level of $r_B(0)$ does not have any effects on bank loans. Increases in the deposit rate i_D, although exogenous in this model, will tend to induce the level of deposit, D, to increase accordingly, thus moving the MCB

curve horizontally to the right. Both loan and excess reserve will increase. An decrease in official required reserve ratio gives the same result.

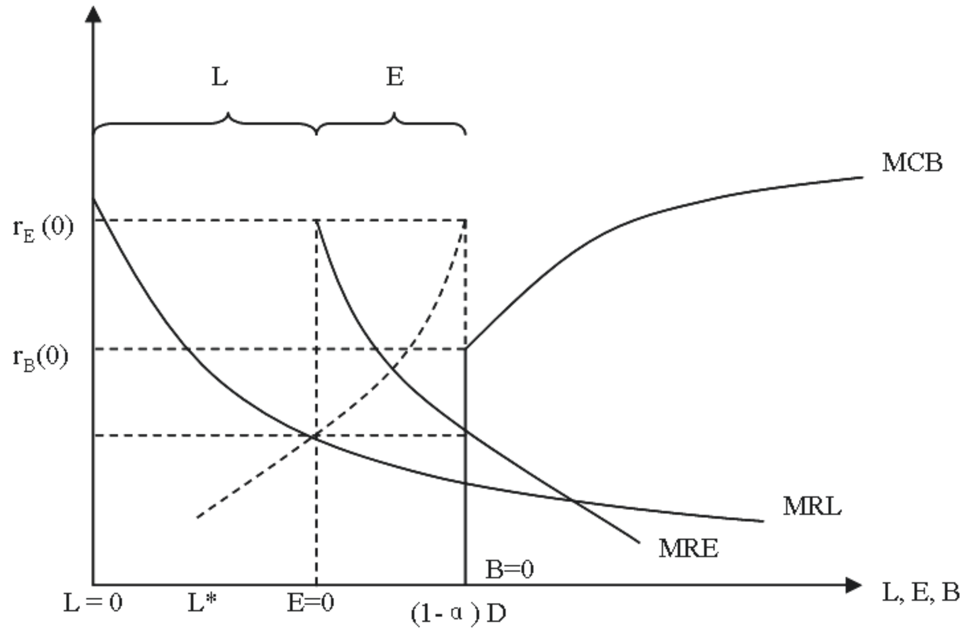


Figure 3.4: *Pre-reform Loan Market Equilibrium when $L > L^*$, $E > 0$ $B = 0$*

However, the assumption that $L = L^*$ is non-binding does not necessarily represent the context of China before reforms. From Appendices, Figure C.2, it is clear that banks in the pre-reform era usually had higher lending than their resources from deposit. The deficiency can only be filled with borrowing from the PBC. Therefore, I shall look at the scenario where $L = L^*$ is binding, and the level of credit quota, L^*, is greater than the costless available resource, $(1 - \alpha)D$. Figure 3.5 below plots a similar graph under the new constraints.

Now we have $L = L^*$ fixed. The shortage of funds of the banks is covered by direct lending from the central bank. The bank then hold excess reserves up to the point where the marginal return on excess reserves equals the marginal cost of borrowing. As Chinese banks always hold a certain amount of excess reserves, I can set the level of $r_E(0)$ to be an upper bound of the MCB curve with negative second order derivative w.r.t. B.

From the graph I can again interpret the implications of monetary policy before reforms.

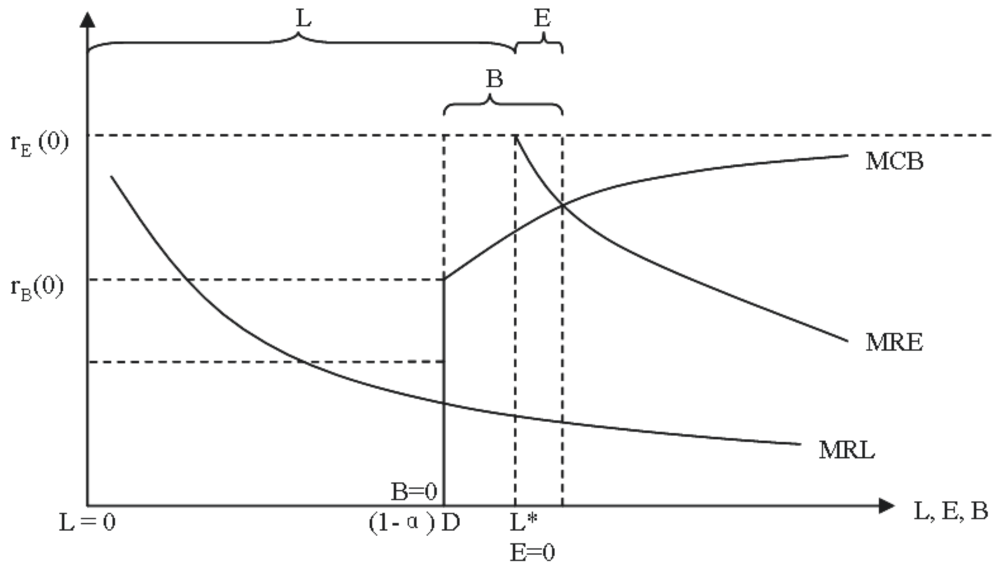


Figure 3.5: *Pre-reform Loan Market Equilibrium when* $L = L^*$, $B > 0$, $E > 0$, $L* > (1 - \alpha)D$

First note that the level of loans is exogenously determined as banks will always lend at the minimum required level L^*. Loan interest rate, by shifting the MRL curve, does not have any impact on the level of loans, excess reserves or borrowing. Borrowing is determined first by the difference between L^* and $(1 - \alpha)D$, then by the MCB and MRE curves. All excess reserve holdings are financed by central bank borrowing. Hence if L^* increases, L increases accordingly, B increases, but E will decrease as MRE curve shifts horizontally to the right, intersecting MCB at a lower level of excess reserve. If the relending rate i_B increases, MCB shifts vertically upwards, resulting in a decrease in both E and B. Lower required reserve ratio and larger total deposit (possibly induced by an increase in i_D) shifts MCB horizontally to the right, resulting in an increase in both E and B.

The figure only represent but one possible regime a specific bank could be in given its objective function and non-pecuniary costs associated with its transactions. Different types of banks, or the same group of banks with different sizes, may well fall in disparate regimes where monetary policies will have dinstinctive effects. In Figure 3.5, for example, if a bank has higher marginal rate of return from loans at a given level of loan supply, its higher MRL

curve could cut the MCB curve beyond the credit quota constraint. Under this scenario, loan interest rate and relending rate will have an impact on loan supply. One of the purpose of this paper is to identify the regimes different banks, or the same bank in different eras, belong, thus drawing conclusions about their responses to monetary instruments.

3.4.2 A Bank Model for the Post-reform Era, 1998-2008

After the banking reform, credit plans no longer exist. Banks have the new option of transaction in the interbank market at the interbank offer rate. I take the basic form of the previous model and make the necessary adjustments. Banks now have net interbank lending I on their asset side. If I is negative, it indicates net interbank borrowing. Assume the interbank rates for lending and borrowing are the same, the banks' profit maximization problem then becomes:

$$\max_{L,I,E,B} U = r_L(L, i_L)L + r_E(E, i_E)E + r_I I - r_D D - r_B(B, i_B)B$$

$$\text{s.t. } E + L + I \leq (1 - \alpha)D + B$$

$$E \geq 0, L \geq 0, B \geq 0$$

where $r_I = i_I$ is the interbank offer rate, the universal rate at which banks borrow and lend in the interbank market[19]. This rate can be perceived as the marginal return of lending and the marginal cost of borrowing in the interbank market at the the same time, i.e. $MRI = MCI = i_I$.

Assume that none of the nonnegativity constraints are binding (In reality, B is closest to be binding, but some SOCBs still borrow small amounts from the PBC as a source of emergency funding). The first-order conditions yield:

$$r'_L L + r_L = \lambda$$

$$r'_E E + r_E = \lambda$$

[19] I assume that there is no transaction or administrative costs in the interbank market, thus the interest on borrowing and lending is the same.

$$r_B'B + r_B = \lambda$$

$$r_I = i_I = \lambda$$

where $\lambda = \frac{i_D}{1-\alpha}$ and other notations are the same as before. Solving the FOCs gives I have the relationship $MRL = MRE = MCB = i_I$, which is illustrated graphically in Figure 3.6:

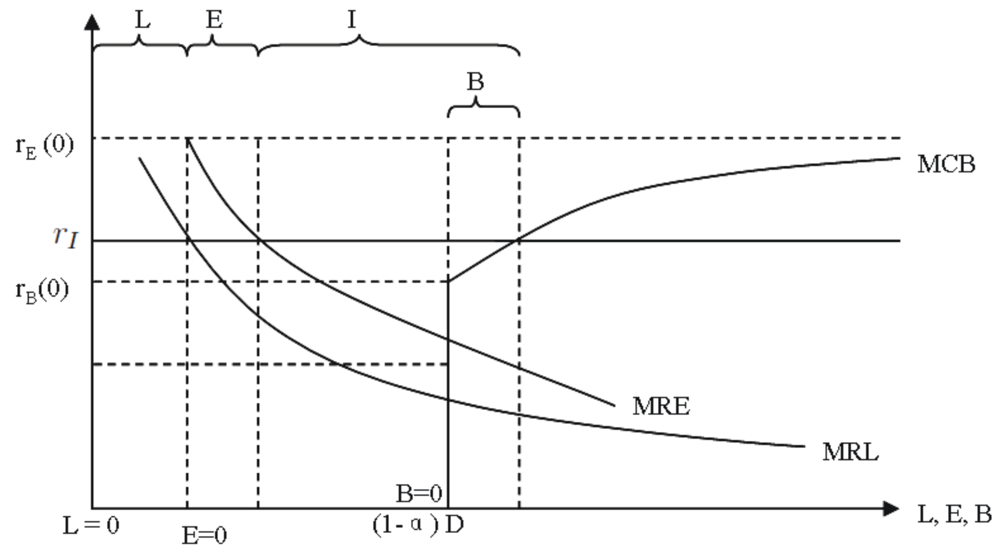


Figure 3.6: *Post-reform Loan Market Equilibrium when L, B, E non-binding, $r_I = i_I$, I is positive*

The implication of the model can be clearly seen on the graph. The amount of loans banks choose to lend depends solely on the interbank interest rate i_I and the return on loans r_L. Banks keep excess reserves until the marginal return on reserves drops below the return on interbank lending. Banks then lend all resources in the interbank market and even borrow from the PBC if the interbank offer rate is higher than the relending rate[20]. Under this framework, the offer rate becomes all important. Although it seems unrealistic that variables such as relending rate, required reserve ratio, excess reserve interest rate all

[20]Of course in reality, the non-pecuniary cost of non-collateralized borrowing from the PBC may be infinitely high if the banks are using the relending facility for purposes other than policy lending or emergency funding.

have no bearings on bank lending, we need to keep in mind that the interbank offer rate is affected by the whole set of interest rates administered by the PBC. The relending rate and excess reserve interest rate are particularly important as they constitute the upper and lower limit for the offer rate (Xie (2004)).

For smaller commercial banks, they are thought of being more market-oriented than the SOCBs. In addition, as the smaller banks are not usually burdened with the task of carrying out policy lending, we would expect the proportion of NPLs for them to be much lower than that of the SOCBs. This means that those banks have a much higher MRL curve, which could intersect the MCB curve above $r_B(0)$. This scenario is plotted in Figure 3.7:

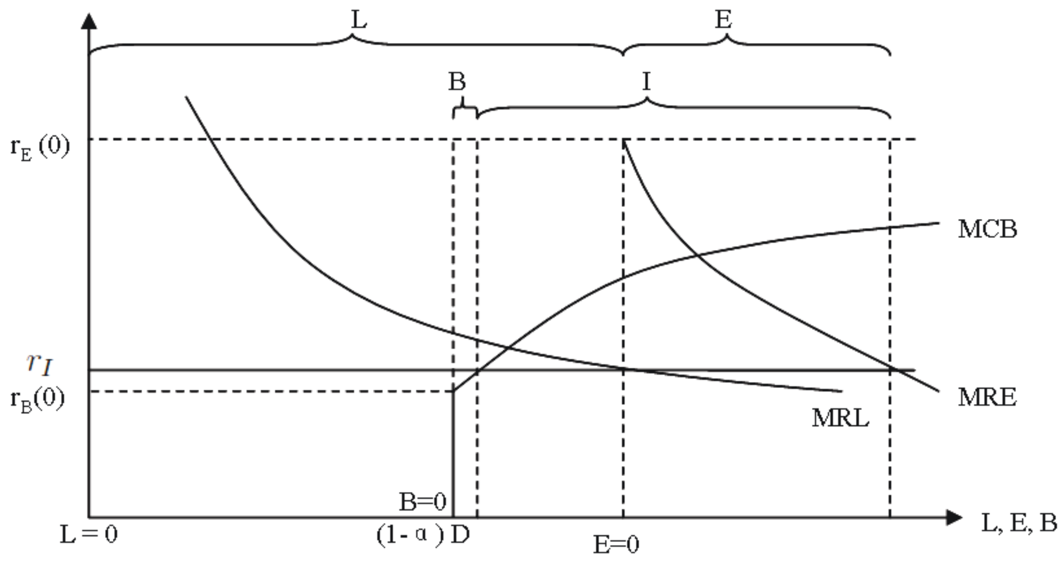


Figure 3.7: *Post-reform Loan Market Equilibrium when L, B, E non-binding, $r_I = i_I$, I is negative*

When the return of loans is high, banks borrow from the interbank market and lend them in the form of bank loans. Excess reserves are also funded by borrowing from the interbank market until the cost of borrowing exceeds the return on reserves. Deriving from the graph alone, interbank offer rate is still the only determinant of the level of L, B, and E. This model is more consistent with the western banking framework, where the interbank market plays the predominant role in influencing bank lending. This result may, to some extent, demonstrate the progress made by the Chinese banking reforms towards a more global standard[21].

It is important to keep in mind that based on the maintained assumption that loan level is supply constrained, my model is restricted to the partial equilibrium on the "supply side", or the banks' response to monetary policy in the form of loan supply changes. To model the demand side, thorough knowledge and understanding of the objectives functions of Chinese firms are required as well as firm-level data which is difficult to obtain. However, I argue that modeling from the supply side is sufficient in most cases in the empirical section.

3.5 Data

The sample of bank data is compiled from the People's Bank of China Statistics, China Finance and Banking Almanac 1986-2008, and various other sources[22]. It contains comprehensive annual data of important macroeconomic indicators and bank level data for the major banks. The set of data I have compiled and will be using extensively is the annual balance sheet data of the four SOCBs and eleven smaller commercial banks over a twenty year span, from 1986 to 2007. A summary of the characteristics of the banks is presented in Table 3.1.

In the previous sections I have outlined the two aspects of the Chinese banking system that motivate the thesis of this paper: the oligopolistic nature of the four dominant State-Owned Commercial Banks (SOCBs) versus the smaller commercial banks and the pre-reform era of direct PBC control versus the post-reform era of indirect market-oriented guidance. Having these objectives in mind, I divide the bank data from 1986-2007 accordingly: by the

[21] I have intentionally left out the rediscount rate from the model, which is thought to be one of the most important monetary policy instruments. This is because the *MCB* curve effectively captures the cost of borrowing from the central bank, which if we assume no direct borrowing post-reform, is substitutable for a marginal cost of collateralized borrowing (rediscount rate) curve. The slope of this curve is then determined by the rediscount rate in the same way as the *MCB* curve depends on the relending rate.

[22] I am indebted to the Division of Monetary Policy, People's Bank of China, in procuring much of the data used in this paper.

