ESSAYS ON INDUSTRIAL ORGANIZATION IN CHINA'S MANUFACTURING SECTOR

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Submitted to the Graduate Faculty of

Arts and Sciences in partial fulfillment

of the requirements for the degree of

Doctor of Philosophy

University of Pittsburgh

2005

UNIVERSITY OF PITTSBURGH

FACULTY OF ARTS AND SCIENCES

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ESSYAYS ON INDUSTRIAL ORGANIZATION IN CHINA'S MANUFACTURING SECTOR

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This dissertation consists of three essays that study the industrial organization of China's manufacturing sector from an empirical perspective. It focuses on applying industrial organization theory and econometrics to the analysis of the effects of market forces and globalization forces on the productivity of China's manufacturing firms.

Chapter 2 examines theories of vertical specialization dated back to Adam Smith. China's economic reform offers an ideal opportunity to test the relationship between the market forces and vertical specialization of firms. Using a comprehensive firm-level dataset in China's manufacturing sector, we find that vertical specialization increases total factor productivity of firms. Our estimation results support Smith's extent-of-market theory, Marshall's input sharing theory and Coase's transaction cost theory, but not Stigler's theory of industry lifecycle. We also find that transaction cost theory is more powerful than other theories in explaining vertical specialization of firms. Market reform that facilitates inter-firm transactions is the driving force behind the vertical specialization process that occurred in China's manufacturing firms during the reform period.

Using a panel dataset of China's manufacturing firms from 2000 to 2003, Chapter 3 examines whether there exist productivity spillovers from foreign direct investment to domestic firms. In estimating productivity, we control for a possible simultaneity bias by using semi-parametric estimation techniques. We investigate FDI spillovers through horizontal, backward,

forward and local linkages. Moreover, we allow for different spillover effects depending on the origin and market orientation of FDI and domestic firms' absorptive capacity. Our evidence suggests that FDI in China tends to generate spillovers mainly through backward and local linkages. We find little evidence of horizontal and forward spillovers.

Chapter 4 analyzes the relationship between firm productivity and export behavior in China's manufacturing firms. We find that exporters show superior initial performance relative to non-exporters, which is consistent with the self-selection hypothesis. Moreover, using matching and difference-in-difference methods, we find strong evidence supporting the learning-by-exporting hypothesis. On average, exporting raises the productivity by 13 percent in the first year.

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ACKNOWLEDGEMENTS

During the course of my Ph.D. study, a long list of mentors, classmates, friends and family provided many years of support. It is my privilege to express my sincere appreciation to several people who guided, encouraged, and supported me in the completion of this dissertation.

First in order of gratitude is my dissertation advisor, Professor Thomas Rawski, who stood solidly behind me during my many years of dissertation work. My understanding of China's economy benefited enormously from my work as a research assistant for Prof. Rawski in the past three years. I also want to thank him for allowing me to use his dataset in the dissertation.

I would also like to express my sincere gratitude to my dissertation committee. I am indebted to Prof. Daniel Berkowitz, Prof. Steven Klepper, Prof. Alexis Leon, and Prof. Soiliou Namoro. I am grateful for their continuous help and guidance in my dissertation research.

The dissertation is dedicated to my family in both China and the U.S., especially to my wife, Chunmei. Without her support, I could never have reached this point in my life.

1. INTRODUCTION

1.1. Background of the Dissertation

In December 1978, the Central Committee of the Communist Party of China held a historic meeting in Beijing. One of the important decisions made at this meeting was to adopt reform and open-door policies. The reform policy was aimed at invigorating the economy through market-oriented reforms. The open-door policy was expected to utilize the opportunities in the international economy. Since then, China has embarked on a gradual switch from a planned economy to a market economy and from a closed economy to an open economy. It turned out that marketization and internationalization became two most fundamental changes in China's economy in the past twenty-five years. This dissertation collects three empirical studies aiming at assessing the impacts of market forces and globalization forces on the China's manufacturing firms.

Chapter 2 studies the market forces. It examines the effects of market expansion and reduction of transaction cost on vertical specialization of firms. We test alternative theories of vertical specialization dating back to Adam Smith. These widely accepted theories have surprisingly little empirical support. This chapter attempts to fill the gap in the literature by exploiting rich variation in regional market development and vertical specialization in China's manufacturing sector.

Chapter 3 and Chapter 4 study the globalization forces. We distinguish the impacts of "passive" internationalization from "active" internationalization. Chapter 3 focuses on "passive" internationalization, looking at the effects of inward foreign direct investment on domestic firms. Chapter 4 examines "active" internationalization, testing the impacts of active exporting on firms' performance.

The rest of Chapter 1 is a brief introduction to the three topics in this dissertation: vertical specialization, FDI and exporting.

1.2. Vertical Specialization and Firm Performance

When production involves more than one stage, firms must decide whether to vertically specialize or integrate all stages. The study of vertical specialization goes far back to Adam Smith's idea of division of labor. In the very first sentence of Wealth of Nations, Adam Smith claims that, "the greatest improvement in the productive power of labor, and the greater skill, dexterity, and judgment with which it is anywhere directed or applied, seem to have been the effects of the division of labor" (Smith, 1776, Chapter 1). Division of labor allows workers to exploit their comparative advantage, improve their skills, and increase the efficiency of firms. Although Adam Smith's original idea was about specialization within a firm, his insight has been extended to specialization between firms (Young, 1928; Stigler, 1951).

Adam Smith further claims that division of labor is limited by the extent of market. Based on this idea, Stigler (1951) discusses the relationship between vertical specialization and industry lifecycle. He argues that new industries are usually vertically integrated. Then as intermediate-inputs suppliers enter the market, the degree of vertical specialization rises. In the declining stage of the lifecycle, the industries become vertically integrated again. Also following the idea of extent of market, Marshall (1920) explains that industries concentrated in particular regions should be more vertically specialized because input sharing allows the emergence of more specialized intermediate-inputs suppliers.

Another related theory is the transaction cost literature originated by Coase (1937) and further developed by Williamson (1975, 1985). Coase argues that a firm will purchase from the market if the cost of organizing production within the firm is higher than the cost of carrying out the transaction through the market. Thus, a firm's vertical specialization decision rests on the comparison of internal organizational cost and external market transaction cost.

Given the importance of these ideas in economics, one might presume that there is extensive empirical study on the nature of vertical specialization. Surprisingly, this is not the case. In particular, at the firm level, there is little systematic evidence quantifying vertical specialization (Perry, 1989). A rare example of the firm-level empirical evidence on Smith's idea that vertical specialization increases productivity appears in Murakami, Liu and Otsuka's (1996) study of China's machine tool industry. There is no firm-level empirical study of Smith's idea of extent of market, because existing empirical work focuses either on nation or state level data (Ades and Glaeser, 1999), or on the division of labor within firms (Ippolito, 1977; Caricano and Hubbard, 2003). Stigler's industry lifecycle theory was tested by Tucker and Wilder (1977), among others, with mixed results. Holmes (1999) finds evidence from U.S. that supports Marshall's theory. There are also some studies on agglomeration and input sharing in regional economics. The transaction cost literature provides relatively abundant firm-level evidence, but most of it comes from case studies.

There may be two reasons for the lack of empirical study. First, the availability of large firm-level dataset has always been a major difficulty for researchers (Yang and Ng, 1993, pp. 434-436). Our dataset provides extremely detailed information for all state firms and all non-state firms[1] with sales above 5 million Yuan (or about \$600,000) in China's manufacturing sector in 2002. Total number of firms in our dataset exceeds 160,000. Second, in a mature market economy like the United States, cross section and time series variations of market development and vertical specialization are quite small. In the past forty years, the vertical specialization index of U.S. manufacturing changed by only one percentage point.[2] As we see in Figure 1.1, China's substantial rise in vertical specialization was accompanied by enormous growth of market forces during the reform period, which began in the late 1970s. The development of market system also differed markedly across sectors and regions in China. We believe that China's market reform offers a unique opportunity to examine the effects of market expansion and reduction of transaction cost on vertical specialization of firms.