Table 3.1: *Summary Statistics of Banks*

Bank Abbrev.	Years Data Available	Total Assets *	Total Liabilities*	Total Loans*	Total Deposits*	Total Reserves*
ICBC†	1985 - 2007	3287-86843	3062-81400	2963-39575	1935-68984	325-11423
ABC†	1985 - 2007	1990-60501	1990-59614	1687-34801	912-52833	290-9346
BOC†	1985 - 2007	2605-50102	2512-46194	947-23360	1162-36178	3-7877
CCB†	1985 - 2007	1688-65981	1504-61758	552-31832	576-53403	317-9673
BOCM	1987 - 2007	201-21036	175-19748	66-10827	93-15558	87-2596
CITIC	1987 - 2007	87-10112	87-9270	38-5658	49-7872	0-1233
Everbright	1992 - 2007	26-7393	18-7146	16-3951	8-5406	0-1206
Huaxia	1996 - 2007	227-5925	198-5793	102-2985	162-4388	47-830
Minsheng	1996 - 2007	86-9198	72-8491	19-5473	40-6712	11-1103
GDDB	1989 - 2007	35-4375	35-4221	22-1938	8-2891	0-616
SZDB	1987 - 2007	4-3525	4-3395	3-2158	4-2813	1-407
CMB	1988 - 2007	24-13106	24-12426	19-6544	16-9435	0-1526
CIB	1991 - 2007	32-8513	25-8124	18-3930	13-5054	8-939
SHPDB	1994 - 2007	178-9195	165-8867	98-5357	133-7635	37-1414
Evergrowing	1992 - 2007	9-1074	9-1054	7-369	7-556	1-156

Note. 1. All bank level data are compiled from China Finance and Banking Almanac 1986-2008.
2. Total reserve data come from documented results and author's calculation, which might be prone to errors.
3. All values are the current year value, not adjusted to a base year, rounded off to zero decimal place.
4. Bank Abbreviations stand for: ICBC,*Industrial and Commercial Bank of China*; ABC,*Agricultural Bank of China*; BOC,*Bank of China*; CCB,*Construction Bank of China*; BOCM,*Bank of Communications*; CITIC,*China CITIC Bank*; Everbright,*China Everbright Bank*; Huaxia,*Huaxia Bank*; Minsheng,*China Minsheng Bank*; GDDB,*Guangdong Development Bank*; SZDB,*Shenzhen Development Bank*; CMB,*China Merchants Bank*; CIB,*China Industrail Bank*; SHPDB,*Shanghai Pudong Development Bank*; Evergrowing,*Evergrowing Bank*.
*: All values are of unit 100 million RMB (1 Yi), displaying minimum and maximum value over the years available.
†: State Owned Commercial Banks (SOCB).

nature of the banks and whether it is in the pre-reform or post-reform periods.

It is easy to separate the data by banks as the SOCBs have always consisted the "Big Four": Industrial and Commercial Bank of China, Agricultural Bank of China, China Construction Bank and Bank of China, each of which focuses on a different sector, namely industry and commerce, agriculture, construction and foreign currency transactions[23]. These four banks will be grouped together under "SOCBs" in my regression analysis. All other banks in the data set are either much smaller national banks such as Bank of Communications and CITIC Bank, or local commercial banks such as Shanghai Pudong Development Bank. They will be categorized under the "non-SOCBs" group.

Separating the two decades from 1986-2007 into pre-reform and post-reform era, however, is not as straightforward. The reform started since early 1990s as described earlier. Although the most groundbreaking steps have taken place before the year 2000, I still cannot assert that the reform has completed[24]. The most significant policy changes by the PBC did not happen within a short period of time, but rather spanned across at least five years in mid-1990s. Table 3.2 (Park and Sehrt (2001)) summarizes the timeline of major policy changes during the reform.

Due to the fact that some of the PBC's policy instruments did not become fully operational until late 1990s, it is difficult to analyze the entire data set with a reform dummy. The strategy of this paper is to split the data into two periods: pre and post-reform, and apply empirical analysis specifically suited to that period. Although the reform has been a gradual, and indeed ongoing, process, our strategy requires us to identify a threshhold year that distinguishes the pre and post-reform eras.

I have several candidates to choose from based on the reform summary table. In 1994, the PBC centralized relending and prohibited local PBC branches from making direct

---

[23]In recent years, Bank of Communications has grown both in size and importance to that comparable to the "Big Four", and indeed has been considered a SOCB by many. However, PBC statistics still categorize the bank under "Other Commercial Banks". I follow this official classification in this paper.

[24]The agenda of liberalizing interest rate and exchange rate has until now stagnated, as argued in Mehran and Quintyn (1996).

lending decisions. This prevented excessive lending arising from the political influence of local government officials on the branch managers. In the same year, the PBC initiated a new method of managing approved credit volume of banks. From a "quantitative management" of setting administrative credit targets, the PBC switched to a "ratio management" of assigning credit volume based on a maximum ratio between deposits and loans (Xie (2004)). Banks were granted more flexibility in allocating funds by drawing on interbank transfers. Also in that year, three policy banks were set up to take away part of the policy loan obligations from the SOCBs, lending them more autonomy in pursuing commercial goals. Another year of interest is 1996. The new commercial bank law aiming at improving managerial incentives were in full swing (it was legislated in May, 1995). A fully functional interbank market was established and CHIBOR (China Interbank Offer Rate) were officially documented since then. The year 1998 was also marked by exceptional policy turning points. The explicit credit quota was eliminated and central bank relending discontinued its role as a tool of managing total credit and became a lender of last resort. The rediscount rate became an independent monetary policy instrument and started to play a significant role in steering the economy. Before 1998, it was set to float around 5-10% below the ongoing loan interest rate.

In light of the above discussion, I choose 1998 as the first year of the post-refrom era noting that the timing of several reforms does not agree exactly with such division.

3.6 Empirical Analysis and Results

3.6.1 Empirical Strategy

In the previous section I have outlined the method of dividing the data set into four subsets: pre-reform SOCBs, pre-reform non-SOCBs, post-reform SOCBs and post-reform non-SOCBs. From the bank maximization model developed in earlier sections, I can identify the endogenous variables as the quantities of loans, excess reserves and borrowing from

Table 3.2: *Financial Reform Summary: 1991-1998*

Policy Reform	1991	1992	1993	1994	1995	1996	1997	1998
1. Guidance, rather than binding credit plans	yes	yes	no July	no	yes	yes	yes	yes
2. Centralized relending	no	no	no	yes June	yes	yes	yes	yes
3. Ratio management	no	no	no	yes Feb	yes	yes	yes	yes
4. Commercial Bank Law	no	no	no	no	yes May	yes	yes	yes
5. Policy banks	no	no	no	yes* Dec	yes	yes	yes	yes
6. Interbank market	yes	yes	no July	no	no	yes	yes	yes
7. Indep. rediscount rate	yes	yes	no	no	no	yes	yes	yes

Notes Sources for reform dates: 1. Zhu Rongji's 16 point program.
2. Announced May 9, implemented June 21, 1994. Yinfa[PBC Regulation] no. 43 (1994) in PBC ed., *1994 nian xindai zijin guanli wenjian huibian* [Compendium of Documents on Loan Fund Management 1994] (Beijing: Zhongguo jinrong chunbanshe), pp. 92-98.
3. Announced February 15, implemented later in the year. Yinfa [PBC Regulation] no. 38 (1994) in PBC,ed., *1994 nian jinrong guizhang zhidu xuanbian* [Selected Financial Rules and Regulations 1994] (Beijing: Zhongguo jinrong chubanshe), vol. 1: pp. 25-31.
4. "Zhongguo renmin gongheguo shangye yinhangfa." [Commercial Bank Law of the People's Republic of China] in PBC(1996). *1995 nian jinrong guizhang zhidu xuanbian.* [Selected Financial Rultes and Regulations 1995] (Beijing: Zhongguo jinrong chubanshe), vol. 1, pp. 8 ff.
5. Policy banks established gradually beinning mid-year. China Development Bank established April 14th, Import-Export Bank established July 1, and Agricultural Development Bank of China branches established mostly in late 1994. PBC(1995). *Zhongguo jinrong nianjian 1995.* [China Financial Yearbook] (Beijing: Zhongguo jinrong chubanshe), p. 145.
6. PBC Department for Monetary Policy (1997). *1996 Quanguo tongyi de yinhang jian tongye chaijie shichang nianbao.* [1996 Annual Report of the National Interbank Market]. (Beijing: Zhongguo renmin yinhang huobi zhengcesi)
* Policy banks were established gradually throughout the year. Most ADBC branches were established in late 1994.

PBC, while the exogenous variables are centrally administered interest rates[25] and the level of deposit[26]. Banks choose the level of loans, excess reserves and borrowing from PBC

[25] They include, but are not limited to: loan rates of different maturities, deposit rates of different maturities, relending rate, excess reserve interest rate, rediscount rate, required reserve ratio.

[26] As the banks cannot autonomously adjust their deposit rate, it is safe for us to assume that they cannot determine the level of deposit in our simple model. I also assume that the depositors in China are generally not sensitive to banks' balance sheet conditions. As a centrally planned economy, China has never allowed any major commercial banks to go into default, hence there should be very little concern from the depositors over the safety of their assets. Furthermore, since the central bank mandates the required reserve ratio, banks

to maximize profit (objective function). To analyze the working of the credit channel, I posit bank loans as the dependent variable, with independent variables being the various exogenous interest rates and the level of deposit.

Before regression analysis, I take first difference of the loan, excess reserve, PBC borrowing and deposit levels to eliminate the potential non-stationarity in the panel time series. The difference in levels are normalized by the previous year's total assets to mitigate the cross sectional heterogeneity of levels. Table 3.3 shows the unit root test statistics for the post-reform panels[27] using both the Levin-Lin-Chu (Levin *et al.* (2002)) test and Im-Pesaran-Shin test (Im *et al.* (2003)). The result suggests that the post-reform balance panel exhibits strong stationarity in asset-weighted first-differenced loan supply.

Table 3.3: *Unit Root Tests for Post-reform Changes in Loans*

Bank Sample		Panel Unit Root Tests IPS	LLC
	Test Statistic	-3.832**	-8.379**
Big SOCB	5% Critical Value	-2.280	-6.993
	Test Statistic	-2.447**	-8.627**
Small non-SOCB	5% Critical Value	-1.950	-5.537

Notes: IPS is the t-bar test statistic from the Im, Pesaran and Shin test. LLC is the test statistic from the Levin, Lin and Chu test. Both tests use zero lag as the dependent variable is already the first difference. **Significant at 1% level. *Significant at 5% level.

Furthermore, bank fixed effects are controlled for in the regressions. This is because the State-owned Commercial Banks each have their own preferential sectors to which they extend loans. The smaller banks, on the other hand, face different loan situations according to geographical locations or specialized functions[28]. Therefore, there are bank

effectively face an exogenous required reserve level too.

[27] pre-reform panels are not balanced and cannot be easily tested. I did not use the more common Multivariate Augmented Dickey-Fuller test (Taylor and Sarno (1998)) because the non-SOCB panel has time dimension smaller than the cross-sectional dimention.

[28] For example, Shanghai Pudong Development Bank was established to support the development of the Pudong pioneer economic zone. China Merchants Bank, on the other hand, is a nation-wide bank founded with

level idiosyncratic characteristics that affect their loan supply.

Although the data set has been divided into SOCBs and smaller commercial banks, banks within the same group still exhibit dissimilar constraints. One of the constraints that directly influences lending decisions and hence the effectiveness of the credit channel is the level of capitalization, or in other words, the shareholders' equity given by the difference between total assets and total liabilities. Kishan and Opiela (2000) find that from 1980 to 1995, small and under-capitalized banks were most significantly affected by monetary contractions. Without the luxury of a large data set for finer divisions by capital-asset ratio, I propose to include interaction terms between banks' normalized capitalization and the policy variables in order to explore the cross-sectional differences within a group.

From the earlier discussions of characteristics of the Chinese banking system in the pre-reform era, I hypothesize that credit quotas were not a hard constraint for banks (especially SOCBs which carried the obligation of majority of the policy loans). In other words, although the SOCBs needed to utilize heavily the PBC relending facility to meet the policy lending quotas, they were still able to pursue some degree of commercial lending after meeting the credit targets. This restricted flexibility allowed them to respond to changes in interest rates. The credit quotas were determined by the government's policy objectives, the state of development of different sectors of the economy and regional preferential policies, which were intangible characteristics that could not be captured by my model. Thus, for state-owned large banks heavily constrained by the credit quota, they should be much more responsive to the relending rate than to the loan interest rate.

In the pre-reform period, the main policy instruments of the PBC were credit plans, relending policies and benchmark interest rates. Although the required reserve ratio was at the disposal of the PBC, it was never used for most of the 1986-1995 period, staying constant at 13%[29]. I propose the following estimation equation for both SOCBs and non-SOCBs:

---

the mission of providing retail services.

[29]This is because with heavy quantity management like credit plans in place, the usage of another quantity policy instrument such as the required reserve ratio became redundant.

$$\begin{aligned}\Delta L_{it} &= \beta_0 + \beta_1 r_{Bt} + \beta_2 r_{Et} + \beta_3 r_{Lt} + \beta_4 \Delta D_{it} + \beta_5 year \\ &+ \beta_6 cap_{it} + \beta_7 cap_{it} * r_{Bt} (+\beta_8 cap_{it} * r_{Et})(+\beta_9 cap_{it} * r_{Lt}) \\ &+ \lambda_i + u_{it} \end{aligned} \tag{3.1}$$

Where just as in my earlier models, ΔL denotes change in loans normalized by previous year's asset, λ_i is a vector of bank dummy variables, r_B is the relending rate, r_E denotes excess reserve interest rate, r_L is the weighted average loan interest rate, ΔD is normalized change in deposit, *year* represents the time trend, and *cap* is bank's capitalization which is interacted with each policy instrument in separate regressions. The variable *cap* is calculated as follows[30]:

$$cap_{it} = \text{capitalization}_{it} = \frac{\text{total assets}_{it} - \text{total liabilities}_{it}}{\text{total asset}_{it-1}}$$

The parenthesis in the regression model indicates that the interaction terms are applied one at a time and separately estimated. A summary of the variables are reported in Table 3.4 below[31].

After the reforms, direct credit control was discontinued and a large portion of the policy lending obligations were transferred to policy banks. Commercial banks were given more flexibility in making their own credit allocations to pursue greater commercial gains. As a result, changes in loan levels would then respond to a slightly different set of PBC policy instruments. Despite the fact that excess reserve level had gone down considerably as reform deepened, the average level of around 5% in the post-reform period was still high enough to affect lending volume. PBC direct lending became history together with credit

[30]The *capitalization* variable is similar to the capital-asset ratio, except that total equity is divided by past year's assets instead of current year's assets to avoid potential endogeneity issues.

[31]Due to inconsistencies in balance sheet format, some non-SOCBs categorized owners' equity under liabilities, thus creating equal amount of total asset and total liabilities. This explains the minimum value of zero for the capitalization of non-SOCBs.

Table 3.4: *Pre-Reform Summary Statistics: 1986-1997*

State-owned Commercial Banks				
Variable	Obs	Mean	Minimum	Maximum
Change in Loans (ΔL)	48	0.112	-0.111	0.270
Change in Deposits (ΔD)	48	0.118	0.0296	0.290
Capitalization (cap)	48	0.0559	0.0	0.125
Other Commercial Banks				
Variable	Obs	Mean	Minimum	Maximum
Change in Loans (ΔL)	68	0.275	-0.0583	1.184
Change in Deposits (ΔD)	68	0.376	-0.104	2.165
Capitalization (cap)	68	0.0936	0.0	0.463
Policy Instruments				
Variable	Obs	Mean	Minimum	Maximum
Relending Rate (r_B)	12	8.73	4.68	11.03
Excess Reserve Interest (r_E)	12	7.31	4.92	9.18
Loan Interest (r_L)	12	9.65	7.92	11.52

plans. As a result, the data on PBC borrowing was too sparse and random to merit serious analysis.

Besides the usual policy tools such as loan rate, relending rate and excess reserve interest, the rediscount rate became an effective arsenal of the central bank. More importantly, the rediscount rate can be actively managed by the PBC to influence interbank offer rate in the interbank market. The required reserve ratio as a monetary policy instrument has reassumed its importance after the reforms. It has been used frequently to drain excess liquidity from the banking system (Xie (2004)). Thus I propose the following estimation equation in the post-reform period for both SOCBs and non-SOCBs:

$$\begin{aligned}\Delta L_{it} &= \beta_0 + \beta_1 r_{Bt} + \beta_2 r_{Et} + \beta_3 r_{Lt} + \beta_4 r_{Rt} + \beta_5 \Delta RRR_t \\ &\quad + \beta_6 \Delta D_{it} + \beta_7 year + \beta_8 cap_{it} + \beta_9 cap_{it} * r_{Bt} (+\beta_{10} cap_{it} * r_{Et}) \\ &\quad (+\beta_{11} cap_{it} * r_{Lt})(+\beta_{12} cap_{it} * r_{Rt})(+\beta_{13} cap_{it} * \Delta RRR_t) + \lambda_i + u_{it} \end{aligned} \tag{3.2}$$

Where r_R is the weighted average rediscount rate and $\Delta_R RR$ is the change in official reserve requirement. Similar to the pre-reform estimation equation, I interact capitalization with each policy instrument in separate regressions. Table 3.5 reports a summary of the variables[32].