This dissertation is the first study that examines all the alternative theories simultaneously and compares their explanatory power. In Chapter 2, using industry size as an instrument for vertical specialization, we find that an increase in vertical specialization raises total factor productivity of the firms. Our OLS estimation of the determinants of vertical specialization supports Smith's extent-of-market theory, Marshall's input sharing theory and Coase's transaction cost theory. In terms of quantitative significance, our results suggest that transaction cost may have the largest impact on vertical specialization of firms, which implies that market reform in China that facilitates inter-firm transactions and reduces transaction cost is the driving force of the vertical disintegration process after the reform. However, we fail to find strong evidence in support of Stigler's industry lifecycle theory.

[1] "State firms" include all wholly state-owned firms and state shareholding firms.

[2] Vertical specialization index is defined as 1-value added/sales. See discussions in Section 2.1. Vertical specialization index of U.S. manufacturing decreased from 0.54 in 1963 to 0.53 in 2001. Source: Author's calculation based on Statistical Abstracts of United States (1970) and (2003).

1.3. FDI and Spillover effects

One of the primary motivations for governments around the world to attract foreign direct investment (FDI) is the belief that FDI will generate positive spillovers to domestic firms. World Bank (1993) writes that “FDI brings with it considerable benefits: technology transfer, management know-how, and export marketing access. Many developing countries will need to be more effective in attracting FDI flows if they are to close the technology gap with high-income countries, upgrade managerial skills, and develop their export markets.” These claims have encouraged developing countries as well as developed countries to create costly programs, such as tax breaks, subsidized industrial infrastructure, and duty exemptions, in order to attract FDI. From 1991 to 2002, developing countries made over 1,500 regulatory changes favorable to FDI (UNCTAD, 2003, p.21).

Despite its importance to policy choices, recent empirical studies on FDI spillovers find mixed results. In a summary of the existing evidence, Rodrik (1999, p.37) concludes, “today’s policy literature is filled with extravagant claims about positive spillovers from FDI, but the hard evidence is sobering.”

According to the theories, FDI spillovers can work through a number of channels. First, domestic firms can benefit from the presence of FDI in the same industry, leading to intra-industry or horizontal spillovers, through labor turnover, demonstration effects, competition effects, etc. Second, there may be spillovers from foreign firms operating in other industries,[3] leading to inter-industry or vertical spillovers. This type of spillover effect is often attributed to buyer-supplier linkages and therefore may be towards upstream (backward spillovers) or

[3] Here “foreign firms” include all firms partly or fully funded by investors from foreign countries as well as Hong Kong, Macao and Taiwan.

downstream industries (forward spillovers). Third, domestic firms may also benefit from the FDI in the same region, leading to local spillovers.

Chapter 3 examines the extent of FDI spillovers using firm-level panel data from China's manufacturing sector. China is of particular interest because it is the largest economy among developing countries, and more importantly the largest recipient of FDI in the world. Guided by FDI-oriented philosophy, Chinese local governments at all levels compete with each other to offer tax breaks and other incentives to foreign investors. In the past 25 years, tens of thousands of global corporations invested in China, bringing with them over 560 billion dollars in FDI. Figure 1.2 shows the FDI inflow into China between 1980 and 2004.

The general approach in this chapter is to regress firm-level TFP on measures of foreign presence in the firm's related industries and region. We use a first differences model to remove firm-specific unobservable variables. In line with previous studies such as Pavcnik (2002) and Javorcik (2004), we employ a semi-parametric estimation technique following Levinsohn and Petrin (2003) to get consistent estimates of total factor productivity (TFP).

We find strong effects of backward and local spillovers. In our study, however, there is little evidence of horizontal and forward spillovers. We further conduct several robustness checks. First, we allow the effect of spillovers to differ for overseas Chinese FDI and OECD FDI. Second, we allow for the heterogeneity of FDI by distinguishing spillovers from primarily export-oriented and domestic-market-oriented FDI. Third, we allow for different spillover effects depending on domestic firms' absorptive capacity. The results of the robustness checks are consistent with our main findings.

1.4. Exporting and Performance

A growing body of empirical literature has documented the superior performance of exporters relative to non-exporters. The theories suggest at least two mechanisms that can explain a positive correlation between exporting and productivity. The first is related to self-selection: only the best firms are able to compete in the international markets. The second explanation is "learning-by-exporting": after firms enter the export markets, they gain new knowledge and expertise that improve their productivity. While the self-selection hypothesis has been confirmed by various studies, the evidence on the learning hypothesis is mixed. In this dissertation, we carry out empirical tests for both hypotheses using a large panel dataset from China's manufacturing firms.

Learning-by-exporting theory is often cited as an argument for active export promotion policies such as export subsidies in developing countries. World Bank (1998) writes that, "improving the policy and business environments to create conditions favorable to trade, especially exports, is one of the most important ways for countries to obtain knowledge from abroad." In particular, the economic success of East Asian economies has been attributed, to a large extent, to the export-led development strategy. For example, Krueger (1995) argues that the key distinction between East Asian success and Latin American stagnation is the openness of international trading regimes in East Asia. Our study sheds some light on these policy issues, although the hypotheses tested in this chapter are only a subset of the arguments for export promotion.

There is an ongoing debate on the link between exports and growth. Some economists believe that exports generate economic growth (e.g., Edwards, 1998) while others argue that the reality is more complicated and the role of exports overstated (e.g., Rodrik and Rodriguez, 2000). Our study contributes to this basically macroeconomic debate by adding microeconomic evidence.

Being a major exporter in the world, the case of China is of considerable interest in this context. Since the economic reform started in the late 1970s, China's government has actively promoted exports. In 1978, the share of China's exports in world trade was negligible. After a quarter century of rapid growth, China surpassed Japan as the world's third largest trading economy (behind the United States and Germany) in 2004.[4] Figure 1.3 shows the growth of China exports between 1980 and 2004.

In searching for causal links between exporting and firm productivity, we use propensity score matching and difference-in-difference techniques developed in microeconometrics (e.g., Heckman, Ichimura, and Todd, 1997). Such methods allow us to construct a reasonable counterfactual and determine the changes in productivity that can be reliably attributed to exporting.

Our main findings can be summarized as follows. First, we find that Chinese exporters and non-exporters differ significantly. The exporters tend to have higher TFP but lower labor productivity. They are larger, less capital intensive and pay higher wages. Second, our estimation from a probit model shows that more productive firms self-select into export markets. Third, our difference-in-difference estimates based on matched samples suggest that exporting helps improve performance. On average, exporting raises the productivity by 13 percentage points in the first year. The learning effects of exporting last at lest three years. Fourth, we distinguish foreign invested firms from domestic firms. We find that although multinationals usually have more international experience and are often closer to the world technology frontier, there are still

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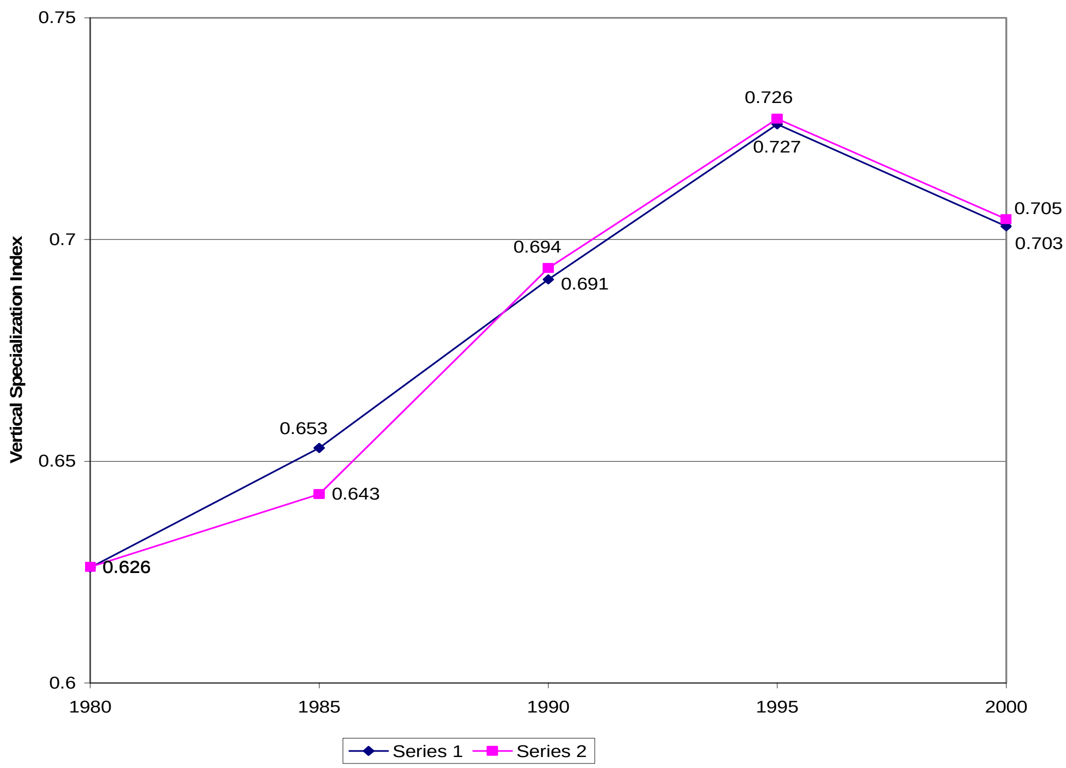
[4] Source: "China replaced Japan as world's 3rd largest exporter," *People's Daily* online, April 15, 2005. http://english.people.com.cn/200504/15/eng20050415_181246.html.