Table 3.5: *Post-Reform Summary Statistics: 1998-2007*

State-owned Commercial Banks				
Variable	Obs	Mean	Minimum	Maximum
Change in Loans (ΔL)	40	0.0571	-0.183	0.246
Change in Deposits (ΔD)	40	0.107	-0.0490	0.193
Capitalization (cap)	36	0.0561	0.0166	0.0985
Other Commercial Banks				
Variable	Obs	Mean	Minimum	Maximum
Change in Loans (ΔL)	110	0.143	-0.0892	0.412
Change in Deposits (ΔD)	110	0.217	-0.286	0.794
Capitalization (cap)	99	0.0486	-0.0139	0.165
Policy Instruments				
Variable	Obs	Mean	Minimum	Maximum
Relending Rate (r_B)	10	4.09	3.24	6.99
Excess Reserve Interest (r_E)	10	2.55	0.99	4.67
Loan Interest (r_L)	10	5.96	5.31	7.50
Change in Reserve Ratio (ΔRRR)	10	-0.14	-4.17	3.59
Rediscount Rate (r_R)	10	3.13	2.16	5.15

Before discussing the results, I will briefly review the interpretation of coefficients according to the predictions of my earlier model. Before the reforms took place, large banks borrow heavily from the central bank. In addition to meeting the credit quota, PBC loans also helped to fund the limited autonomous loans which the banks could pursue to maximize profit. Therefore, large banks' loan levels should be strongly affected by fluctuations in relending rate. Loan interest rates may have an impact too, but it is expected to be smaller than the effect of relending rate, depending on the degree of flexibility individual bank enjoys. Non-SOCBs on the other hand should not respond to the relending rate since they

[32]The culprit for the seemingly impossible negative minimum capitalization for non-SOCBs is the Everbright Bank. From 2004 to 2006, the bank reported negative owners' equity. Clearly the government has allowed the bank to survive when it was effectively bankrupt.

barely borrowed from the PBC. Unencumbered by heavy policy lending responsibilities, the smaller commercial banks were expected to be more profit oriented.

One of the most notable impacts of the reform on the banks is the elimination of credit quotas and discontinuation of PBC direct lending as a means of controling the total credit in the market. If the reform has achieved its goals, banks would become more market-oriented and react more aggressively to a broader set of interest rates. Rediscount rate affects a bank's ability to obtain collateralized funds from the central bank and acts as a beacon for the interbank market. Increases in required reserve ratio should directly constrain the resources available for banks to make loans. Even though most banks keep a substantial level of excess reserves which acts as a buffer to such policy shocks, their loan levels would decrease nonetheless if banks are reluctant to allow their excess reserves to shrink substantially.

The story outlined in Kishan and Opiela (2000) should also be true in China's case. Both before and after the reforms, small banks with low capital-asset ratio would have trouble securing other types of funds when monetary policies are contractionary. Monetary policies would then have the most notable impact on their loan supply. Compared to well-capitalized SOCBs, such banks would be more prone to using the PBC's relending facility as a lender of last resort in the post-reform era, hence become more exposed to relending rate fluctuations. Kishan and Opiela identify similar mechanisms that serve as evidence of the existence of the narrow credit channel in the US. Through empirical analysis, I would like to test if such mechanism is at work in China's context, and whether the large, liquid banks are affected as well.

3.6.2 Results

Table 3.6 reports the estimation result of equation (1) for pre-reform period. The effect of the loan interest rate behaves according to our predictions. Increases in the loan interest rate result in increases in the loans by SOCBs, although the coefficients are not statistically different from zero as shown in column 1. The lack of significance suggests that those banks were subject to heavy state control and credit quotas so that they did not respond to market interest rates as one would expect commercial banks to. The non-SOCBs were subject to fewer policy lending obligations and were more profit oriented. Not surprisingly, the loan interest rate has an impact on their loan supply which is significant at 5% level as column 5 and 6 of Table 3.6 demonstrates.

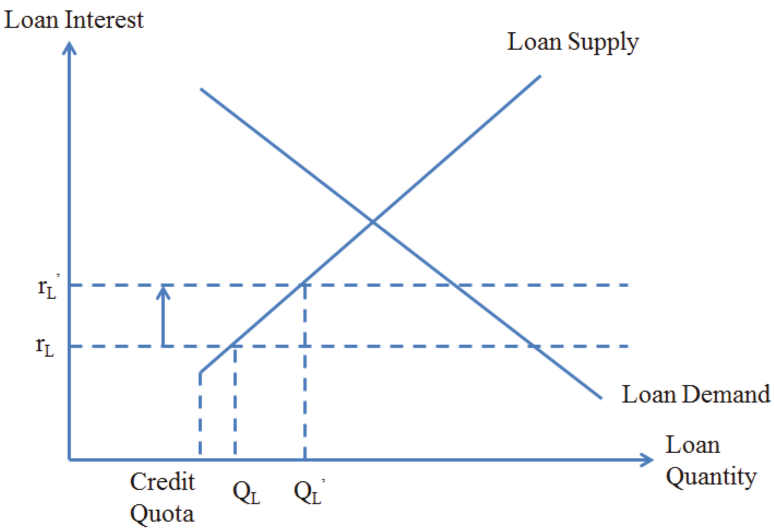
Interestingly, the coefficients are negative for the non-SOCBs: 1 percentage point increase in loan interest rate decreases the level of loans by more than 10% of past year's asset. The characteristic structure of the Chinese banking system before reforms could be invoked to explain this phenomenon. Before late 1990s, the state-owned enterprises were the largest consumers of loans and were supported by policy loans from the SOCBs. As a result, large state banks dominated the loan market (Geiger (2008)). Their loan supply was the binding constrait that determined the eventual level. Hence increases in loan interest has a positive effect on loan level through influencing the supply side. For many small banks, however, loan demand was binding as their customers were either small enterprises or regional businesses, and they have to compete with SOCBs for the large businesses. Increase in loan interest depresses demand, thus reducing the loan levels of the non-SOCBs. Figure 3.8 is a simple illustration of the above discussion. As price takers facing exogenous loan interest rate, higher demands for loans from the SOCBs resulted in the market equilibrium loan interest rate above the actual level, while the equilibrium was below the actual interest rate level for non-SOCBs. Figure (a) also shows the scenario where credit quotas for the state banks were not a hard constraint.

As expected, positive changes in the relending rate are associated with negative changes in SOCBs' loan supply. The large state banks extended enormous amount of policy loans which were mainly supported by the relending facility. This explains their sensitivity towards the interest rate charged on the borrowed funds from PBC. A one percentage point increase in the relending rate is associated with a decrease in the level of loans equivalent to roughly 2.5% to 3% of previous year's asset. Given the fact that loans comprised more than 70% of the total asset on banks' balance sheets before 1998, the impact is relatively mild. This result demonstrates the effectiveness of credit quotas even when they are not strictly

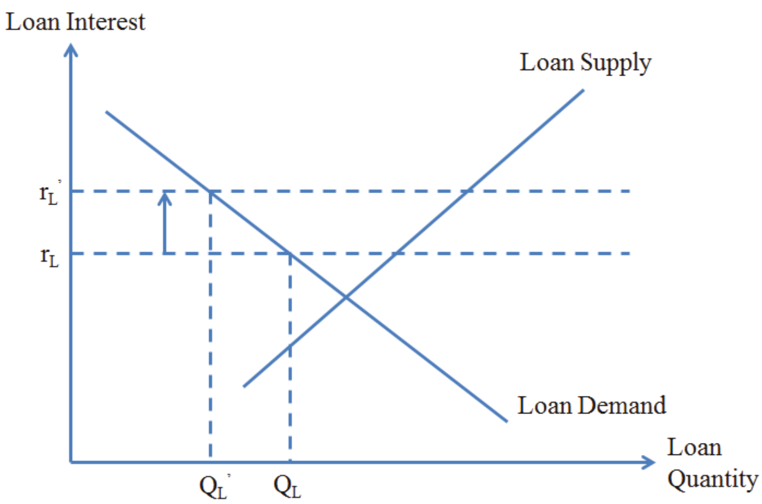
Table 3.6: *Pre reform Determinants of Loan Changes*

VARIABLES	(1) SOCB	(2) SOCB	(3) SOCB	(4) SOCB	(5) non-SOCB	(6) non-SOCB	(7) non-SOCB	(8) non-SOCB
Loan Interest (r_L)	0.0111	0.00739	0.00670	-0.00895	-0.129**	-0.124**	-0.0886*	-0.135**
	(0.0210)	(0.0205)	(0.0219)	(0.0387)	(0.0503)	(0.0519)	(0.0509)	(0.0540)
Relending Rate (r_B)	-0.0240**	-0.0246**	-0.0315**	-0.0311***	0.0793*	0.0797*	0.0456	0.0774*
	(0.00954)	(0.00998)	(0.0144)	(0.0108)	(0.0412)	(0.0471)	(0.0484)	(0.0446)
Change in Deposit (ΔD)	0.324*	0.333*	0.315	0.296	0.394***	0.353**	0.339**	0.337**
	(0.168)	(0.173)	(0.202)	(0.209)	(0.143)	(0.151)	(0.141)	(0.133)
Capitalization (cap)		0.235	-0.320	-1.949		0.303	-3.648**	-5.945**
		(0.183)	(1.365)	(3.043)		(0.257)	(1.651)	(2.607)
cap*r_B			0.0749				0.427**	
			(0.170)				(0.177)	
cap*r_L				0.246				0.620**
				(0.335)				(0.256)
Observations	48	48	48	48	68	68	68	68
R-squared	0.280	0.288	0.294	0.312	0.706	0.719	0.753	0.760
Number of Banks	4	4	4	4	11	11	11	11

Notes 1. Robust standard errors in parentheses, interest rates in percentage points.
2. Panel data unbalanced for non-SOCBs and balanced for SOCBs.
3. * significant at 10%, ** significant at 5%, *** significant at 1%.



(a) *SOCB in response to an increase in* r_L



(b) *Demand Constrained non-SOCB in response to an increase in* r_L

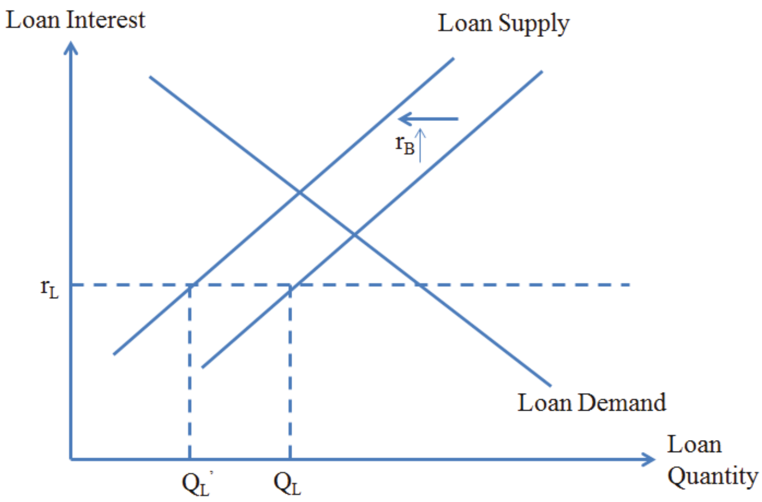
Figure 3.8: *Pre-reform Loan Market Equilibrium when* r_L *increases*

binding. The state banks did not have much flexibility in utilizing the relending facility to fund their commercial lendings.

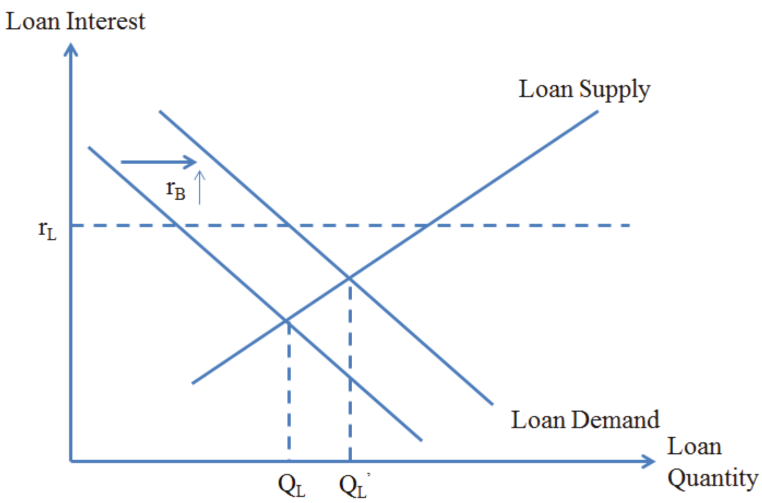
Surprisingly, non-SOCBs' loan supply is positively associated with relending rate with a larger elasticity than the SOCBs. The coefficients are only weakly significant, echoing the fact that they did not have any access to the relending facility as the SOCBs. Following from the dicussion of the impact of loan interest on SOCBs vs. non-SOCBs above, this can also be perceived as a negative spillover effect. If the market equilibrium loan interest rate for SOCBs remained constantly above the exogenously set rate as hypothesized earlier, loan supply from them was binding. A supply-side shock such as an increase in relending rate would cause SOCBs to issue less loans, creating a larger pool of unmet loan demand. The state-owned enterprises as well as small and medium sized enterprises that fell victim to this drop in loan supply would possibly turn to smaller commercial banks. As loan demand was the binding constraint for those banks, their loan level would increase in response to the contractionary relending rate shock. Given the much smaller size of their balance sheets, the positive coefficient is rather large. Figure 3.9 also illustrates the working of this mechanism. In graph (a), the loan supply curve for the SOCBs shifts to the left due to an adverse shock from increases in relending rate, creating an additional $Q_L' - Q_L$ of excess loan demands. Some of these excess demands spill over to the demand for non-SOCB loans, causing an outward shift of the demand curve in graph (b). The quantity of loans given by the small commercial banks thus increases. Unfortunately, I do not have the means to test this spillover mechanism with the data available at hand, and proving this idea will be left to future research.

The level of deposits has a positive coefficient for both types of banks, reflecting the role of deposit as a source of funding for bank loans. Nevertheless, the coefficient is much more significant for non-SOCBs than SOCBs. This is because state banks could also borrow from the PBC through relending (and they did borrow heavily), while small banks depended almost exclusively on deposits to support loans.

The interaction terms shed light on how capitalization, a measure of a bank's financial health, influences the scale of impact monetary policies have on a bank's lending decisions. The interaction terms are statistically insignificant for SOCBs, which can be caused by either the small sample size, or that those banks, directly supported by the state, had little worry about under-capitalization. The opposite signs between the coefficients of loan interest and its interaction term with capitalization for non-SOCBs (both significant at 5% level)



(a) *SOCB in response to an increase in r_B*



(b) *Demand Constrained non-SOCB in response to an increase in r_B*

Figure 3.9: *Pre-reform Loan Market Equilibrium when r_B increases*

indicate that high capitalization served as an effective buffer for adverse monetary policy shocks. In other words, when monetary policy becomes contractionary, a small bank with healthier capital leverage would be able to lessen the reduction in lending. It also means that under-capitalized small banks would face most difficulty raising funds to maintain loan growth in a contractionary environment, coinciding with the findings of Kishan and Opiela (2000).

Post-reform estimation results are reported in Table 3.7 and Table 3.8. Compared to the pre-reform era, the striking difference in the banks' responses to relending rate suggests that credit quota elimination has fundamentally transformed the role of direct central bank lending. SOCBs became insensitive to changes in relending rate, because they no longer needed direct PBC relending to meet loan targets[33]. The relending rate was still managed by the state although central bank direct lending only acted as a lender of last resort which the banks drew on when they were in a tight position, or short on cash. The state-owned commercial banks, with their deposit holdings burgeoning since 1990s, did not have much need for emergency PBC lending[34]. However, the smaller banks, especially those with low liquidity, would be more concerned with the availability of this emergency fund. The fact that on average SOCBs kept a much lower level of excess reserves than non-SOCBs is an indicator of the aforementioned situation. Therefore, higher relending rate represents an increased marginal cost of obtaining such funds, which may cause the under-capitalized banks to become more cautionary in making loans. Table 3.8 indicates that 1 percentage point increase in relending rate reduces loan supply equivalent to nearly 20% of past year's asset. Given that the relending rate stayed below 4% after 1999, a 1 percentage point increase represents a highly contractionary monetary policy. Such a scale in loan reduction is hence plausible.