significant learning effects for foreign invested firms in China. However, compared to domestic firms, the size of their learning effects is smaller. In summary, our results support both self-selection and learning-by-exporting theories.

Figure 1.1 Evolution of Vertical Specialization of China's Industry (1980-2000)



Notes: Vertical specialization index is defined as 1 – Value Added/Gross Output. Series 1 does not control for structural change. Series 2 controls for structural change. In Series 2, 1980 industry output shares are used as weights to calculate weighted average.

Sources: 1980 and 1985 Author's calculation based on Industry Volume, *The Data of Industrial Census of People's Republic of China in 1985*.

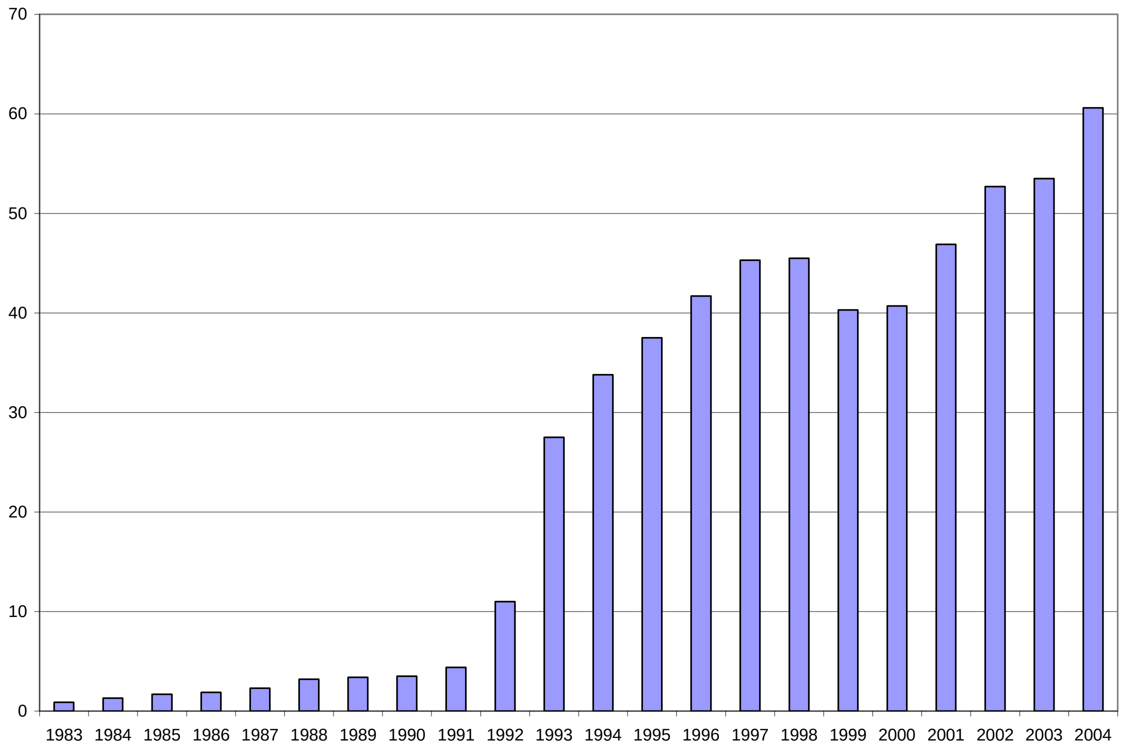
1990 Author's calculation based on *China Statistical Yearbook* (1991).

1995 Author's calculation based on Industry Volume, *The Data of Third National Industrial Census of People's Republic of China in 1995*.

2000 Author's calculation based on *China Statistical Yearbook* (2001).

Figure 1.2 FDI Inflow into China (1983-2004)

Unit: Billion US Dollars

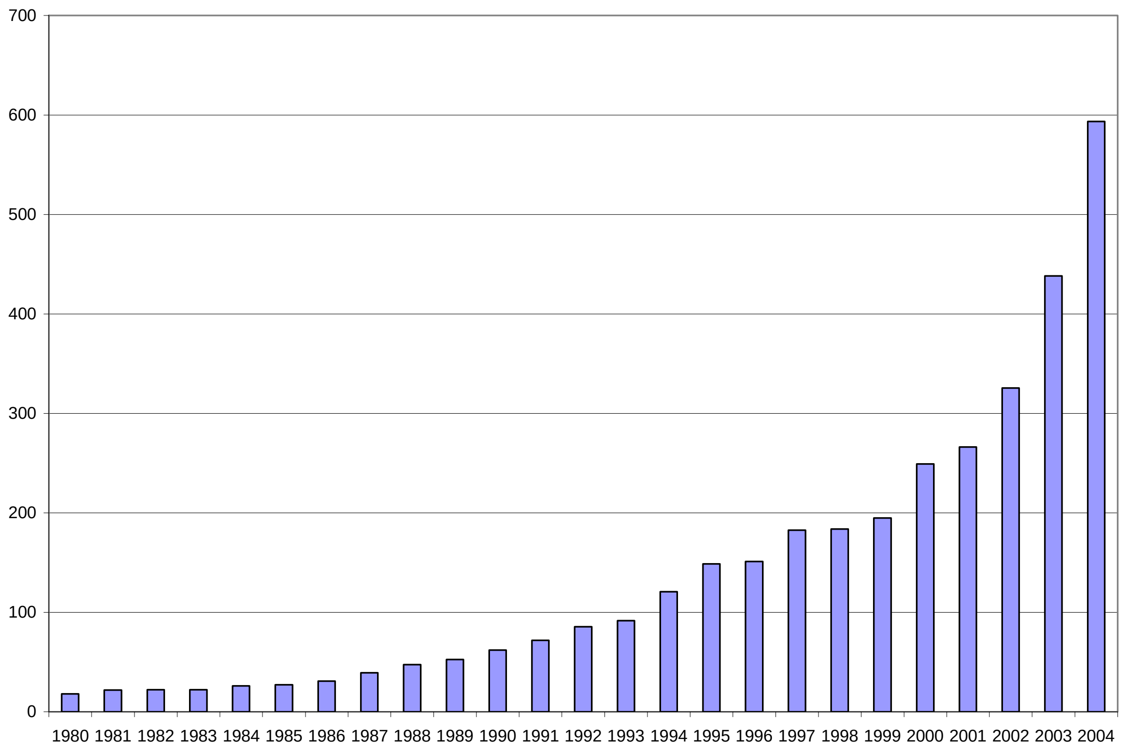


Sources: 1983-2003: *China Statistical Yearbook*, 1988, 1995, 2004;

2004: Statistical Communiqué of the People's Republic of China on the 2004 National Economic and Social Development, www.stats.gov.cn/english/newrelease/statisticalreports/t20050228_402231957.htm.