The coefficient on the loan interest rate remains statistically insignificant for SOCBs, although the sign of the coefficients has changed from positive in the pre-reform era to negative. Despite the discontinuation of explicit credit plans, state control on the "Big Four" was by no means lax. Credit quotas were taken over by implicit Window Guidance modeled after Japan's experience (Geiger (2008)), which could possibly explain the persisting unresponsiveness of SOCBs to loan rate changes.

It is intriguing to note that although the interest rates in the regression are each

[33]See Appendices, Figure C.1, Borrowing from the PBC for those banks has decreased sharply since mid-1990s and practically stopped completely after 2000.

[34]See Appendix 2. The surplus of deposits net loans has been widening drastically since the onset of the reform.

Table 3.7: *Post-reform Determinants of Loan Changes for SOCBs*

VARIABLES	(1)	(2)	(3)	(4)	(5)
Relending Rate (r_B)	0.141	0.213	0.209		
	(0.0924)	(0.136)	(0.137)		
Loan Interest (r_L)	-0.0780	-0.122**	-0.102	0.0387***	0.0282**
	(0.0532)	(0.0620)	(0.0639)	(0.0147)	(0.0138)
Rediscount Rate (r_R)	-0.0702	-0.0685	-0.0744		
	(0.0666)	(0.0706)	(0.0987)		
Change in RRR (ΔRRR)	0.0338	0.0277	0.0288	0.0174	0.0227
	(0.0258)	(0.0291)	(0.0305)	(0.0160)	(0.0189)
Change in Deposit (ΔD)	0.910*	0.858*	0.843	0.823	0.978**
	(0.497)	(0.521)	(0.561)	(0.508)	(0.498)
cap*r_L		0.354			
		(0.473)			
cap*r_R			0.127		
			(1.726)		
$r_L - r_R$				-0.0327	
				(0.0216)	
$r_L - r_B$					-0.0349
					(0.0325)
Observations	40	36	36	40	40
R-squared	0.430	0.390	0.387	0.292	0.263
Number of Banks	4	4	4	4	4

Notes 1. Robust standard errors in parentheses, interest rates in percentage points.
2. RRR stands for required reserve ratio.
3. The spread variables are calculated as presented in the table.
4. * significant at 10%, ** significant at 5%, *** significant at 1%.

statistically insignificant, they are jointly very significant[35], which is an indication that the major post-reform policy instruments are highly correlated with each other[36]. This finding echos one of the unique characteristics of the PBC's approach to monetary policies as outlined in Geiger (2008): the central bank would quite often make use of a combination

[35] An F-test on the joint significance of relending rate, excess reserve interest, loan interest and rediscount rate rejects the null hypothesis at 5% level.

[36] This can also be seen in Figure 3.1, where major monetary policy instruments move in a roughly synchronized manner.

of monetary policy tools simultaneously to achieve the fine tuning of the economy.

Although the variable levels do not contain large amount of information, it is likely that the spread between different interest rates could have a significant impact (Friedman and Kuttner (1992)). Therefore, I re-estimate the regression with less policy variables and the addition of spreads between loan rate and other interest rates. The results are reported in column (4) and (5). Despite the spread terms still being insignificant, we can now clearly see the significantly positive relationship between loan interest rate and loan supply, reinstating the result in the pre-reform case.

The restriction of window guidance on smaller banks was probably much looser, allowing them to adjust loan supply based on market interest rates in pursuit of maximizing profit. As the result demonstrates, loan rate affects non-SOCBs' loan level and is significant at 1%. Interestingly, the correlation between loan rate and changes in loan level of the non-SOCBs becomes positive, suggesting that the officially established loan rate was below the market equilibrium and loan supply became binding. This is confirmed by the historical movement of loan interest, which stayed above 8% before 1998 and was kept below 6% after the reforms took place. Furthermore, the growth of non-SOCBs and their increasing shares in the banking system compared to the "Big Four" have made them more attractive to enterprises seeking loans. The taking-off of the economy in late 1990s has also sparked off higher growth in demand for loans, especially from the burgeoning small and medium enterprises that found it hard to obtain loans from the SOCBs, thus outstripping the growth in banks' ability to supply. Both mechanisms likely contributed to the rightward shift of loan demand, making loan supply the constraining factor.

Deposits are still an important source of funding for loans. Both the coefficient and the significance level of changes in deposit remain roughly the same compared to the pre-reform regression for non-SOCBs. Interestingly, the impact of deposits on loans has increased substantially for SOCBs with coefficients increasing from around 0.3 to well above 0.8, representing more than 80% of the changes in deposits manifested as changes in loans on the other side of the balance sheet. One reason could be that SOCBs used to raise funds from both deposit and PBC relending, which are two substitutable sources (Appendices, Table C.1)[37]. After the major reforms took place, PBC direct lending was terminated. Coupled with ballooning deposit growth and limited other external finance options, banks had to depend predominantly on deposits.

Both large state banks and smaller commercial banks encountered similar limitations in sources of external finance other than deposits. One may wonder why changes in deposit level had a much larger impact for the SOCBs. One explanation can be derived from the differences in their excess reserve responses to deposit change. Historically, almost all Chinese banks kept a high level of excess reserves. While the SOCBs was able to gradually lower the level to below 3% after the reform, smaller banks still maintained their excess reserve level above 5%. For non-SOCBs, it is possible that a larger portion of the changes in deposit contributed to changes in excess reserves, resulting in a smaller change in loans. To test this theory, I run a similar post-reform regression on normalized changes in excess reserve (Appendices, Table C.2). I find that the portion of changes in deposit that turned into changes in excess reserves is roughly 25% higher on average for non-SOCBs, consistent with my explanation.

Table 3.8 demonstrates that non-SOCBs reduced their loan supply by little more than 3% of total asset when the required reserve ratio is increased by 1 percentage point. This finding is consistent with both my model and economic intuition: holding everything else constant, banks' ability to extend loans is reduced if they have to allocate a bigger portion of their assets to required reserve deposits at the central bank. Given the high base level of required reserve ratio (around 8% post-reform and well over 10% in 2007) and the high level of excess reserve holdings in non-SOCBs that acts as a buffer to such shocks, the relatively small impact is plausible.

On the other hand, the SOCBs' loan supply is positively correlated with changes in

---

[37]To test the substitutability, I run a pre-reform regression with borrowing from PBC as the dependent variable and the same set of exogenous covariates and interaction terms. From the results presented in Table C.1, I find that only deposit has a statistically significant impact. Changes in deposits are negatively correlated with changes in borrowed funds from PBC, reaffirming my hypothesis that the two sources of funds are substitutable.

Table 3.8: *Post-reform Determinants of Loan Changes for non-SOCBs*

VARIABLES	(1)	(2)	(3)	(4)
Relending Rate (r_B)	-0.181***	-0.279***	-0.227***	-0.181***
	(0.0478)	(0.0906)	(0.0881)	(0.0478)
Loan Interest (r_L)	0.108***	0.201***	0.128***	
	(0.0377)	(0.0696)	(0.0471)	
Rediscount Rate (r_R)	0.0984***	0.108***	0.173***	0.207***
	(0.0308)	(0.0311)	(0.0521)	(0.0643)
Change in RRR (ΔRRR)	-0.0390***	-0.0287**	-0.0327***	-0.0390***
	(0.0101)	(0.0123)	(0.0116)	(0.0101)
Change in Deposit (ΔD)	0.282***	0.281***	0.276***	0.282***
	(0.0807)	(0.0841)	(0.0854)	(0.0807)
cap*r_L		-1.348*		
		(0.719)		
cap*r_R			-1.378**	
			(0.669)	
$r_L - r_R$				0.108***
				(0.0377)
Observations	110	99	99	110
R-squared	0.396	0.420	0.424	0.301
Number of Banks	11	11	11	11

Notes 1. Robust standard errors in parentheses, interest rates in percentage points.
2. RRR stands for required reserve ratio.
3. The spread variables are calculated as presented in the table.
4. * significant at 10%, ** significant at 5%, *** significant at 1%.

required reserve ratio, although the coefficients are not statistically different from zero. The existence of reverse causality could be the reason behind this counter-intuitive phenomenon. To check for evidence of reverse causality, I run the same regression again with one period lagged change in required reserve ratio as an additional regressor. I find that although the contemporary change still has a positive slope, the coefficient of the lagged change is negative. This provides some evidence that the positive coefficient in the original regression is inconsistent, possibly attributable to contemporary reverse causation effect. While the changes in aggregate loans from non-SOCBs did not have a huge impact on the condition of the economy, an excessive growth of credit from the SOCBs is influential enough to induce the PBC to react with contractionary monetary policies: a hike in required reserve ratio in this case.

The positive relationship between the rediscount rate and non-SOCBs' loan changes is puzzling, as an increase in the rediscount rate usually signals a contractionary monetary stance of the PBC. I could not provide an intuition for this observation and further research with a more comprehensive data set is warranted.

In exploring the cross-sectional differences between banks within the same group, analysis of the interaction effects yields similar results as that of the pre-reform regression. Coefficients of loan interest rate and rediscount rate have opposite signs to their interaction terms with capitalization for both groups of banks, although they are statistically more significant for non-SOCBs than SOCBs for the same reason as in the pre-reform era. This result reaffirms our hypothesis and the findings of Kishan and Opiela (2000): the smaller the size and the lower the capital-asset ratio of a bank, the harder it is for them to solicit external finance and maintain a consistent loan growth after contractionary monetary policy shocks. In other words, contractionary monetary policies generally affect non-SOCBs more than large state banks.

3.6.3 Robustness

In the regression strategy, I normalize first difference in levels of loans, deposits, excess reserves and PBC direct lending by last year's total assets. As a robustness check for the potential endogeneity arising from total assets, I reestimate the fixed effect model in Equation (1) and (2) with real growth rate of loans and deposits. That is, I divide the first difference of the levels by the level of the same variable in the previous year and adjust the growth rate to take into account of inflation. The results are reported in Appendices, Table C.3 (pre-reform) and Appendices, Table C.4 (post-reform). One of the differences between the two models is that the balance sheet identity holds with normalized first differences of levels which are our original dependent variables. With real growth rates, however, the balance sheet identity only holds when I multiply the growth rates with the lagged level of respective variables. The findings of the new models are consistent with the original ones, with slight changes in significance and generally larger absolute value of coefficients.

I have assumed fixed effects in the OLS regressions under the belief of the existence of bank heterogeneity[38]. It could be argued, however, that bank fixed effects would have been mitigated by categorizing them under SOCBs and non-SOCBs, effectively distinguishing them by their size and functionality. Especially for the group of SOCBs, where the entities are all nation-wide banks with minimum heterogeneity arising from geographical locations, there is a strong case for adopting random effects model. Furthermore, since the size of the data set is limited, using a fixed effect model incorporating bank dummy variables incurs the risk of leaving too few degrees of freedom for consistent and rigorous regression analysis. As a check for robustness, I also run the same regressions of equation (1) and (2) with a random effects model. The results are presented in Appendices, Table C.5 (pre-reform) and Appendices, Table C.6 (post-reform). The random effect model yields consistent results: the signs, absolute values and significance levels of the coefficients are all comparable to those in the fixed effect model.

The choice of the threshold year can potentially create bias in the estimation as the major reform measures have spanned over many years in the 1990s. I check the consistency of the results by reestimating the regression models with 1994 and 1996, instead of just 1998, as the threshold year. The outcome is presented in Table C.7 and Table C.8 in Appendices. It is clear that both the sign and significance of the new estimation coefficients in the pre-reform period for both types of banks are largely in agreement with my original result. However, we have to be aware that the post-reform estimation with new threshold years is essentially identical to the original model. This is because the variable "Rediscount Rate" has only missing values prior to 1998[39] therefore not estimated. We also need to exercise

[38]Hausman Tests on the regression models have a clear preference for fixed effect model as well.

[39]Before 1998, rediscount rate is set to float within 5% to 10% of the ongoing weighted average loan rate. It only became an independently administered monetary policy instrument after 1998.

extraordinary conservation when interpreting the pre-1994 behavior of non-SOCBs. Indeed, the panel data for small commercial banks is highly skewed and sparse before 1994, as very few commercial banks besides the "Big Four" even existed at that time. The high R-squared value (> 0.9) is a manifestation of such drawbacks in using too early a cut-off year. In fact, this robustness check effectively serves to support my choice of 1998 as the reform threshold.

Figure 3.2 demonstrates that although the four official SOCBs are in a dominant position over smaller commercial banks, Bank of Communications (BOCM) comes close. With its loan and deposit level towering over all other non-SOCBs, BOCM is perceived by many as one of the mega state banks. Therefore I check the consistency of my model by categorizing BOCM under SOCB and present the results in Table C.9. The signs of coefficients for non-SOCBs are generally consistent with my original estimation and the significance level has improved in the post-reform period after removing BOCM as an "outlier" of the small commercial banks. The new SOCB estimations, however, yields results that are insignificant. This suggests that BOCM, despite having a large balance sheet compared to other non-SOCBs, essentially still behaves like a small bank and the inclusion of which in the already small SOCB group would introduce too much noise.

Lastly, my theoretic model predicts that loan *levels* respond to fluctuations in interest rate *levels*. It should naturally follow that *changes* in loan level, which is the dependent variable in my estimation model, respond to *changes* in interest rates. Nevertheless, I use interest rate levels instead of changes as my independent variables. The strategy is motivated by my belief that monetary policy instruments have a long-run lasting effect on the growth rate of loan supply. In other words, banks may have a loan growth target that is dependent on the *levels* of various interest rates. To provide support to this hypothesis, I reestimate the regression model with a lag on loan interest and test the null hypothesis that changes in interest rate levels do not have an impact on changes in loan levels (Sum of coefficients of r_{Lt} and $r_{L\,t-1}$ is zero). As the result in Table C.10 demonstrates, I cannot reject the null hypothesis at conventional significance levels for all estimations besides the post-reform regression on non-SOCBs, where I can reject the null at 1% significance (column 7 and 8). I conclude, therefore, that it is more appropriate to use interest rate *levels* instead of *changes* as regressors.

3.6.4 Caveats

In section 4, I have identified the possible behaviors of different banks in response to various monetary policy shocks with a profit maximization model. It is also imperative for us to be aware of the limitations associated with the model. Fundamentally, the model only captures the supply side equilibrium in which banks maximize their profits by choosing the level of loans they extend. In terms of describing real life behaviors, this set-up would only be appropriate if loan supply is the binding constraint. As can be seen from the empirical results and discussions of Figure 3.8, such an assumption does not always hold. Similarly, I cannot simply assume the central bank's relending or rediscount facilities are only determined by the demands of commercial banks. The PBC's supply curve may very well be subjected to shifts and become constraining without it actively manipulating one of its monetary policy tools. The shifts could be caused by the PBC managing non-pecuniary costs on its lending facilities, such as the strictness of window guidance. Therefore, to construct a general equilibrium involving firms, commercial banks and the central bank, thorough knowledge about the objective functions of the different entities is required. This warrants further research.

One should also keep in mind the quality of data available while fashioning empirical strategy and interpreting the results. *First*, the limited size of the data set poses enormous challenge for consistent and rigorous statistical analysis. The small time dimension (20 years) does not allow me to test for stationarity or serial correlation. The small number of observations also leaves little room to include lags of the policy variables. Our interpretation is thus restricted to the contemporaneous effects of the covariates where reverse causality is highly likely. *Second*, the data only contains annual observations at the bank level. This is an immediate concern as banks usually respond promptly to monetary policy shocks, and some policy instruments, required reserve ratio for example, are adjusted several times a year[40]. In order to accurately capture the nuances of the financial sector, quarterly or even monthly data would be more suitable for my purposes. *Third*, due to inconsistencies in the format of documenting balance sheets both cross-sectionally across banks and intertemporally across time, many numbers are cryptic in nature[41] and some variables, such as Total Excess Reserves, are based on the author's calculations. The reader needs to bear in mind the inaccuracies of the observations and exercise greater caution when interpreting empirical results.

3.7 Conclusion

The main focus of this paper is to analyze the effectiveness of monetary policy instruments on Chinese banks both cross-sectionally and intertemporally, incorporating the impact of the banking reform. I find that in the pre-reform period, large state banks and smaller commercial banks' responses to changes in relending rates and loan interest rates were directly opposite. This result can be explained by the existence of credit quotas for SOCBs and the PBC relending facility that was designed to help the SOCBs meet their targets. I deduce from the sign of loan interest rates that loan supply was the binding constraint for SOCBs while non-SOCBs were demand constrained. This gives rise to a "spillover" effect of loans which provides an explanation for the weakly significant positive relationship between relending rate and non-SOCB's loan levels.