Figure 1.3 China's Exports (1980-2004)

Unit: Billion US Dollars



Sources: 1980-2003: *China Statistical Yearbook*, 1991, 2004;

2004: Statistical Communiqué of the People's Republic of China on the 2004 National Economic and Social Development, www.stats.gov.cn/english/newrelease/statisticalreports/t20050228_402231957.htm.

2. VERTICAL SPECIALIZATION OF FIRMS: EVIDENCE FROM CHINA'S MANUFACTURING SECTOR

2.1. Conceptual Framework

Vertical specialization occurs when: (1) a good is produced in two or more sequential stages; (2) two or more firms provide value added during its production. "Vertical disintegration" and "outsourcing" are common synonyms conveying similar idea.[5]

Technology is probably the most important determinant of vertical specialization. Some industries are less decomposable than others. A typical example is the energy saving from not having to reheat steel in the production of steel sheet. Technology explains why even in the same city, vertical specialization of firms varies widely by industry. In the regression, we will include two-digit industry dummies to control for the industry-specific technology differences.

Our measure of vertical specialization of firms is the vertical specialization index (*VSI*), defined as the ratio of intermediate inputs to sales. Since total sales are the sum of intermediate inputs and value added, *VSI* is also equal to one minus the ratio of value added to sales. Thus,

[5] There is a closely related but different concept of vertical specialization in international trade literature. Rather than produce final products, countries increasingly specialize in particular stages of production (Yi, 2003). This leads to discussions of vertical specialization spanning regions or countries. It differs from our concept which focuses on specialization among firms. To illustrate the difference, suppose a multinational firm operates several subsidiaries in different countries. Vertical specialization of countries occurs if these subsidiaries constitute a global vertical production chain. According to our definition, however, vertical specialization is zero because this activity is confined within a single firm.

$$VSI = \frac{M}{Y} = 1 - \frac{VA}{Y}, \tag{2.1}$$

where M is intermediate inputs, VA is value added, and Y is sales. If a firm were entirely vertically integrated, VSI would be zero. Over time, an increase (decrease) in VSI suggests that a firm has become more vertically specialized (integrated).

However, VSI is not a perfect measure of vertical specialization. First, given the same amount of value adding activity, a firm that specializes in the earlier stages of production will have lower VSI than a firm in later stages of production. This limitation complicates cross-sectional comparison of industries or firms. In the regression analysis, we will exclude mining and utilities and focus only on manufacturing sector. In addition, our two-digit industry dummies in the regression should control for the positions of industries in the production chain.

Second, a change in relative prices of final products will change VSI even when there is no change in vertical specialization. This is particularly relevant in China. Before reform, the prices of raw materials such as coal were artificially depressed by the government. When reform liberalized price system, the relative prices of raw materials rose rapidly. Since an increase in the relative prices of raw materials tends to raise VSI in the downstream sectors, time-series comparison of VSI requires caution. To deal with this problem, in Section 2.2, when we study the evolution of VSI in China's industrial sector, we include the mining and utilities industries and control for structural change by using 1980 fixed industry weights.

The use of VSI was pioneered by Adeleman (1955). Despite these shortcomings, it is widely accepted and used in the literature (see, for example, Tucker and Wilder, 1977; Levy, 1984; Holmes, 1999).

2.2. Evolution of Vertical Specialization in China's Industrial Sector

After the People's Republic of China was founded in 1949, Chinese economic system was modeled on the Soviet planned economy. Vertical integration of firms was a hallmark of China's industrial structure under planning system.[6] As shown by Table 2.1, *VSI* defined by net value decreased from 0.68 in 1949 to 0.62 in 1970 and remained below 0.65 in the 1970s.[7] Vertically integrated firms were often referred to as "big and complete" or "small and complete." In 1976, for example, 80 percent of over 6,100 firms under the supervision of the First Machinery Ministry were "full-function" firms (Ji and Rong, 1980). Because Chinese firms relied heavily on self-supply, most of the large and medium firms even built their own schools and hospitals. It is widely acknowledged by Chinese economists that such production structure of firms fails to reach the optimal scale and scope (Sheng, 1994, pp. 1-5). Chinese government began to address this problem as early as the 1950s. However, little progress had been made until the reform began in the late 1970s (Rawski, 1980).

Why do firms in planned economies tend to be more vertically integrated than their market economy counterparts? Coase's idea of transaction cost can be applied to socialist firms with slight modification. Although there is no formal market transaction in a planned economy, other types of external transaction costs do exist and can be very high. According to Kornai (1980), Soviet-type firms face chronic vertical shortage as well as horizontal shortage (pp. 200-201). In the presence of vertical shortage, firms' requests for resources are frequently turned down by administrative authority because the sum of claims often exceeds the quantity available

[6] The lack of vertical specialization is a universal problem of all socialist economies. See, for example, Berliner (1957) and Granick (1960) for the Soviet Union, and Rawski (1980) and Sheng (1994) for China.

[7] China's statistical system did not report value added until 1992. Net value = value added -- depreciation (National Statistical Bureau, 1992).

to the authority. Even if the administrative authority meets the requests, firms still face horizontal shortage. In the relationship of seller and buyer, refused orders, long waiting time and forced substitution are not unusual. In order to get full supply on time, firms must bargain with administrative authority and suppliers. When such costs exceed in-house organizational cost, it is optimal for the firms to produce intermediate inputs internally. Coase's original idea is to compare the costs associated with hierarchy and market. In a planned economy, firm's decision is actually based on comparing internal hierarchy cost with external hierarchy cost. Our explanation here is consistent with the behavior of Chinese firms. Rawski (1980) finds that before reform, Chinese managers often preferred to make rather than buy inputs because they wanted to reduce the dependence on potentially unreliable suppliers (p. 128).

China's tax system borrowed from the Soviet Union was based on sales taxes (Wong and Bird, 2004). By taxing the portion of sales, the product taxes or industrial-commercial taxes encouraged vertical integration within firms. In 1994, Chinese government replaced the old tax system with value added taxes and eliminated such distortionary effect.

When reform began in the late 1970s, markets emerged and developed quickly. As a result, state firms purchased more and more intermediate inputs through markets. In the machinery industry, for example, thousands of parts production units within those "full-function" firms were spun off during the "sixth five-year plan" period between 1981 and 1985 (He, 1990, p. 92). The government also merged different firms' production units with similar products into "specialized firms" (He, 1990, pp. 94-96). In addition, new foreign firms, private firms and township and village enterprises entered the markets of intermediate inputs, supplying specialized products to state firms.

Murakami, Liu and Otsuka (1996) study a survey of 44 firms in China's machine tool industry. They find a positive relationship between production efficiency and purchased parts ratio in 1991 but not in 1980. Their results suggest that at the beginning of the reform, vertical integration production structure still had an advantage over vertical specialization. The comparative advantage of vertical integration declined gradually and almost disappeared in the 1980s.

Figure 1.1 illustrates the evolution of *VSI* in China's industrial sector after reform. The *VSI* continued to rise between 1980 and 1995 and declined slightly after 1995. There are two possible reasons why the trend was reversed after 1995. First, China National Statistical Bureau (NBS) changed the definition and coverage of gross industrial output in 1995 (for details, see NBS, 1997, pp. 89-106). The new definition reduced the level of 1995 gross industrial output by about 10 percent (Third National Industrial Census Office, 1997, p. 46). Second, in 1998, NBS revised its statistical system to limit the coverage to state firms and those non-state firms reporting more than 5 million Yuan in annual sales. To the extent that smaller firms are more vertically specialized, excluding small non-state firms may lower *VSI*.

Since the change in industry structure and relative price may affect *VSI*, we control for the structural change by calculating industry weighted average of *VSI* with weights being 1980 industry output shares. As shown in Series 2 of Figure 1.1, controlling for structural change does not make much difference.

The evolution of vertical specialization of two-digit industries is reported in Table 2.2. Between 1980 and 2000, the largest increase in *VSI* occurred in petroleum processing, coking products and gas production. During the twenty-year period, 27 out of 31 two-digit industries became more vertically specialized.