The fact that relending rate stopped having an effect on SOCB's loans after the reforms confirms the success of one major reform agenda: the elimination of credit quotas. However, SOCBs persisting unresponsiveness to loan interest rate suggests that credit quota might be replaced by a softer constraint: window guidance. The relending rate did not disappear

[40] See Figure 3.1.

[41] An example would be the required reserves a bank holds at the central bank. Some banks accumulate required reserves with interbank deposits, while some accumulate reserves with cash. After 1997, a new central bank rule states that excess reserves should be merged with required reserves into a single "Reserves" account, which changed the appearance of bank balance sheets across the board.

from the PBC's arsenal though as the non-SOCBs are demonstrated to be very sensitive to its fluctuations. Central bank direct lending continues to act as a monetary signal as well as a lender of last resort and affect smaller banks more due to greater liquidity concerns.

The deposit level, which I assume to be exogenous to the banks, has a significantly positive impact on all banks at all times. In the post-reform period, nearly 90% of the total changes in loans by SOCBs are funded by changes in deposits after PBC relending becomes obsolete. This serves as evidence of a unique feature of the Chinese banking system: that the banks do not have much access to external finance options such as foreign capital markets. Although deposit[42] holdings have exploded across all banks after the reform, which were brought about by economic growth and stoked by the lack of other capital investment options. Loan supply was still the binding constraint as manifested in the positive coefficients of loan interest rates. The phenomenon that banks exercise great caution in extending loans is consistent with another two characteristics of the financial intermediation in China: banks have lower asset quality[43] than their foreign counterparts and banks keep high levels of excess reserve.

There is no evidence that shows banks are more sensitive to the spread between various centrally administered interest rates than their levels. Nevertheless, I was able to separate the post-reform loan interest impact on the SOCBs by reestimating the regression model with spreads. The interaction terms between capitalization ratio and policy variables investigate cross-sectional differences within a group. From interpreting the interaction results, I reach a similar conclusion as Kishan and Opiela (2000) that banks with smaller size and less capitalization tend to be affected more by contractionary monetary policy shocks. SOCBs, for example, being well-capitalized and "too big to fail", are insensitive to the interactions.

Overall the reform has achieved certain progress such as the departure from credit planning and direct quantity management. The replacement by window guidance and the

[42]See Appendices, Figure C.2.

[43]Ratio of non-performing loans (NPL) is estimated to be 19.15 percent in 2004 and much higher before reforms by CBRC Statistics.

monopolistic nature of the SOCBs, however, have mitigated the impact of the reform on the state banks. While generally very effective, the credit channel does exhibit a larger effect on small commercial banks. Because most benchmark interest rates are still centrally administered by the PBC, banks as price takers usually face a disequilibrium in the loan market due to their inability to influence the loan demand curve. To slowly eliminate such market distortions, a gradual deepening of reforms in interest rate liberalization is desirable, however the central government sees fit.

References

Acemoglu, D., Aghion, P. and Zilibotti, F. (2006). Distance to frontier, selection, and economic growth. *Journal of the European Economic association*, **4** (1), 37–74.

—, Antràs, P. and Helpman, E. (2007). Contracts and technology adoption. *The American Economic Review*, pp. 916–943.

Agénor, P.-R. and Montiel, P. J. (2008). Monetary policy analysis in a small open credit-based economy. *Open Economies Review*, **19** (4), 423–455.

Ando, A. and Modigliani, F. (1963). The" life cycle" hypothesis of saving: Aggregate implications and tests. *The American Economic Review*, **53** (1), 55–84.

Antras, P. (2003). Firms, contracts, and trade structure. *The Quarterly Journal of Economics*, **118** (4), 1375–1418.

— and Chor, D. (2013). Organizing the global value chain. *Econometrica*, **81** (6), 2127–2204.

—, Fort, T. C. and Tintelnot, F. (2014). *The margins of global sourcing: theory and evidence from US firms*.

— and Helpman, E. (2004). Global sourcing. *Journal of Political Economy*, **112** (3), 552–580.

Barnett, S. (2004). Banking sector developments. *OCCASIONAL PAPER-INTERNATIONAL MONETARY FUND*, pp. 43–50.

Bennett, J. and Dixon, H. D. (2001). Monetary policy and credit inchina: A theoretical analysis. *Journal of Macroeconomics*, **23** (2), 297–314.

Bernanke, B. and Gertler, M. (1989). Agency costs, net worth, and business fluctuations. *The American Economic Review*, pp. 14–31.

Bernanke, B. S. and Blinder, A. S. (1988). Credit, money, and aggregate demand. *The American Economic Review*, **78** (2), 435–439.

— and — (1992). The federal funds rate and the channels of monetary transmission. *The American Economic Review*, pp. 901–921.

— and Gertler, M. (1995). Inside the black box: The credit channel of monetary policy. *The Journal of Economic Perspectives*, **9** (4), 27–48.

Bernard, A. B. and Jensen, J. B. (1999). Exceptional exporter performance: cause, effect, or both? *Journal of International Economics*, **47** (1), 1–25.

—, —, Schott, P. K. and Redding, S. J. (2010). Intra-firm trade and product contractibility. *Peterson Institute for International Economics Working Paper*, (10-3).

Boler, E. A., Moxnes, A. and Ulltveit-Moe, K. H. (2014). R&d, international sourcing and the joint impact on firm performance. *Working Paper*.

Bustos, P. (2011). Trade liberalization, exports, and technology upgrading: Evidence on the impact of mercosur on argentinian firms. *The American Economic Review*, **101** (1), 304–340.

Corcos, G., Irac, D. M., Mion, G. and Verdier, T. (2012). *The Determinants of Intrafirm Trade: Evidence from French Firms*.

Costinot, A., Vogel, J. and Wang, S. (2013). An elementary theory of global supply chains. *The Review of Economic Studies*, **80** (1), 109–144.

Defever, F. and Toubal, F. (2007). *Productivity and the sourcing modes of multinational firms: evidence from French firm-level data*. Centre for Economic Performance, London School of Economics and Political Science.

Dickinson, D. and Jia, L. (2007). The real effects of monetary policy in china: An empirical analysis. *China Economic Review*, **18** (1), 87–111.

Doraszelski, U. and Jaumandreu, J. (2013). R&d and productivity: Estimating endogenous productivity. *The Review of Economic Studies*, **80** (4), 1338–1383.

Eaton, J. and Kortum, S. (2002). Technology, geography, and trade. *Econometrica*, pp. 1741–1779.

Farinas, J. C. and Martín-Marcos, A. (2010). Foreign sourcing and productivity: evidence at the firm level. *The World Economy*, **33** (3), 482–506.

Federico, S. (2010). Outsourcing versus integration at home or abroad and firm heterogeneity. *Empirica*, **37** (1), 47–63.

Friedman, B. M. and Kuttner, K. N. (1992). Money, income, prices, and interest rates. *The American Economic Review*, pp. 472–492.

Gao-qi, M. (2005). The empirical study of monetary transmission mechanism in china during the transformed period. *Journal of Chongqing University (Natural Science Edition)*, **11**.

García-Herrero, A., Gavilá, S. and Santabárbara, D. (2006). China's banking reform: an assessment of its evolution and possible impact. *CESifo Economic Studies*, **52** (2), 304–363.

Geiger, M. (2008). *Instruments Of Monetary Policy In China And Their Effectiveness: 1994–2006*.

Griliches, Z. (1979). Issues in assessing the contribution of research and development to productivity growth. *The Bell Journal of Economics*, pp. 92–116.

Grossman, G. M. and Rossi-Hansberg, E. (2006). The rise of offshoring: it's not wine for cloth anymore. *The new economic geography: effects and policy implications*, pp. 59–102.

Grossman, S. J. and Hart, O. D. (1986). The costs and benefits of ownership: A theory of vertical and lateral integration. *The Journal of Political Economy*, pp. 691–719.

Guadalupe, M., Kuzmina, O. and Thomas, C. (2012). Innovation and foreign ownership. *The American Economic Review*, pp. 3594–3627.

Hall, B. H. and Mairesse, J. (1995). Exploring the relationship between r&d and productivity in french manufacturing firms. *Journal of Econometrics*, **65** (1), 263–293.

Hart, O. and Moore, J. (1990). Property rights and the nature of the firm. *Journal of political economy*, pp. 1119–1158.

Im, K. S., Pesaran, M. H. and Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, **115** (1), 53–74.

Ito, B. and Tanaka, A. (2013). Open innovation, productivity, and export: Evidence from japanese firms.

Kashyap, A. K. and Stein, J. C. (1994). *Monetary policy and bank lending*, Monetary policy, The University of Chicago Press, pp. 221–261.

Kishan, R. P. and Opiela, T. P. (2000). Bank size, bank capital, and the bank lending channel. *Journal of Money, Credit and Banking*, pp. 121–141.

Klette, T. J. (1996). R&d, scope economies, and plant performance. *The Rand journal of economics*, pp. 502–522.

Kohler, W. and Smolka, M. (2009). Global sourcing decisions and firm productivity: Evidence from spain. *Working Paper*.

Kohler, W. K. and Smolka, M. (2011). Sourcing premia with incomplete contracts: theory and evidence. *The BE Journal of Economic Analysis & Policy*, **11** (1).

Kuttner, K. N. and Mosser, P. C. (2002). The monetary transmission mechanism: some answers and further questions. *Federal Reserve Bank of New York Economic Policy Review*, **8** (1), 15–26.

Lai, E. L.-C., Riezman, R. and Wang, P. (2009). Outsourcing of innovation. *Economic Theory*, **38** (3), 485–515.

Levin, A., Lin, C.-F. and Chu, C.-S. J. (2002). Unit root tests in panel data: asymptotic and finite-sample properties. *Journal of Econometrics*, **108** (1), 1–24.

Mehran, H. and Quintyn, M. (1996). Financial sector reforms in china. *Finance and Development-English Edition*, **33** (1), 18–21.

Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica*, **71** (6), 1695–1725.

Meltzer, A. H. (1995). Monetary, credit and (other) transmission processes: a monetarist perspective. *The Journal of Economic Perspectives*, **9** (4), 49–72.

Mishkin, F. S. (1995). Symposium on the monetary transmission mechanism. *The Journal of Economic Perspectives*, **9** (4), 3–10.

Naghavi, A. and Ottaviano, G. I. (2010). Outsourcing, complementary innovations, and growth. *Industrial and Corporate Change*, **19** (4), 1009–1035.

Nunn, N. and Trefler, D. (2008). The boundaries of the multinational firm: an empirical analysis. *The organization of firms in a global economy*, pp. 55–83.

Olley, G. S. and Pakes, A. (1996). The dynamics of productivity in the telecommunications equipment industry. *Econometrica*, **64** (6), 1263–1297.

Pakes, A. (1994). Dynamic structural models, problems and prospects. Advances in Econometrics. Sixth World Congress, Cambridge University Press.

Pan, L. and Tao, X. (1995). The monetary policy transmission in china. *Perspectives*, **9**.

Park, A. and Sehrt, K. (2001). Tests of financial intermediation and banking reform in china. *Journal of Comparative Economics*, **29** (4), 608–644.

Rodríguez-Clare, A. (2010). Offshoring in a ricardian world. *American Economic Journal: Macroeconomics*, pp. 227–258.

Romer, C. D. and Romer, D. H. (1993). Credit channel or credit actions? an interpretation of the postwar transmission mechanism. *NBER Working Paper*, (w4485).

Schwarz, C. and Suedekum, J. (2014). Global sourcing of complex production processes. *Journal of International Economics*, **93** (1), 123–139.

Taylor, M. P. and Sarno, L. (1998). The behavior of real exchange rates during the post-bretton woods period. *Journal of International Economics*, **46** (2), 281–312.

Tintelnot, F. (2014). Global production with export platforms.

Tomiura, E. (2007). Foreign outsourcing, exporting, and fdi: A productivity comparison at the firm level. *Journal of International Economics*, **72** (1), 113–127.

Xie, P. (2004). China's monetary policy: 1998-2002. *Stanford Center for International Development Working Paper*, **217**.

Zhang, C. and Clovis, J. (2009). Financial market turmoil: Implications for monetary policy transmission in china. *China & World Economy*, **17** (3), 1–22.

Zhou, M. and Li, M. (2006). The empirical study on transmission channel of monetary policy in china - basing on the facts from 1998. *Journal of Shanxi Finance and Economics University*.

Appendix A

Appendix to Chapter 1

A.1 Proof of Proposition 1

Equations (15) and (17) gives

$$M_j(\psi_{i,-p_z}^{j,-p_z}) - M_i(\psi_{i,-p_z}^{j,-p_z}) = w_i f_j$$

Equations (16) and (18) gives

$$E(p_z^{(\sigma-1)a/(a-1)})(a-1)\frac{1}{w_i^{1/(a-1)}}[(\frac{M_j(\psi_{i,p_z}^{j,p_z})}{a})^{a/(a-1)} - (\frac{M_i(\psi_{i,p_z}^{j,p_z})}{a})^{a/(a-1)}] = w_i f_j$$

We know that M_i and M_j are both linear and monotonically increasing in $\psi^{\sigma-1}$, also $M_i(0) = M_j(0) = 0$, $M_j'(\psi) > M_i'(\psi)$. Given the assumption that $a > 1 \Rightarrow a/(a-1) > 1$, the power function above will increase at a greater rate when ψ increases, while the linear function will increase at a constant rate. Therefore, past a certain point in ψ, or for f_j large enough, we always have

$$M_j(\psi) - M_i(\psi) < E(p_z^{(\sigma-1)a/(a-1)})(a-1)\frac{1}{w_i^{1/(a-1)}}[(\frac{M_j(\psi)}{a})^{a/(a-1)} - (\frac{M_i(\psi)}{a})^{a/(a-1)}]$$

However, combining the first two equations from above we have

$$M_j(\psi_{i,-p_z}^{j,-p_z}) - M_i(\psi_{i,-p_z}^{j,-p_z}) =$$

$$E(p_z^{(\sigma-1)a/(a-1)})(a-1)\frac{1}{w_i^{1/(a-1)}}[(\frac{M_j(\psi_{i,p_z}^{j,p_z})}{a})^{a/(a-1)}-(\frac{M_i(\psi_{i,p_z}^{j,p_z})}{a})^{a/(a-1)}]=w_i f_j$$

Therefore it has to be the case that $\psi_{i,-p_z}^{j,-p_z} > \psi_{i,p_z}^{j,p_z}$, proving the first part of the proposition.

Similarly, equations (15) and (16) gives

$$E(p_z^{(\sigma-1)a/(a-1)})(a-1)\frac{1}{w_i^{1/(a-1)}}(\frac{M_i(\psi_{i,-p_z}^{i,p_z})}{a})^{a/(a-1)}-M_i(\psi_{i,-p_z}^{i,p_z})=w_i(f_p+f_z)$$

And equations (17) and (18) gives

$$E(p_z^{(\sigma-1)a/(a-1)})(a-1)\frac{1}{w_i^{1/(a-1)}}(\frac{M_j(\psi_{j,-p_z}^{j,p_z})}{a})^{a/(a-1)}-M_j(\psi_{j,-p_z}^{j,p_z})=w_i(f_p+f_z)$$

As $M_j(\psi) > M_i(\psi)$ for any given value of $\psi > 0$, it is easy to see that

$$E(p_z^{(\sigma-1)a/(a-1)})(a-1)\frac{1}{w_i^{1/(a-1)}}(\frac{M_j(\psi)}{a})^{a/(a-1)}-M_j(\psi) >$$
$$E(p_z^{(\sigma-1)a/(a-1)})(a-1)\frac{1}{w_i^{1/(a-1)}}(\frac{M_i(\psi)}{a})^{a/(a-1)}-M_i(\psi) > 0$$

Where it is then clear that $\psi_{i,-p_z}^{i,p_z} > \psi_{j,-p_z}^{j,p_z}$, concluding the second part of the proposition.

A.2 Proof of Proposition 2

From equations (15) - (18), it is clear that $\Pi_{i,-p_z}$ has the lowest marginal rate of increase w.r.t. increasing ψ and the lowest fixed cost, while $E(\Pi_{j,p_z})$ has the highest marginal rate of increase and the highest fixed cost. So as long as domestic sourcing and no R&D is not dominated by another doublet before the market exit productivity threshold, it will be the category for the lowest pure productivity draws. Similarly, foreign sourcing with R&D would be the category for the highest pure productivity firms.

1) Let $\psi_{i,p_z}^{j,p_z} > \psi_{i,-p_z}^{i,p_z}$. Combining the results in Proposition 1, we have the threshold ordering

$$\psi_{i,-p_z}^{j,-p_z} > \psi_{i,p_z}^{j,p_z} > \psi_{i,-p_z}^{i,p_z} > \psi_{j,-p_z}^{j,p_z}$$

Using Lemma 1, it is straightforward to assign doublet choices to the following productivity range: if $\psi < \psi^{j,p_z}_{j,-p_z}$, choose $\{i, -p_z\}$; if $\psi^{j,p_z}_{i,p_z} > \psi > \psi^{i,p_z}_{i,-p_z}$, choose $\{i, p_z\}$; if $\psi > \psi^{j,-p_z}_{i,-p_z}$, choose $\{j, p_z\}$.

For $\psi^{i,p_z}_{i,-p_z} > \psi > \psi^{j,p_z}_{j,-p_z}$, we know that i is chosen as sourcing destination from Lemma 1. Definition of $\psi^{i,p_z}_{i,-p_z}$ pins down the choice as $\{i, -p_z\}$

For $\psi^{j,-p_z}_{i,-p_z} > \psi > \psi^{j,p_z}_{i,p_z}$, we know that p_z is chosen as R&D strategy from Lemma 1. Definition of ψ^{j,p_z}_{i,p_z} pins down the choice as $\{j, p_z\}$. Hence concluding the first case in the proposition.

2) Again let $\psi^{j,p_z}_{j,-p_z} > \psi^{j,-p_z}_{i,-p_z}$. The threshold ordering in light of Proposition 1 is

$$\psi^{i,p_z}_{i,-p_z} > \psi^{j,p_z}_{j,-p_z} > \psi^{j,-p_z}_{i,-p_z} > \psi^{j,p_z}_{i,p_z}$$

Using the same method as above, one can assign doublet choices to every productivity range and prove the second case in the proposition.

3) For all other scenarios, barring the knife-edge case where the productivity thresholds coincide, we always have

$$\psi^{j,p_z}_{i,p_z} < \psi^{i,p_z}_{i,-p_z}, \quad \psi^{j,p_z}_{j,-p_z} < \psi^{j,-p_z}_{i,-p_z}$$

First look at $\psi^{j,p_z}_{i,p_z} < \psi^{i,p_z}_{i,-p_z}$. Suppose $\{i, p_z\}$ exists in equilibrium for some ψ. Then by definition, $\psi < \psi^{j,p_z}_{i,p_z}$ or else $\{j, p_z\}$ will be chosen. So $\psi < \psi^{i,p_z}_{i,-p_z}$, which is a contradiction as $\{i, -p_z\}$ will be chosen by definition. Therefore $\{i, p_z\}$ does not exist in equilibrium.

Similarly, we can prove that when $psi^{j,p_z}_{j,-p_z} < \psi^{j,-p_z}_{i,-p_z}$, $\{j, -p_z\}$ does not exist in equilibrium.

Hence overall, only two categories, namely $\{i, -p_z\}$ and $\{j, p_z\}$, will exist in equilibrium, proving the third case in the proposition. It also becomes clear that the 4 possible categories will never co-exist in an equilibrium, concluding the proof.

A.3 Pure Productivity Estimation in the Olley-Pakes Framework

The production function to be estimated is assumed to be Cobb-Douglas

$$
\begin{aligned}
& y_{it} = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \beta_a a_{it} + \mu_{it} \\
\text{where} \quad & \mu_{it} = \omega_{it} + \epsilon_{it} \\
\text{and} \quad & \omega_{it} = \beta_r c_{it-1} + \psi_{it}
\end{aligned}
\tag{A.1}
$$

where y_{it} is log output for firm i in period t; l_{it}, k_{it}, a_{it} and c_{it} are the log values of labor, capital, age and knowledge capital respectively; ω_{it} is the total factor productivity shock in the canonical OP framework, observed by the firm but not by the econometrician; ψ_{it} is the pure/core productivity of the firm that is the interest of this paper.

Following Olley-Pakes, the function for capital investment can be inverted to back out unobserved total factor productivity shock ω_{it}

$$
\omega_{it} = h(i_{it}, k_{it}, a_{it}) \tag{A.2}
$$

which is strictly increasing in i_{it} as shown in Pakes (1994). This function can be used to control for simultaneity bias. The production function becomes

$$
y_{it} = \beta_l l_{it} + \phi(i_{it}, k_{it}, a_{it}) + \epsilon_{it} \tag{A.3}
$$

where $\phi(i_{it}, k_{it}, a_{it}) = \beta_0 + \beta_k k_{it} + \beta_a a_{it} + h(i_{it}, k_{it}, a_{it})$ can be approximated with a second order polynomial in age, capital and investment. The production function above can then be estimated using OLS to obtain a consistent estimate of β_l.

Note that $\omega_{it} = h(i_{it}, k_{it}, a_{it}) = \beta_r r_{it-1} + \psi_{it}$. In the next step, using the Markov property of pure productivity $\psi_{it} = E(\psi_{it}|\psi_{it-1}, survive) + \xi_{it}$ and taking into account survival bias:

$$
y_{it} = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \beta_a a_{it} + \beta_r c_{it-1} + E(\psi_{it}|\psi_{it-1}, survive) + \xi_{it} + \epsilon_{it} \tag{A.4}
$$

which after substitution can be written as

$$
\begin{aligned}
y_{it} - \hat{\beta}_l l_{it} = {} & \beta_0 + \beta_k k_{it} + \beta_a a_{it} + \beta_r c_{it-1} \\
& + g(\hat{\phi}(i_{it-1}, k_{it-1}, a_{it-1}) - \beta_k k_{it-1} - \beta_a a_{it-1} - \beta_r c_{it-2}, \hat{P}_{it}) + \xi_{it} + \epsilon_{it}
\end{aligned}
\tag{A.5}
$$

where $\hat{P}$ is the estimated probability of survival using a probit regression. Function g

is approximated by a second order polynomial in $\hat{\phi}(i_{it-1}, k_{it-1}, a_{it-1}) - \beta_k k_{it-1} - \beta_a a_{it-1} - \beta_r c_{it-2}$ and $\hat{P}_{it}$. Using non-linear least squared, I can consistently estimate β_k, β_a and β_r, thus backing out pure productivity ψ_{it} from the production function.

A.4 Results of Robustness Checks

Table A.1: *Estimation of Premia by Mutually Inclusive Sourcing and R&D Strategy, Perpetual Inventory Knowledge Capital*

Dependent Variable: Olley-Pakes Pure Productivity						
	Pooled OLS			Between-Estimator		
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Foreign	0.557***	0.420***	0.385***	0.635***	0.478***	0.448***
	(0.053)	(0.053)	(0.051)	(0.065)	(0.066)	(0.064)
RD	0.879***	0.719***	0.642***	0.987***	0.807***	0.719***
	(0.062)	(0.063)	(0.062)	(0.067)	(0.068)	(0.067)
Export		0.619***	0.551***		0.600***	0.541***
		(0.065)	(0.064)		(0.069)	(0.068)
Age			0.0120***			0.0116***
			(0.0014)			(0.0012)
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	No	No	No
Observations	4393	4393	4393	4393	4393	4393
R-squared	0.28	0.32	0.36	0.28	0.31	0.35

Notes Firms that do not source inputs are excluded. Parentheses show standard errors. Constants included in estimation but not reported. Robust standard errors clustered by firm are computed for regressions (1) - (3). *Foreign*, *RD* and *Export* are dummy variables, *Age* is the total number of years since founding of the firm. * , ** and *** indicate significance at 10%, 5% and 1% respectively.

Table A.2: *Estimation of Premia by Mutually Exclusive Sourcing and R&D Strategies, Perpetual Inventory Knowledge Capital*

Dependent Variable: Olley-Pakes Pure Productivity						
	Pooled OLS			Between-Estimator		
Variables	(1)	(2)	(3)	(4)	(5)	(6)
ForeignRD β_1	1.435***	1.138***	1.027***	1.619***	1.289***	1.169***
	(0.070)	(0.076)	(0.074)	(0.079)	(0.086)	(0.084)
ForeignNoRD β_2	0.593***	0.414***	0.386***	0.650***	0.450***	0.431***
	(0.069)	(0.069)	(0.067)	(0.082)	(0.083)	(0.081)
DomesticRD β_3	0.931***	0.711***	0.643***	1.010***	0.763***	0.693***
	(0.086)	(0.087)	(0.085)	(0.103)	(0.105)	(0.102)
Export		0.619***	0.551***		0.604***	0.544***
		(0.065)	(0.064)		(0.070)	(0.068)
Age			0.0120***			0.0116***
			(0.0014)			(0.0012)
$\beta_1 = \beta_3$	0.00	0.00	0.00	0.00	0.00	0.00
$\beta_1 = \beta_2$	0.00	0.00	0.00	0.00	0.00	0.00
$\beta_2 = \beta_3$	0.00	0.00	0.00	0.00	0.00	0.01
Industry Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	No	No	No
Observations	4393	4393	4393	4393	4393	4393
R-squared	0.28	0.32	0.36	0.28	0.31	0.35

Notes Firms that do not source inputs are excluded. Parentheses show standard errors. Constants are estimated but not reported. Robust standard errors clustered by firm are computed for regressions (1) - (3). *ForeignRD*, *ForeignNoRD*, *DomesticRD* and *Export* are dummy variables, *Age* is the number of years since the founding of the firm. * , ** and *** indicate significance at 10%, 5% and 1% respectively. Hypothesis testing performed on null hypothesis that coefficients are equal, the P-value results presented in lower panel.

Table A.3: *R&D Extensive Margin Estimation, Perpetual Inventory Knowledge Capital*

Dependent Variable: R&D dummy in logistic regression							
		Pooled OLS Odds Ratio			Population Average Odds Ratio		IV Bi-Probit
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Foreign	2.185***	1.774***	1.770***	1.413***	1.346***	1.349***	1.452***
	(0.24)	(0.20)	(0.20)	(0.089)	(0.089)	(0.090)	(0.148)
PureOPprod	2.079***	1.849***	1.789***	1.515***	1.459***	1.415***	0.201***
	(0.13)	(0.11)	(0.11)	(0.055)	(0.055)	(0.054)	(0.041)
σ		0.994**	0.994**		0.998	0.998	-0.00446***
		(0.0028)	(0.0029)		(0.0012)	(0.0012)	(0.0017)
Export		3.815***	3.728***		2.613***	2.559***	0.340***
		(0.59)	(0.58)		(0.27)	(0.27)	(0.11)
Age			1.007**			1.012***	0.00273*
			(0.0030)			(0.0026)	(0.0016)
Marg. Effect	0.142	0.098	0.097	0.070	0.057	0.057	0.467
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4393	4393	4393	4393	4393	4393	4393
Pseudo R^2	0.25	0.28	0.28				

Notes Firms that do not source inputs are excluded. Parentheses show standard errors. Robust standard errors clustered by firm are computed. Average marginal effect is computed for Foreign dummy. Constant is used in regression but not reported. Coefficients in (1) - (6) are reported in odds ratio. * , ** and *** indicate significance at 10%, 5% and 1% respectively.

Table A.4: *R&D Intensive Margin Estimation, Perpetual Inventory Knowledge Capital*

	Dependent Variable: log total expenditure in R&D						
	Pooled OLS			Population Average			IV
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Foreign	1.773***	1.245***	0.956***	0.762***	0.645***	0.422***	2.068**
	(0.27)	(0.26)	(0.25)	(0.13)	(0.13)	(0.13)	(1.00)
PureOPprod	1.916***	1.649***	-0.645***	0.896***	0.826***	-0.132	-0.674***
	(0.11)	(0.12)	(0.18)	(0.069)	(0.070)	(0.085)	(0.19)
σ		-0.00455	-0.0111***		-0.00112	-0.00400**	-0.0121***
		(0.0049)	(0.0042)		(0.0018)	(0.0018)	(0.0042)
Export		2.603***	1.832***		1.854***	1.094***	1.537***
		(0.28)	(0.27)		(0.20)	(0.19)	(0.36)
Age			0.00801			0.0104*	0.00738
			(0.0063)			(0.0057)	(0.0063)
Size			2.494***			2.156***	2.439***
			(0.18)			(0.11)	(0.18)
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4393	4393	4393	4393	4393	4393	4393
Pseudo R^2	0.35	0.38	0.44				

Notes Firms that do not source inputs are excluded. Parentheses show standard errors. Robust standard errors clustered by firm are computed. Constant is used in regression but not reported. * , ** and *** indicate significance at 10%, 5% and 1% respectively.

Appendix B

Appendix to Chapter 2

B.1 Proof of Prediction 3

First note that with only one mode, domestic outsourcing, the share for DO remains at 1 when productivity increases. After crossing the threshold and adding new modes, the share of domestically sourced supplier remains at $s^{DO}(\theta) = \frac{G(n_{EXIT}(\theta)) - G(n_{DO}^{FO}(\theta))}{G(n_{EXIT}(\theta))}$. Using the Pareto distribution functional form $G(n)$, the partial derivative of the fraction w.r.t. productivity measure $\theta^{\frac{\alpha}{1-\alpha}}$ is:

$$\frac{\partial}{\partial\theta^{\frac{\alpha}{1-\alpha}}} \frac{(n_{DO}^{FO})^{-\omega} - (n_{EXIT})^{-\omega}}{1 - (n_{EXIT})^{-\omega}} = \frac{(1 - (n_{EXIT})^{-\omega})[-\omega(n_{DO}^{FO})^{-\omega-1} \frac{\partial n_{DO}^{FO}}{\partial\theta^{\frac{\alpha}{1-\alpha}}} + \omega(n_{EXIT})^{-\omega-1} \frac{\partial n_{EXIT}}{\partial\theta^{\frac{\alpha}{1-\alpha}}}]}{(1 - (n_{EXIT})^{-\omega})^2}$$
$$- \frac{((n_{DO}^{FO})^{-\omega} - (n_{EXIT})^{-\omega})(\omega(n_{EXIT})^{-\omega-1} \frac{\partial n_{EXIT}}{\partial\theta^{\frac{\alpha}{1-\alpha}}})}{(1 - (n_{EXIT})^{-\omega})^2}$$

From (17), the thresholds follow the ordering: $n_{EXIT} > n_{DO}^{FO} > n_{FO}^{DI} > n_{DI}^{FI}$, and we can immediately see that

$$\frac{\partial n}{\partial\theta^{\frac{\alpha}{1-\alpha}}} = \frac{n}{\theta^{\frac{\alpha}{1-\alpha}}}$$

.

And the partial derivative equation above can be rewritten as

$$\frac{\partial}{\partial \theta^{\frac{\alpha}{1-\alpha}}} \frac{(n_{DO}^{FO})^{-\omega} - (n_{EXIT})^{-\omega}}{1-(n_{EXIT})^{-\omega}} = \frac{(1-(n_{EXIT})^{-\omega})[-\omega(n_{DO}^{FO})^{-\omega} + \omega(n_{EXIT})^{-\omega}]}{\theta^{\frac{\alpha}{1-\alpha}}(1-(n_{EXIT})^{-\omega})^2} - \frac{((n_{DO}^{FO})^{-\omega} - (n_{EXIT})^{-\omega})(\omega(n_{EXIT})^{-\omega})}{\theta^{\frac{\alpha}{1-\alpha}}(1-(n_{EXIT})^{-\omega})^2}$$

As $(n_{DO}^{FO})^{-\omega} > (n_{EXIT})^{-\omega}$ following the ordering $n_{EXIT} > n_{DO}^{FO} > n_{FO}^{DI} > n_{DI}^{FI}$, the first term on the RHS above is negative and the second term on the RHS is positive, thus, the partial derivative is negative, or the fraction of domestically outsourced suppliers is always decreasing in productivity.

For foreign integration that only exists when a firm uses all four modes to source inputs, the partial derivative of its share $s_4^{FI}(\theta)$ w.r.t. productivity measure is

$$\begin{aligned}
\frac{\partial}{\partial \theta^{\frac{\alpha}{1-\alpha}}} \frac{1-(n_{DI}^{FI})^{-\omega}}{1-(n_{EXIT})^{-\omega}} &= \frac{(1-(n_{EXIT})^{-\omega})(\omega(n_{DI}^{FI})^{-\omega-1}\frac{\partial n_{DI}^{FI}}{\partial \theta^{\frac{\alpha}{1-\alpha}}})}{\theta^{\frac{\alpha}{1-\alpha}}(1-(n_{EXIT})^{-\omega})^2} \\
&\quad - \frac{(1-(n_{DI}^{FI})^{-\omega})(\omega(n_{EXIT})^{-\omega-1}\frac{\partial n_{EXIT}}{\partial \theta^{\frac{\alpha}{1-\alpha}}})}{\theta^{\frac{\alpha}{1-\alpha}}(1-(n_{EXIT})^{-\omega})^2} \\
&= \frac{(1-(n_{EXIT})^{-\omega})\omega(n_{DI}^{FI})^{-\omega} - (1-(n_{DI}^{FI})^{-\omega})\omega(n_{EXIT})^{-\omega}}{\theta^{\frac{\alpha}{1-\alpha}}(1-(n_{EXIT})^{-\omega})^2} \\
&= \frac{\omega(n_{DI}^{FI})^{-\omega} - \omega(n_{EXIT})^{-\omega}}{\theta^{\frac{\alpha}{1-\alpha}}(1-(n_{EXIT})^{-\omega})^2}
\end{aligned}$$

The above expression is clearly positive give the ranking order of thresholds of n. In other words, the fraction of foreign integrated suppliers is always increasing with productivity.