Table 2.3 documents the regional evolution of *VSI* between 1980 and 2000. Zhejiang was the most vertically specialized province in 2000, followed by Tianjin, Jiangsu, Shanghai, and Guangdong, all located in the most developed coastal region. The five least vertically specialized regions in 2000 were Tibet, Yunnan, Heilongjiang, Xinjiang and Inner Mongolia, all located in interior regions that form part of China's land borders. The last two rows of Table 2.3 compare coastal regions with non-coastal regions. In 1980, the coastal regions were not very different from non-coastal regions in terms of vertical specialization. After twenty years of reform, the average *VSI* of coastal regions was 8.1 percentage points above that of non-coastal regions in 2000. Actually, the average *VSI* of non-coastal regions even decreased between 1980 and 2000.

2.3. Theories and Hypotheses

Theories of vertical specialization address two questions. First, what determines the degree of vertical specialization across firms? Second, does vertical specialization improve firms' productivity? In this section, we first introduce a simple model of vertical specialization that attempts to answer both questions. Then on the basis of existing theories and the model, we develop testable hypotheses.

2.3.1. A Theoretical Example

In a very influential paper, Dixit and Stiglitz (1977) construct a theoretical model of competition under increasing returns. In the Dixit-Stiglitz framework, Holmes (1999) develops a model that shows the relationship between geographic concentration and vertical specialization. Here we incorporate the transaction cost and labor productivity into the model and use it to derive predictions that are consistent with major theories of vertical specialization.

Assume there is only one industry in the economy, which is populated by *L* individuals. Each individual is endowed with one unit of labor. Only one firm produces final good but there are many intermediate good producers. There is a continuum of intermediate goods that are differentiated and indexed by $x \in [0,1]$. Each intermediate good producer specializes in the production of one good. We further assume that in the equilibrium there is only one producer of each intermediate good. The final-good producer uses labor and intermediate goods to produce final good that will be consumed by all *L* individuals. In this context, the final-good producer can be a car assembly firm, purchasing various auto parts manufactured by specialized firms.

The production function of the final good is specified as follows:

$$f\left(l, m(x)\right) = l^{1-\alpha}\left(\int_0^1 m(x)^{\rho}\, dx\right)^{\frac{\alpha}{\rho}}, \tag{2.2}$$

where l is the labor directly used in final good production and $m(x)$ denotes the quantity of intermediate good *x*. The production function has a Cobb-Douglas form: $f\left(l, M\right) = l^{1-\alpha} M^{\alpha}$, where *M* can be treated as a composite intermediate good and its production function is given by

$$M = \left(\int_0^1 m(x)^{\rho}\, dx\right)^{\frac{1}{\rho}}, \tag{2.3}$$

The CES-type functional form of *M* has important properties of constant returns to scale and constant elasticity of substitution.

The technology allows firms to produce one unit of intermediate good with one unit of labor. The final-good firm can produce intermediate goods by itself. Alternatively, it can purchase intermediate goods from the specialized firms.

If intermediate goods are manufactured within the final-good firm, there is an extra cost of γ units of labor that is proportional to the quantity produced. This additional cost is needed to coordinate the production of different goods. Thus, in-house production of $m(x)$ units of intermediate good x costs the final-good firm $(1+\gamma)m(x)$ units of labor. We assume that $(1+\gamma) > \frac{1}{\rho} > 1$. Basically this assumption states that the coordination cost should be high enough to guarantee the existence of the equilibrium. Specialized intermediate-good firms do not have coordination cost because they produce only one good. However, a fixed set-up cost of θ units of labor occurs when the firm is established. In addition, there is a transaction cost of δ units of labor that is devoted to contract negotiation or contract enforcement. Assume δ is fixed and independent of quantity produced. For simplicity, we further assume that specialized firms bear all the transaction cost. Therefore, the labor cost of $m(x)$ units of intermediate good x is equal to $(m(x)+\theta+\delta)$ if the good is produced in a specialized firm. It can be easily seen that the marginal cost of specialized firms is lower, while the disadvantages of specialized firms are the fixed set-up cost and transaction cost.

The final good is taken as the numeraire (price set to unity). Let w denote the price of labor in terms of final good. Without loss of generality, assume all the intermediate goods produced by specialized firms are indexed between 0 and s. Let $p(x)$ be the price of specialized intermediate good x. The remaining intermediate goods indexed s to 1 are produced by the final-good firm.

The final-good firm maximizes its profit by choosing labor l and a vector of intermediate goods:

$$\max\left\{ l^{1-\alpha}\left(\int_0^1 m(x)^\rho dx\right)^{\frac{\alpha}{\rho}} - \int_0^s p(x)m(x)dx - \int_s^1 (1+\gamma)wm(x)dx - wl \right\}. \tag{2.4}$$

The first term is the value of total output. The second term is final-good firm's total expenditure on specialized intermediate goods. The third term is total labor cost associated with producing intermediate goods within the firm. It is equal to the sum of quantity of labor used in internal production and coordination, $(1+\gamma)m(x)$, multiplied by labor price, w. The last term is total cost of labor directly applied in final-good production.

Given the symmetry of the intermediate goods, let m_S and p_S be the equilibrium output and price of a representative specialized intermediate good and m_I represent the equilibrium output of a typical internally produced intermediate good. Taking derivatives with respect to m_S and m_I yields the following first order conditions

$$\alpha l^{1-\alpha}\left(\int_0^1 m(x)^\rho dx\right)^{\frac{\alpha-\rho}{\rho}} m_S^{\rho-1} = p_S, \tag{2.5}$$

and

$$\alpha l^{1-\alpha}\left(\int_0^1 m(x)^\rho dx\right)^{\frac{\alpha-\rho}{\rho}} m_I^{\rho-1} = (1+\gamma)w. \tag{2.6}$$

Equations (2.5) and (2.6) imply that

$$\left(\frac{m_I}{m_S}\right)^{\rho-1} = \frac{(1+\gamma)w}{p_S}. \tag{2.7}$$

With constant elasticity, Dixit and Stiglitz (1977) give the standard result to pin down p_S: profit maximization of specialized firms implies that price is a constant markup over marginal cost, or $p_S = \frac{w}{\rho}$. Assuming free entry, we can derive the zero profit condition for specialized firms

$$\frac{wm_S}{\rho} = w(m_S + \theta + \delta). \tag{2.8}$$

Here the left-hand side is sales revenue and the right-hand side is total cost. Solving (2.8) for equilibrium output of the specialized intermediate good gives

$$m_S = \frac{\rho(\theta + \delta)}{1 - \rho}. \tag{2.9}$$

Plugging $p_S = \frac{w}{\rho}$ into (2.7) yields

$$m_I = \left[(1 + \gamma)\rho\right]^{\frac{1}{\rho - 1}} m_S. \tag{2.10}$$

Since our final-good production function is Cobb-Douglas form in nature, it is easy to show that the equilibrium quantity of labor directly applied to final good production l^* equals $(1 - \alpha)L$. The rest of labor in the economy is allocated to the production of intermediate goods. Thus we have

$$s(m_S + \theta + \delta) + (1 - s)(1 + \gamma)m_I = \alpha L. \tag{2.11}$$

Recall that s is the measure of the set of differentiated intermediate goods that are produced by specialized firms. Plugging (2.9) and (2.10) into (2.11) and solving for s give

$$s = \frac{\dfrac{\alpha L(1 - \rho)}{\rho(\theta + \delta)} - (1 + \gamma)\left[(1 + \gamma)\rho\right]^{\frac{1}{\rho - 1}}}{\dfrac{1}{\rho} - (1 + \gamma)\left[(1 + \gamma)\rho\right]^{\frac{1}{\rho - 1}}}. \tag{2.12}$$

Given the assumption that $(1+\gamma) > \frac{1}{\rho} > 1$, it is straightforward to show $\frac{1}{\rho} - (1+\gamma)\left[(1+\gamma)\rho\right]^{\frac{1}{\rho-1}} > 0$ and therefore $\frac{\partial s}{\partial L} > 0$. Our result is consistent with Adam Smith's extent-of-market theory: when the industry size (employment in the model) increases, more intermediate goods will be produced by specialized firms.