Note that for FO and DI suppliers in (18), the expression for the fraction is analogous to that of s_2^{DO} if it is not the most advanced sourcing mode, and analogous to that of s_4^{FI} if it is the most advanced mode. It follows that the fraction of foreign outsourced or domestically integrated suppliers will increase with productivity initially when they are the new addition to the multiple sourcing strategy set, but will decrease with productivity if a new mode is added to the set. This concludes the proof.

B.2 Results of Robustness Checks

Table B.1: *Estimation of Productivity Impact on the Composition of Multiple Sourcing, Population Average Model*

	Dependent Variable: Share in Total Intermediate Inputs Value							
	DO		FO		DI		FI	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Prod.	-1.13**	-0.751	0.144	0.124	0.294	0.183	0.312***	0.299***
	(0.48)	(0.48)	(0.12)	(0.12)	(0.21)	(0.21)	(0.065)	(0.066)
Trade Intens.	-31.0***	-26.2***	11.0***	10.40***	-2.31***	-4.21***	2.59***	2.59***
	(1.48)	(1.54)	(0.38)	(0.41)	(0.70)	(0.73)	(0.21)	(0.22)
Age	-0.0651**	0.00884	-0.00597	-0.015**	0.0102	-0.0286*	-0.00799*	-0.00799*
	(0.029)	(0.029)	(0.0075)	(0.0077)	(0.015)	(0.015)	(0.0043)	(0.0044)
Foreign Cap.	-0.134***	-0.093***	-0.003	-0.007*	0.00	-0.014*	0.033***	0.032***
	(0.015)	(0.015)	(0.0039)	(0.0041)	(0.0074)	(0.0076)	(0.0021)	(0.0023)
Capital Intens.		-1.539***		0.380***		0.710***		-0.102
		(0.463)		(0.12)		(0.22)		(0.067)
Firm Size		-4.212***		0.389***		2.008***		0.0737
		(0.45)		(0.12)		(0.23)		(0.068)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6416	6416	6419	6419	6417	6417	6415	6415

Notes: Productivity is constructed using Olley-Pakes method. Firms that do not source inputs are excluded. Constant is not reported. Parentheses show standard errors. Robust standard errors clustered by firm. * , ** and *** indicate significance at 10%, 5% and 1% respectively.

Table B.2: *Estimation of Productivity Impact on the Composition of Multiple Sourcing*

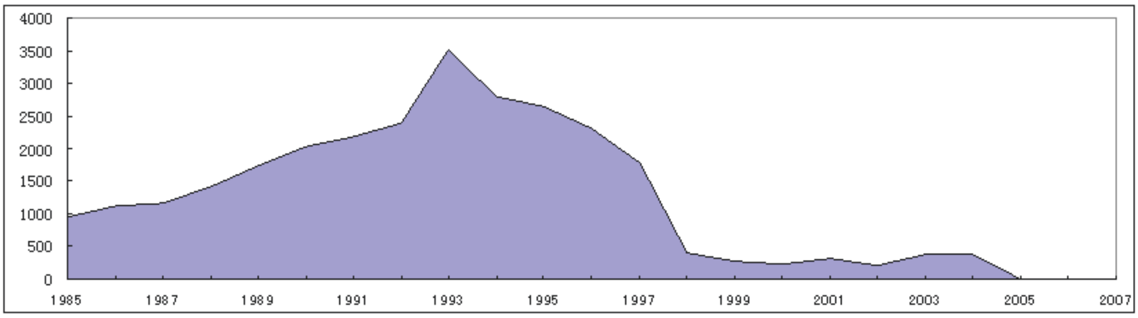
	Dependent Variable: Share in Total Intermediate Inputs Value							
	DO		FO		DI		FI	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Prod.	-4.106***	-2.143***	0.835***	0.499**	1.414***	0.146	0.419***	0.590***
	(0.75)	(0.74)	(0.19)	(0.20)	(0.50)	(0.47)	(0.13)	(0.14)
Trade Intens.	-34.6***	-29.5***	10.1***	9.31***	-0.780	-4.29***	2.24***	2.58***
	(2.03)	(2.23)	(0.70)	(0.76)	(1.07)	(1.23)	(0.39)	(0.45)
Age	-0.0431	0.00938	-0.00550	-0.0124	0.000884	-0.0329**	-0.00462	-0.00212
	(0.028)	(0.028)	(0.0080)	(0.0084)	(0.016)	(0.017)	(0.0042)	(0.0042)
Foreign Cap.	-0.151***	-0.112***	-0.004	-0.008	0.004	-0.021**	0.048***	0.049***
	(0.018)	(0.019)	(0.0060)	(0.0061)	(0.0099)	(0.010)	(0.0046)	(0.0050)
Capital Intens.		-0.795		0.351***		0.704*		-0.297***
		(0.582)		(0.13)		(0.43)		(0.077)
Firm Size		-3.789***		0.388***		2.423***		-0.0779
		(0.53)		(0.15)		(0.33)		(0.094)
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6427	6416	6430	6419	6428	6417	6426	6415
Pseudo R^2	0.30	0.30	0.22	0.23	0.06	0.10	0.24	0.24

Notes: Productivity is real value added per capita. Firms that do not source inputs are excluded. Constant is not reported. Parentheses show standard errors. Robust standard errors clustered by firm. * , ** and *** indicate significance at 10%, 5% and 1% respectively.

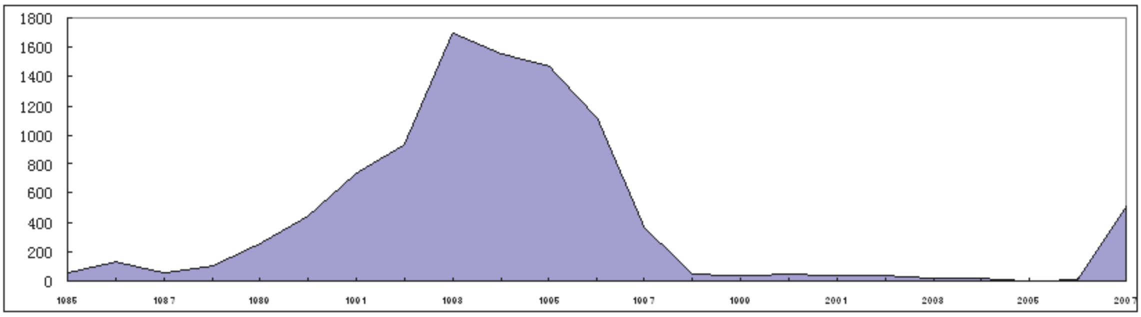
Appendix C

Appendix to Chapter 3

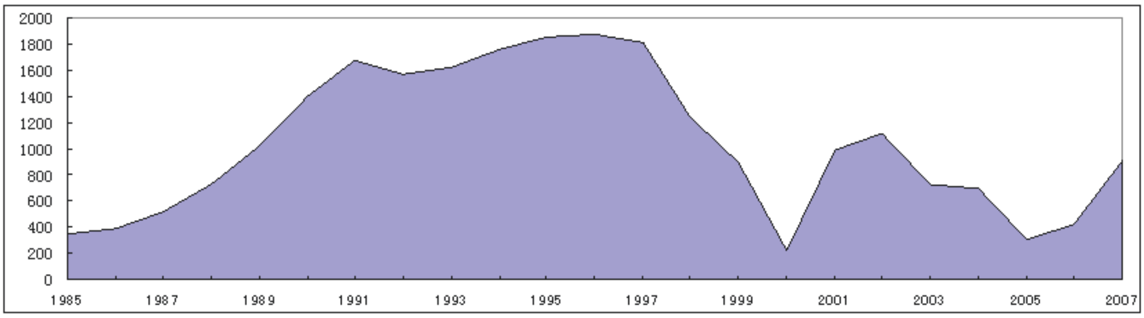
C.1 Supplemental Figures and Tables



(a) *Industrial and Commercial Bank of China*

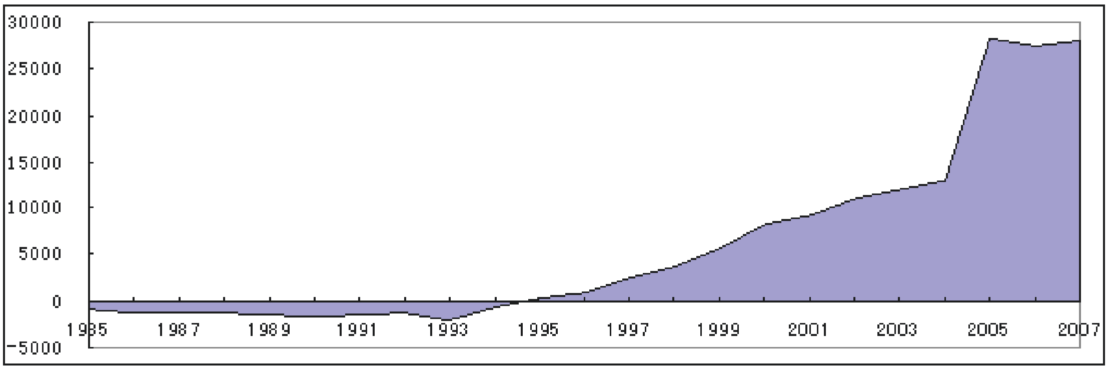


(b) *China Construction Bank*

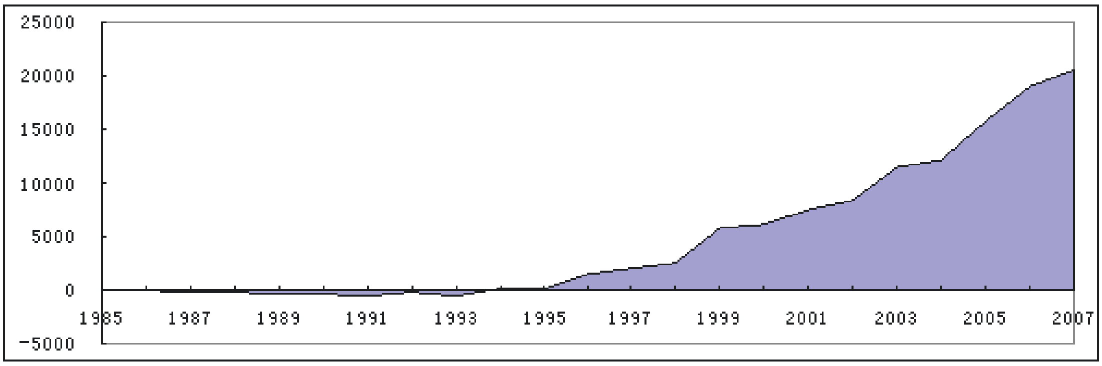


(c) *Bank of China*

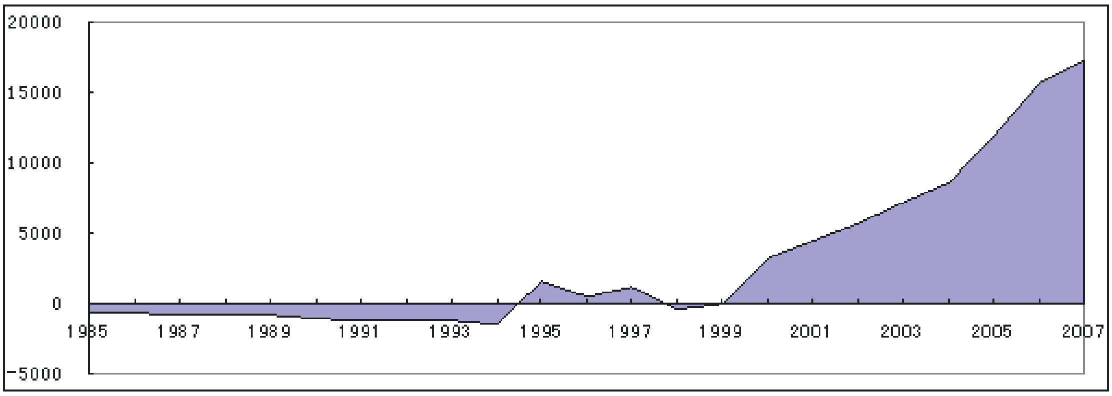
Figure C.1: *Direct Lending of the PBC to Major SOCBs (Unit: 100 Mil Yuan)*



(a) *Industrial and Commercial Bank of China*



(b) *China Construction Bank*



(c) *Agricultural Bank of China*

Figure C.2: *Deposit Surplus (Total Deposits - Total Loans) for SOCBs (Unit: 100 Mil Yuan)*

Table C.1: *Pre Reform Determinants of Changes in Borrowing from PBC*

VARIABLES	(1) SOCB	(2) SOCB	(3) SOCB	(4) SOCB	(5) SOCB
Relending Rate	-0.0145	-0.0139	-0.0205	-0.0187	-0.0193
	(0.0214)	(0.0220)	(0.0274)	(0.0238)	(0.0235)
Loan Interest	0.0504	0.0541	0.0526	0.0512	0.0409
	(0.0369)	(0.0423)	(0.0430)	(0.0429)	(0.0453)
Change in Deposit	-0.447**	-0.463**	-0.474**	-0.476**	-0.475**
	(0.191)	(0.199)	(0.205)	(0.207)	(0.210)
Capitalization		-0.170	-0.643	-0.998	-1.635
		(0.401)	(1.170)	(1.440)	(1.917)
$cap * r_B$			0.0654		
			(0.127)		
$cap * r_E$				0.132	
				(0.191)	
$cap * r_L$					0.167
					(0.197)
Observations	39	39	39	39	39
R-squared	0.259	0.264	0.270	0.274	0.277
Number of Banks	4	4	4	4	4

Notes 1. Robust standard errors in parentheses.
2. Borrowing from PBC data liable to errors due to inconsistent balance sheet formats
3. * significant at 10%, ** significant at 5%, *** significant at 1%.

Table C.2: *Post Reform Determinants of Excess Reserve Changes*

VARIABLES	(1) SOCB	(2) SOCB	(3) SOCB	(4) non-SOCB	(5) non-SOCB	(6) non-SOCB
Relending Rate	-0.0109	0.0108	0.0113	-0.0640	0.110	0.110
	(0.0212)	(0.0359)	(0.0366)	(0.0499)	(0.0808)	(0.0814)
Exc. Reserve Interest	-0.000951	0.0108	0.00720	-0.0463**	0.0563	0.0551
	(0.00700)	(0.0183)	(0.0164)	(0.0227)	(0.0398)	(0.0404)
Loan Interest	0.0223	0.0137	0.0134	0.0629**	0.0141	0.0146
	(0.0140)	(0.0158)	(0.0165)	(0.0320)	(0.0390)	(0.0393)
Rediscount Rate	-0.000901	-0.00111	-0.00205	0.0268	0.0240	0.0241
	(0.0143)	(0.0129)	(0.0139)	(0.0345)	(0.0345)	(0.0348)
Change in RRR	0.00196	0.00116	0.00150	-0.00642	-0.0184*	-0.0182*
	(0.00438)	(0.00508)	(0.00484)	(0.00962)	(0.0102)	(0.0103)
Change in Deposit	0.0579	0.0553	0.0664	0.0648	0.0865	0.0854
	(0.0812)	(0.0814)	(0.0880)	(0.0717)	(0.0646)	(0.0646)
Capitalization		0.154	0.0501		0.0509	-0.0373
		(0.216)	(0.415)		(0.210)	(0.464)
$cap * r_E$			0.0673			0.0347
			(0.175)			(0.174)
Observations	40	36	36	110	99	99
R-squared	0.337	0.431	0.436	0.268	0.344	0.344
Number of Banks	4	4	4	11	11	11

Notes 1. Robust standard errors in parentheses, interest rates in percentage points.
2. Panel data unbalanced for non-SOCBs and balanced for SOCBs.
3. * significant at 10%, ** significant at 5%, *** significant at 1%.
4. Excess reserve levels are author's calculation, which are subject to impreciseness.
Formula: Excess Reserves = Total Reserves - Total Deposit * Required Reserve Ratio

Table C.3: *Pre Reform Determinants of Real Loan Growth*

VARIABLES	(1) SOCB	(2) SOCB	(3) SOCB	(4) SOCB	(5) non-SOCB	(6) non-SOCB	(7) non-SOCB	(8) non-SOCB
Relending Rate	-0.00810	-0.0130	-0.0273	-0.0292	0.169	0.176	0.139	0.179
	(0.0238)	(0.0217)	(0.0305)	(0.0230)	(0.111)	(0.113)	(0.122)	(0.114)
Loan Interest	0.0707	0.0522	0.0534	0.0177	-0.378**	-0.342**	-0.295*	-0.350**
	(0.0473)	(0.0424)	(0.0421)	(0.0620)	(0.163)	(0.154)	(0.160)	(0.154)
Real Deposit Growth	0.339**	0.341***	0.308**	0.257*	0.0641	-0.0215	-0.0101	-0.00940
	(0.132)	(0.113)	(0.146)	(0.156)	(0.0853)	(0.0820)	(0.0817)	(0.0806)
Capitalization		1.229***	0.0730	-4.296		1.471***	-3.434	-5.640
		(0.334)	(2.192)	(5.024)		(0.517)	(3.236)	(5.982)
$cap * r_B$			0.157				0.522	
			(0.277)				(0.335)	
$cap * r_L$				0.624				0.698
				(0.555)				(0.579)
Observations	48	48	48	48	68	68	68	68
R-squared	0.422	0.474	0.479	0.506	0.443	0.531	0.548	0.548
Number of Banks	4	4	4	4	11	11	11	11

Notes 1. Robust standard errors in parentheses.
2. Panel data unbalanced for non-SOCBs and balanced for SOCBs.
3. * significant at 10%, ** significant at 5%, *** significant at 1%.

Table C.4: *Post Reform Determinants of Real Loan Growth*

VARIABLES	(1) SOCB	(2) SOCB	(3) SOCB	(4) SOCB	(5) non-SOCB	(6) non-SOCB	(7) non-SOCB	(8) non-SOCB
Relending Rate	0.256	0.396	0.400	0.396	-0.500***	-0.672**	-0.723***	-0.552**
	(0.178)	(0.249)	(0.251)	(0.255)	(0.139)	(0.266)	(0.272)	(0.250)
Loan Interest	-0.139	-0.182	-0.200*	-0.182	0.303***	0.355**	0.582**	0.346**
	(0.103)	(0.120)	(0.119)	(0.123)	(0.116)	(0.153)	(0.229)	(0.145)
Rediscount Rate	-0.141	-0.120	-0.121	-0.0941	0.271***	0.277***	0.302***	0.517***
	(0.124)	(0.132)	(0.135)	(0.182)	(0.0883)	(0.0919)	(0.0906)	(0.165)
Change in RRR	0.0550	0.0362	0.0352	0.0378	-0.105***	-0.0921***	-0.0770**	-0.0903***
	(0.0480)	(0.0588)	(0.0588)	(0.0619)	(0.0293)	(0.0353)	(0.0378)	(0.0347)
Real Deposit Growth	1.237**	1.035	1.041	1.063	0.402***	0.453**	0.467***	0.458**
	(0.612)	(0.630)	(0.651)	(0.721)	(0.151)	(0.191)	(0.178)	(0.182)
Capitalization		0.886	-0.994	2.437		-0.112	25.80**	12.34**
		(0.931)	(6.247)	(10.88)		(1.088)	(12.55)	(5.216)
$cap * r_L$			0.312				-4.382**	
			(0.942)				(2.177)	
$cap * r_R$				-0.507				-4.533**
				(3.520)				(2.161)
Observations	40	36	36	36	110	99	99	99
R-squared	0.416	0.380	0.381	0.381	0.302	0.361	0.401	0.408
Number of Banks	4	4	4	4	11	11	11	11

Notes 1. Robust standard errors in parentheses.
2. Panel data unbalanced for non-SOCBs and balanced for SOCBs.
3. * significant at 10%, ** significant at 5%, *** significant at 1%.

Table C.5: *Pre Reform Determinants of Loan Changes with Random Effects*

VARIABLES	(1) SOCB	(2) SOCB	(3) SOCB	(4) SOCB	(5) non-SOCB	(6) non-SOCB	(7) non-SOCB	(8) non-SOCB
Relending Rate	-0.0226**	-0.0235**	-0.0320**	-0.0311***	0.0653*	0.0688*	0.0396	0.0664*
	(0.0101)	(0.0104)	(0.0141)	(0.0113)	(0.0353)	(0.0388)	(0.0411)	(0.0378)
Loan Interest	0.0101	0.00606	0.00510	-0.0129	-0.0933*	-0.0895*	-0.0730	-0.105*
	(0.0211)	(0.0224)	(0.0235)	(0.0367)	(0.0502)	(0.0520)	(0.0511)	(0.0542)
Change in Deposit	0.363**	0.368**	0.344*	0.322	0.435***	0.407***	0.361***	0.377***
	(0.169)	(0.168)	(0.193)	(0.200)	(0.118)	(0.123)	(0.120)	(0.111)
Capitalization		0.263	-0.406	-2.214		0.231	-2.765*	-5.159**
		(0.202)	(0.967)	(2.237)		(0.255)	(1.587)	(2.287)
$cap * r_B$			0.0914				0.331*	
			(0.141)				(0.175)	
$cap * r_L$				0.281				0.544**
				(0.267)				(0.228)
Observations	48	48	48	48	68	68	68	68
R-squared	0.279	0.287	0.293	0.311	0.701	0.712	0.748	0.753
Number of Banks	4	4	4	4	11	11	11	11

Notes 1. Robust standard errors in parentheses.
2. Panel data unbalanced for non-SOCBs and balanced for SOCBs.
3. * significant at 10%, ** significant at 5%, *** significant at 1%.

Table C.6: *Post Reform Determinants of Loan Changes with Random Effects*

VARIABLES	(1) SOCB	(2) SOCB	(3) SOCB	(4) SOCB	(5) non-SOCB	(6) non-SOCB	(7) non-SOCB	(8) non-SOCB
Relending Rate	0.133*	0.206*	0.209*	0.205*	-0.181***	-0.243**	-0.253***	-0.204**
	(0.0744)	(0.121)	(0.122)	(0.123)	(0.0534)	(0.0949)	(0.0965)	(0.0912)
Loan Interest	-0.0742*	-0.100*	-0.114**	-0.0996*	0.110***	0.122***	0.171***	0.117***
	(0.0427)	(0.0561)	(0.0512)	(0.0567)	(0.0404)	(0.0464)	(0.0625)	(0.0452)
Rediscount Rate	-0.0644	-0.0638	-0.0640	-0.0411	0.102***	0.102***	0.107***	0.176***
	(0.0538)	(0.0581)	(0.0588)	(0.0764)	(0.0339)	(0.0343)	(0.0337)	(0.0424)
Change in RRR	0.0313	0.0271	0.0262	0.0278	-0.0381***	-0.0326**	-0.0294**	-0.0320**
	(0.0200)	(0.0257)	(0.0264)	(0.0269)	(0.0114)	(0.0134)	(0.0146)	(0.0134)
Change in Deposit	0.823***	0.793**	0.792**	0.812**	0.379***	0.371***	0.375***	0.356***
	(0.294)	(0.338)	(0.347)	(0.369)	(0.0865)	(0.0900)	(0.0861)	(0.0862)
Capitalization		0.388	-1.079	1.675		0.159	5.733	4.091***
		(0.389)	(2.608)	(4.630)		(0.339)	(3.895)	(1.329)
$cap * r_L$			0.247				-0.942	
			(0.401)				(0.654)	
$cap * r_R$				-0.413				-1.413***
				(1.428)				(0.511)
Observations	40	36	36	36	110	99	99	99
R-squared	0.429	0.386	0.389	0.385	0.387	0.377	0.402	0.412
Number of Banks	4	4	4	4	11	11	11	11

Notes 1. Robust standard errors in parentheses.
2. Panel data unbalanced for non-SOCBs and balanced for SOCBs.
3. * significant at 10%, ** significant at 5%, *** significant at 1%.

Table C.7: *Determinants of Loan Changes with 1994 as the Threshold Year*

VARIABLES	(1) Pre SOCB	(2) Pre SOCB	(3) Pre non-SOCB	(4) Pre non-SOCB	(5) Post SOCB	(6) Post SOCB	(7) Post non-SOCB	(8) Post non-SOCB
Relending Rate	-0.0326***	-0.0263***	0.441	0.642**	0.141	0.137	-0.181***	-0.175***
	(0.0100)	(0.00959)	(0.359)	(0.324)	(0.0924)	(0.0963)	(0.0478)	(0.0502)
Loan Interest	0.0103	0.0450*	-0.224***	-0.262***	-0.0780	-0.129**	0.108***	0.117***
	(0.0107)	(0.0236)	(0.0632)	(0.0575)	(0.0532)	(0.0626)	(0.0377)	(0.0416)
Rediscount Rate					-0.0702	-0.0673	0.0984***	0.0988***
					(0.0666)	(0.0685)	(0.0308)	(0.0310)
Change in RRR					0.0338	0.0337	-0.0390***	-0.0380***
					(0.0258)	(0.0271)	(0.0101)	(0.0103)
Change in Deposit	0.489***	0.488***	0.515***	0.485***	0.910*	0.854*	0.282***	0.274***
	(0.103)	(0.116)	(0.0454)	(0.0478)	(0.497)	(0.512)	(0.0807)	(0.0844)
$cap * r_L$		-0.357*		0.204		0.768		-0.284
		(0.214)		(0.176)		(0.640)		(0.284)
Observations	32	32	31	31	40	40	110	110
R-squared	0.729	0.764	0.925	0.943	0.430	0.483	0.396	0.400
Number of Banks	4	4	8	8	4	4	11	11

Notes 1. Robust standard errors in parentheses.
2. Panel data unbalanced for non-SOCBs and balanced for SOCBs.
3. * significant at 10%, ** significant at 5%, *** significant at 1%.

Table C.8: *Determinants of Loan Changes with 1996 as the Threshold Year*

VARIABLES	(1) Pre SOCB	(2) Pre SOCB	(3) Pre non-SOCB	(4) Pre non-SOCB	(5) Post SOCB	(6) Post SOCB	(7) Post non-SOCB	(8) Post non-SOCB
Relending Rate	-0.0364**	-0.0459**	0.403***	0.407***	0.141	0.137	-0.181***	-0.175***
	(0.0172)	(0.0218)	(0.119)	(0.135)	(0.0924)	(0.0963)	(0.0478)	(0.0502)
Loan Interest	-0.00262	-0.0290	-0.341***	-0.348***	-0.0780	-0.129**	0.108***	0.117***
	(0.0241)	(0.0480)	(0.105)	(0.119)	(0.0532)	(0.0626)	(0.0377)	(0.0416)
Rediscount Rate					-0.0702	-0.0673	0.0984***	0.0988***
					(0.0666)	(0.0685)	(0.0308)	(0.0310)
Change in RRR					0.0338	0.0337	-0.0390***	-0.0380***
					(0.0258)	(0.0271)	(0.0101)	(0.0103)
Change in Deposit	0.385*	0.313	0.341**	0.260**	0.910*	0.854*	0.282***	0.274***
	(0.230)	(0.288)	(0.139)	(0.126)	(0.497)	(0.512)	(0.0807)	(0.0844)
$cap * r_L$		0.367		0.532**		0.768		-0.284
		(0.420)		(0.219)		(0.640)		(0.284)
Observations	40	40	48	48	40	40	110	110
R-squared	0.284	0.338	0.707	0.790	0.430	0.483	0.396	0.400
Number of Banks	4	4	9	9	4	4	11	11

Notes 1. Robust standard errors in parentheses.
2. Panel data unbalanced for non-SOCBs and balanced for SOCBs.
3. * significant at 10%, ** significant at 5%, *** significant at 1%.

Table C.9: *Determinants of Loan Changes with BOCM Classified as SOCB*

VARIABLES	(1) Pre SOCB	(2) Pre SOCB	(3) Pre non-SOCB	(4) Pre non-SOCB	(5) Post SOCB	(6) Post SOCB	(7) Post non-SOCB	(8) Post non-SOCB
Relending Rate	0.0100	0.00686	0.0727	0.0663	0.0406	0.102	-0.187***	-0.291***
	(0.0211)	(0.0197)	(0.0530)	(0.0527)	(0.0541)	(0.119)	(0.0509)	(0.0969)
Loan Interest	-0.000881	0.00367	-0.127**	-0.118*	-0.0283	-0.0381	0.111***	0.188***
	(0.0268)	(0.0399)	(0.0601)	(0.0606)	(0.0333)	(0.0510)	(0.0402)	(0.0674)
Rediscount Rate					-0.00133	0.000455	0.102***	0.111***
					(0.0392)	(0.0409)	(0.0332)	(0.0332)
Change in RRR					0.00415	8.33e-05	-0.0418***	-0.0329**
					(0.0155)	(0.0157)	(0.0109)	(0.0131)
Change in Deposit	0.638***	0.587***	0.389***	0.322**	0.0488	0.0111	0.358***	0.364***
	(0.231)	(0.189)	(0.149)	(0.135)	(0.115)	(0.106)	(0.0923)	(0.0915)
$cap * r_L$		-0.146		0.779***		-0.237		-0.922
		(0.337)		(0.261)		(0.474)		(0.630)
Observations	58	58	58	58	50	45	100	90
R-squared	0.486	0.522	0.697	0.775	0.235	0.218	0.473	0.491
Number of Banks	5	5	10	10	5	5	10	10

Notes 1. Robust standard errors in parentheses.
2. Panel data unbalanced for non-SOCBs and balanced for SOCBs.
3. * significant at 10%, ** significant at 5%, *** significant at 1%.

Table C.10: *Determinants of Loan Changes with Lagged Loan Rate*

VARIABLES	(1) Pre SOCB	(2) Pre SOCB	(3) Pre non-SOCB	(4) Pre non-SOCB	(5) Post SOCB	(6) Post SOCB	(7) Post non-SOCB	(8) Post non-SOCB
Relending Rate	-0.0209**	-0.0283**	0.0783*	0.0818*	0.141	0.141	-0.235**	-0.247**
	(0.00894)	(0.0114)	(0.0428)	(0.0467)	(0.115)	(0.119)	(0.0943)	(0.0963)
Loan Interest r_{Lt}	0.000716	-0.0360	-0.134**	-0.112*	-0.240*	-0.261*	0.185***	0.264***
	(0.0235)	(0.0493)	(0.0634)	(0.0628)	(0.141)	(0.152)	(0.0716)	(0.0905)
Lagged Loan Interest $r_{L\,t-1}$	0.00367	0.00699	0.00298	-0.0140	0.134	0.131	-0.0505	-0.0579
	(0.00520)	(0.00725)	(0.0217)	(0.0195)	(0.102)	(0.107)	(0.0556)	(0.0557)
Rediscount Rate					-0.224	-0.220	0.158**	0.175**
					(0.164)	(0.172)	(0.0724)	(0.0733)
Change in RRR					0.0635	0.0624	-0.0473**	-0.0447**
					(0.0485)	(0.0501)	(0.0216)	(0.0219)
Change in Deposit	0.254	0.193	0.394***	0.335**	0.848*	0.831*	0.266***	0.269***
	(0.192)	(0.243)	(0.145)	(0.135)	(0.471)	(0.493)	(0.0867)	(0.0858)
$cap * r_L$		0.391		0.649**		0.388		-1.386*
		(0.375)		(0.266)		(0.556)		(0.726)
Prob > Chi2	0.54	0.54	0.92	0.99	0.38	0.22	0.0027	0.032
Observations	44	44	68	68	36	36	99	99
R-squared	0.157	0.227	0.706	0.763	0.439	0.447	0.394	0.427
Number of Banks	4	4	11	11	4	4	11	11

Notes 1. Robust standard errors in parentheses.
2. Panel data unbalanced for non-SOCBs and balanced for SOCBs.
3. * significant at 10%, ** significant at 5%, *** significant at 1%.
4. Null hypothesis of Chi-Square test: $\beta(r_{Lt}) + \beta(r_{L\,t-1}) = 0$.
"Prob > Chi2" is the significance level that the null hypothesis is rejected, or that $\beta(r_{Lt}) + \beta(r_{L\,t-1}) \neq 0$.