Since $s \in [0,1]$, we have two critical values for L. s will be zero if

$$L \leq L_1 = \frac{\rho(\theta+\delta)\left[(1+\gamma)\rho\right]^{\frac{1}{\rho-1}}}{\alpha(1-\rho)}. \tag{2.13}$$

And $s = 1$ when

$$L \geq L_2 = \frac{\theta+\delta}{\alpha(1-\rho)}. \tag{2.14}$$

To summarize, when the industry size is small, all intermediate goods will be produced internally by the final-good producer. After industry size exceeds L_1, the range of intermediate goods produced by final-good firm decreases and specialized firms begin to produce some intermediate goods. If the industry size is larger than L_2, all intermediate goods will be produced by specialized firms. The following prediction summarizes the discussion.

Prediction 1: When $L_1 \geq L \geq L_2$, $\frac{\partial s}{\partial L} > 0$.

The model also supports transaction cost theory. From (2.12), it is straightforward to show the following prediction.

Prediction 2: Under the assumptions in the model, $\frac{\partial s}{\partial \delta} < 0$.

This prediction implies that the final-good producer will spin off more intermediate goods production to specialized firms when transaction cost is lower.

Now let us examine the relationship between productivity and vertical specialization. In equilibrium, total income equals total output of final good. So we have the following equation

$$wL = \left[(1-\alpha)L\right]^{1-\alpha}\left\{sm_S^{\rho} + (1-s)\left[(1+\gamma)\rho\right]^{\frac{\rho}{\rho-1}} m_S^{\rho}\right\}^{\frac{\alpha}{\rho}}. \tag{2.15}$$

Solving (2.11) for L and plugging it into (2.15) lead to an expression for w

$$w = \alpha^{-\alpha}(1-\alpha)^{1-\alpha}\rho^{\alpha}\left\{s + (1-s)\left[(1+\gamma)\rho\right]^{\frac{\rho}{\rho-1}}\right\}^{\frac{\alpha(1-\rho)}{\rho}}. \tag{2.16}$$

Since $(1+\gamma) > \frac{1}{\rho} > 1$, we have the following prediction.

Prediction 3: Under the assumptions in the model, $\frac{\partial w}{\partial s} > 0$.

Because w can be interpreted as wage rate or labor productivity, the model predicts that a higher degree of vertical specialization raises living standard or productivity.

Our measure of vertical specialization equals intermediate inputs/sales. In the model, we have

$$VSI = \frac{sm_S w/p}{wL}. \tag{2.17}$$

After rearrangement, (2.17) implies that

$$VSI = \frac{\alpha s}{s\left\{1-\left[(1+\gamma)\rho\right]^{\frac{\rho}{\rho-1}}\right\} + n\left[(1+\gamma)\rho\right]^{\frac{\rho}{\rho-1}}}. \tag{2.18}$$

It is easy to verify that *VSI* is strictly increasing in s. However, the nonlinear relationship between *VSI* and s illustrates the complications of *VSI* in measuring vertical specialization of firms.

2.3.2. Developing Hypotheses

Now we develop the hypotheses based on the theories and model predictions. We begin with the first question raised at the beginning of this section: what determines the vertical specialization of firms? The existing theories can be grouped into two categories: extent-of-market theory and transaction cost theory.

The first theory comes from Smith's famous theorem: the division of labor is limited by the extent of market. Smith writes "when the market is very small, no person can have any encouragement to dedicate himself entirely to one employment" (1776, Chapter 3). Smith uses the pin factory example to show that division of labor requires a large market.

Ippolito (1977) formulates Smith's theory of division of labor within the firm and tests it with data from shipbuilding industry during World War II. His results are strongly supportive of the theory. In a recent study, Garicano and Hubbard (2003) use a dataset of law firms and find that lawyers' field scope narrows as market size increases and individuals specialize. Ades and Glaeser (1999) present some evidence of Smith's theorem at the regional level. They examine twentieth century less developed countries and nineteenth century U.S. states. The authors find in both datasets that openness and initial development are substitutes in generating growth. This finding indicates the importance of the extent-of-market. They also show that the extent-of-market works, in part, through deeper division of labor.

To summarize, we have the following hypothesis.

Hypothesis 1: *Firms in larger markets tend to have higher degree of vertical specialization.*

Marshall (1920) identifies three sources of agglomeration economies: knowledge spillovers, labor pooling and input sharing. He believes that geographical concentration of firms in the same industry creates a market for specialized inputs and lowers the cost of inputs. Suppose, for example, an apparel firm is able to purchase buttons from a local firm that specializes in button manufacturing. If the button production is subject to increasing returns to scale and if transportation is costly, then the presence of other apparel firms nearby will allow them to purchase their buttons more cheaply. Thus, geographic concentration of an industry makes it possible to host more specialized intermediate inputs suppliers. Instead of emphasizing internal increasing returns of specialized intermediate-inputs suppliers, Marshall refers to input sharing as an example of external economies.

The input sharing of geographically concentrated firms is modeled in economic geography literature (e.g., Fujita, Krugman and Venables, 1995). In an empirical study of U.S. manufacturing sector, Holmes (1999) finds that more concentrated industries have a higher value of "purchased input intensity," defined as purchased inputs divided by sales. He uses pantyhose industry as an example. Pantyhose industry is concentrated in North Carolina, which accounts for 62 percent of national employment in the industry. The purchased input intensity of pantyhose industry in North Carolina is 53 percent, compared to 40 percent among other pantyhose firms throughout the United States.

Young (2000) argues that industries have been less concentrated in China because of interregional trade barriers and fragmentation of the domestic markets. In contrast, Bai, Du, Tao, and Tong (2004) find the evidence that Chinese industries have become increasingly concentrated during the reform era. It is well documented that in some Chinese industrial clusters, the vertical specialization is highly developed. For example, Jinxiang township of Zhejiang province supplies about 40 percent of badges in the world. Over ten stages of production, from design to packing, are undertaken by different firms. The whole production process involves more than 800 firms specializing in different stages of production (Qian, 2003).

Hence, we have the following hypothesis.

Hypothesis 2: *Vertical specialization of firms tends to rise in the presence of other firms of the same industry in the same region*.

Building on Smith's extent-of-market theory, Stigler (1951) emphasizes that vertical specialization is closely related to the lifecycle of an industry. During the early stages of production, firms are likely to be vertically integrated. A competitive supply of inputs may not be available because the industry is new. Usually these young firms must design and manufacture their own specialized equipment and intermediate inputs. As the industry matures, new firms may enter each stage, creating a competitive supply of intermediate inputs. The integrated firms may also choose to spin off vertically distinct stages into separate firms. In the declining stages, the industry becomes vertically integrated again because the market scale can no longer support vertically specialized firms. Thus, Stigler writes, "vertical integration should be a typical development in the growing industry, with vertical disintegration more prominent in declining industries" (1951, p. 82).

Tucker and Wilder (1977) examine 54 American manufacturing firms and find that vertical integration of a firm appears to be related to the age of the firm in a way that is consistent with Stigler's idea. Levy (1984) explores census data for 38 industries from 1963, 1967 and 1972. His results confirm those of Tucker and Wilder. By contrast, Stuckey (1983) finds opposite results from a study of the aluminum industry.

We summarize the discussion with the following hypothesis.

Hypothesis 3: *The degree of vertical specialization is low in infant industries, high in mature industries, and low in declining industries. In particular, there is an inverted "U" shape relationship between industry lifecycle and the degree of vertical specialization*.

The second major theory, transaction cost theory, began with the work of Coase (1937), in which the author uses transaction cost to explain the boundary of the firms. According to Coase, all market transactions generate transaction costs. Transaction costs can be generally summarized as "costs of using the price mechanism." Coase believes that in-house production may replace price mechanism if the cost of coordinating internalized transactions is lower than the otherwise cost if the transaction is implemented through markets. The expansion of firm size stops at the point where the organizational cost is equal to the market transaction cost.

Beginning with Williamson (1975, 1985), a body of literature has developed that clarifies the role of transaction cost and asset specificity. The inefficiency from "hold-up" problem gives a reason for vertical integration. In property rights theory, Grossman and Hart (1986) analyze the vertical integration problem from the perspectives of incomplete contracts and control rights. Grossman and Helpman (2002) provide a general equilibrium framework that incorporates these models.

To summarize, we have the following hypothesis.

Hypothesis 4: *The degree of vertical specialization is higher for firms that face lower market transaction cost*.

The hypotheses discussed above are not mutually exclusive. Hypotheses 2 and 3 can be regarded as the extensions of Hypothesis 1, since theories of industry lifecycle and input sharing are built upon Smith's idea of extent-of-market. Transaction cost theory and extent-of-market theory are also closely related because markets expand when transaction cost is reduced.

However, major differences exist between extent-of-market theory and transaction cost theory. The extent-of-market theory adopts a disintegration approach, starting with a fully integrated firm. It tries to explain why the production process can be divided into different tasks that are undertaken by different firms and coordinated by the market mechanism. The focus of the theory is the increasing returns of production generated from concentrating on a limited set of activities. In contrast, the transaction cost theory adopts an integration approach, starting with fully specialized firms. The questions are whether and under what circumstances the vertically specialized firms will be integrated. Later development of transaction cost theory focuses on the bilateral relationship between the firm and its supplier. It is fair to say that the disintegration approach is relatively neglected and underdeveloped as compared with integration approach, even though the former has logical and historical advantages (Andersen, 1998).

Now we turn to the second question. The idea that specialization increases productivity is older than economics itself. More than 2300 years ago, Plato (380 BC, pp. 102-106) discussed the welfare implications of market and division of labor. Adam Smith is commonly referred to as the first person to systematically study division of labor. According to Smith, specialization of functions and division of labor are fundamental to higher productivity and economic growth. He describes how workers in a modern economy do different jobs and enhance each other's productivity. Thus, a group of people working in this way can produce much more per person than they would be able to produce if they worked independently. Smith concludes that there are three advantages of division of labor, each leading to higher productivity: the increase in workers' skill, the saving of time which would be otherwise lost in switches from one type of work to another, and the invention of machines that facilitate special tasks. Smith's view of division of labor is broader than what his example of pin factory indicates. He has in mind specialization not only by skills but also by occupation, firms and industries. In the later context of his book, Smith also refers to so-called territorial division of labor, the basis for interregional and international trade.

There are numerous models to formalize Smith's idea of division of labor. Stigler (1951) shows with a graph that a firm's productivity increases as it narrows down the range of production activities. Becker's model (1981) demonstrates that division of labor occurs when an efficient household exploits comparative advantage among household members. In Kim (1989), labor specialization is modeled based on each worker's human capital decision. Yang and Borland (1991) construct a model which explains economic growth by the evolution of division of labor.

Smith's discussion of division of labor provides an exceptionally lucid analysis of specialization, increasing returns and gains from trade -- principles upon which many fields of modern economics rest. His idea of specialization is more general than Ricardo's concept of comparative advantage. According to Adam Smith, even two ex ante identical individuals can benefit from specialization and trade. For Ricardo, ex ante difference in productivity generates specialization. For Smith, specialization causes ex post difference in productivity. In the international trade literature, Grossman and Helpman (1989) distinguish the so-called "acquired comparative advantage" from "natural comparative advantage." Krugman (1979, 1980) shows that gains from trade exist even if all countries are identical. Smith's idea of specialization also plays an important role in endogenous growth theory. For example, in Romer (1986), endogenous increase in the number of intermediate inputs raises the productivity in the production of final goods.

Extending the analysis of division of labor within a firm to vertical specialization between firms requires some caution. Division of labor within a firm looks more like a cooperative game, because even though workers may have their private goals, there is an authority that coordinates and organizes the division of labor in order to enhance the productivity of the firm as a whole. In a market economy, there is no such authority in the vertical relationship between firms. Therefore, the setting of vertical specialization between firms looks more like a non-cooperative game.

The following hypothesis summarizes the above discussion.

Hypothesis 5: *Firms with higher degrees of vertical specialization tend to be more productive*.

2.4. Measurement and Data

2.4.1. Measuring Variables

We discussed the measurement of vertical specialization in Section 2.1. Here we explain other variables that will be used in the regression analysis.

A. *Extent of Market*

To test the hypothesis that firms in a larger market tend to be more vertically specialized, we use industry size to proxy the extent of market. This measure is also consistent with the model in Section 2.3. We define the industry at the four-digit level.

B. *Geographical Concentration*

Following Holmes (1999), we measure geographical concentration by own-industry neighboring output. I define the neighbor of a firm as all the firms other than the firm itself in the same city. Therefore, own-industry neighboring output shows the total sales of same four-digit industry in the same city except the firm concerned.

C. *Industry Lifecycle*

Our primary measure of the lifecycle of an industry is the weighted average of ages of all the firms in that industry, with the weights given by firms' share of sales. Table 2.4 shows the 10 youngest industries and 10 oldest industries in 2002. To capture the quadratic form of industry age in the hypothesis, we include industry age and industry age squared in our regression. An alternative measure of industry lifecycle is the industry growth rate, which was first proposed by Tucker and Wilder (1977) and later used by Levy (1984). According to these authors, a higher (lower) growth rate of an industry shows that the industry is in its earlier (later) stage of the lifecycle. Again, the industry is defined at the four-digit level. We calculate industry growth rate between 1996 and 2002 using NBS Enterprise Dataset (1996) and (2002).[8] The industry gross output of 2002 is deflated by sectoral ex-factory price index (*China Statistical Yearbook*, 2003).

D. *Transaction Cost*

Transaction cost is difficult to measure. As Coase explains, transaction cost includes cost of discovering input price and costs of negotiating, writing, monitoring and implementing contracts.

We use provincial marketization index of 2001 complied by Fan, Wang and Zhu (2003) as our measure. There are five components in this index: (1) Size of the government in the regional economy; (2) Economic structure, mainly concerning the growth of the non-state sector; (3) Interregional trade barriers; (4) Factor market development, including factor mobility; (5)

[8] Note that there is a difference in the coverage between 1996 dataset and 2002 dataset. The 1996 dataset includes all firms with independent accounting system. The 2002 dataset includes all state firms and all non-state firms above designated size. We assume that the difference in coverage does not vary substantially across industries.

Legal framework. To construct the index, these five variables were first transformed into 0-to-10 scale values. Then principal component analysis was used to generate the weights. The index shows the relative position of a province in the progress towards market economy compared to other provinces. According to the authors, higher index indicates better developed market economy. This index was used before by Zhang (2005) in a study of China's private enterprises.

Market transaction cost is lower if the market system is better developed. We believe the marketization index captures the core of the Coase's concept of transaction cost. Figure 2.1 plots the marketization index and *VSI* of Chinese provinces. As shown by the figure, marketization index has a strong and positive relationship with *VSI*.

2.4.2. The Data

The empirical study is based on a large dataset of Chinese industrial firms built from cross-sectional data collected in a regular survey by China National Bureau of Statistics in 2002. The survey covers all state-owned firms and all non-state firms above designated scale. Only non-state firms with sales under 5 million Yuan are excluded. The total number of observations in the manufacturing sector is 161,868. The industry section of *China Statistical Yearbook* (2003) is complied based on this dataset. *China Markets Yearbook* (2004) reports the basic information of each four-digit industry. The dataset contains detailed information of about 100 variables, including ID number, sales revenue, value added, export, four-digit industry code, six-digit geographical code (county or district level), founding year, ownership type, employment, capital stock, and intermediate inputs. Our data cover 527 four-digit manufacturing industries and 348 cities across the country. Summary statistics of the variables defined in this section are reported in Table 2.5.

2.5. Empirical Tests

2.5.1. Determinants of Vertical Specialization

In this section, we carry out econometric tests of the hypotheses outlined in Section 2.3. We begin with the estimation of the determinants of *VSI*. On the basis of Hypotheses 1-4, we estimate the following equation

$$VSI = \alpha + \beta_1 * Industry\_Size + \beta_2 * Neighboring\_Output + \beta_3 * Industry\_Age$$

$$+ \beta_4 * (Industry\_Age)^2 + \beta_5 * Marketization\_Index + \sum_i \lambda_i X_i + \varepsilon, \qquad (2.19)$$

where X_i 's are control variables.

The explanatory variables are characteristics of the firm's industry, home city or home province, so they are unlikely to be endogenous. The upper panel of Table 2.6 reports the coefficients and standard errors of OLS estimation, while the lower panel shows the quantitative significance of the variables. The standard errors reported throughout the chapter are corrected for two-digit industry-province clustering. All the coefficients in specification (1) are statistically significant at the 1 percent level. The positive coefficient of industry age and the negative coefficient of industry age squared imply an inverted U-shape relationship between *VSI* and industry age. All four hypotheses are supported by the regression results of specification (1).

Suspecting that vertical specialization differs systematically among firms with different ownership, we add ownership dummies in specification (2) of Table 2.6. Based on China's official categorization scheme, we divide the ownership of the firms into four groups: state, collective, private, and foreign firms. In the regression, the dummy for state ownership is omitted. The coefficients hardly change and remain statistically significant at the 1 percent level.

The estimation results also show that private firms have the highest degree of vertical specialization, followed by collectives and foreign invested firms. State firms appear to have the lowest degree of vertical specialization. The *VSI* of the private firms is, on average, 2.08 percentage points higher than that of the state firms.

As explained in Section 2.1, because *VSI* can be affected by industry-specific technology and the relative positions in production chain, it is critical to include two-digit industry dummies in the regression. To control for the huge difference between coastal regions and non-coastal regions, we also add a coastal dummy. The estimation results appear in specification (3) of Table 2.6. The vertical specialization of firms in coastal regions is significantly higher than non-coastal regions. This specification substantially reduces the absolute value of the coefficients for both industry age and industry age squared. The most important change is that the coefficient of industry age squared is no longer statistically significant.

In the last column of Table 2.6, instead of industry age, we use industry growth rate as an alternative measure of industry lifecycle. Industry growth rate and industry growth rate squared both have the expected signs, but neither is statistically significant.

Now we turn to the quantitative significance of the variables, which indicates the response of the dependent variable to a one-standard-deviation increase in the corresponding explanatory variable. In all four cases reported in Table 2.6, provincial marketization index has by far the largest impact on *VSI*. The quantitative significance of other variables is much lower. A one standard deviation increase in the marketization index raises *VSI* by about 1.7 percentage points. Table 2.3 shows that the gap of *VSI* between coastal and non-coastal regions is 8.1 percentage points in 2000. If the marketization index jumps from the average of non-coastal regions (4.46) to the average of coastal regions (6.73), *VSI* would increase by (6.73-

4.46)×1.35=3.12 percentage points, which accounts for about 40 percent of the gap of *VSI* between coastal and non-coastal regions in 2000.

In Table 2.7 and Table 2.8, our objective is to see whether these results are robust to different definitions of industry and region. Most of the firms in our dataset have multiple products. Since each firm reports only one four-digit industry code, it is possible that when we measure the extent of market, four-digit industry is too narrow. In specifications (1) and (2) of Table 2.7, we estimate (2.19) with three-digit industry size and two-digit industry size. The coefficients of both of them are positive and statistically significant. Similarly, the extent of market for some firms goes beyond the national border. To take international markets into consideration, we include three-digit and four-digit industry exports in the regression. The last two columns of Table 2.7 show estimates similar to our baseline results.

In the first two columns of Table 2.8, we replace four-digit industry age and growth rate with three-digit industry age and growth rate. None of the coefficients of these variables are statistically significant. In fact, we obtain an unexpected positive sign for industry age squared in the first column. In addition, we redefine neighboring output at three-digit industry-city and three-digit industry-county level. As shown by the last two columns of Table 2.8, the estimated coefficients of neighboring output are still positive and statistically significant.

In Table 2.9, we conduct two more robustness checks. It is possible that smaller firms tend to be more vertically specialized (Tucker and Wilder, 1977). In the baseline specification, we add the firm size as an independent variable. The results reported in the first column shows that this is true for Chinese firms. Given that the main purpose of this dissertation is to examine the effects of market forces and globalization forces on firm-level performance, we are interested in the impact of globalization on vertical specialization. In particular, we would like to know if the entry of foreign firms increases the vertical specialization in their industries. For example, when foreign car markers built assembly plants in China, they often purchased parts locally, helping create many specialized auto parts suppliers. In the regression, we use the share of FDI in industry output as a proxy for the presence of foreign firms. The second column of Table 2.9 shows that FDI did have a positive effect on vertical specialization, but its quantitative effect is relatively small.

Given that *VSI* is defined to be bounded between 0 and 1, it may not be appropriate to use *VSI* as a dependent variable. We reestimate (2.19) using logistic transformation of *VSI* as the dependent variable:

$$LOGITVSI = \ln\left(\frac{VSI}{1-VSI}\right). \tag{2.20}$$

The estimation results reported in Table 2.10 show a similar pattern. In the first two specifications, the coefficients of all the variables of interest show expected signs and are statistically significant. When industry and coastal dummies are added into specification (3), the coefficient of industry age squared is no longer statistically significant. In specification (4), where industry growth rate is included as a measure of industry lifecycle, the coefficient of industry growth rate squared is not significant. Again, the quantitative significance of marketization index is much larger than all other variables.[9]

In summary, we find evidence that supports Smith's extent-of-market theory, Marshall's input sharing theory and Coase's transaction cost theory. Our data do not support Stigler's industry lifecycle theory because the results obtained in specification (1) of Table 2.6 and Table 2.10 are not robust to the inclusion of industry dummies and coastal dummy. Perhaps the relationship between industry lifecycle and vertical specialization is more complicated than a

[9] I also did the robustness checks for LOGITVSI. The results are available upon request.

simple inverted-U relationship. Indeed, the evolution of some industries, including computers (Fine, 1998) and semiconductors (Langlois, 2000), exhibits successive cycles of integration and specialization.

2.5.2. Vertical Specialization and Productivity

This subsection tests the hypothesis that other things being equal, more vertically specialized firms tend to be more productive. Following Murakami, Liu and Otsuka (1996), we estimate a production function that includes *VSI* as an explanatory variable. Specifically, we assume the Cobb-Douglas form of[10]

$$Y = K^{\alpha} L^{\beta} M^{\gamma} \{\exp.\}^{c+\mu(VSI)+\sum \theta_i Z_i}, \tag{2.21}$$

where *Y* is sales, *K* is capital stock, *L* is total employment, *M* is intermediate inputs, and Z_i 's are control variables.

Taking logarithm, we obtain the following estimable equation:

$$\ln Y = c + \alpha \ln K + \beta \ln L + \gamma \ln M + \mu(VSI) + \sum_i \theta_i Z_i + \varepsilon. \tag{2.22}$$

We begin our analysis by regressing ln*Y* on ln*K*, ln*L*, ln*M* and *VSI* using OLS. The estimation results are reported in the first column of Table 2.11. The coefficient of *VSI* is positive and statistically significant at the 5 percent level. However, the quantitative significance is relatively low. The output increases by only 0.36 percent in response to a one-standard-deviation increase in *VSI*.

It is well known that ownership has a strong impact on firm-level productivity (see, for example, Jefferson, Rawski, Wang and Zheng (2000) for Chinese industry). Thus, we include ownership dummies in specification (2) of Table 2.11. The coefficient of *VSI* is now smaller but

[10] I also estimated translog form of production function. The results are qualitatively the same.

still significant at the 10 percent level. In specification (3), *VSI* is not statistically significant after we add two-digit industry dummies and province dummies.

By definition, *VSI* is a function of *Y*, so it is clearly an endogenous variable in (2.22). Instrumental variable (IV) method is needed to obtain unbiased estimates.

Independent variables in (2.19) are natural candidates for instrumental variables. A preliminary examination of these variables indicates that marketization index, neighboring output, industry age are unlikely to be exogenous in (2.22). Since marketization index correlates with the quality of the institutions, it may have a direct effect on firm's productivity. Neighboring output correlates with geographic concentration of an industry, which may affect firm-level productivity through externalities such as labor pooling and knowledge spillovers. Regarding the industry age, old industries may exhibit lower productivity if they use outdated technology.

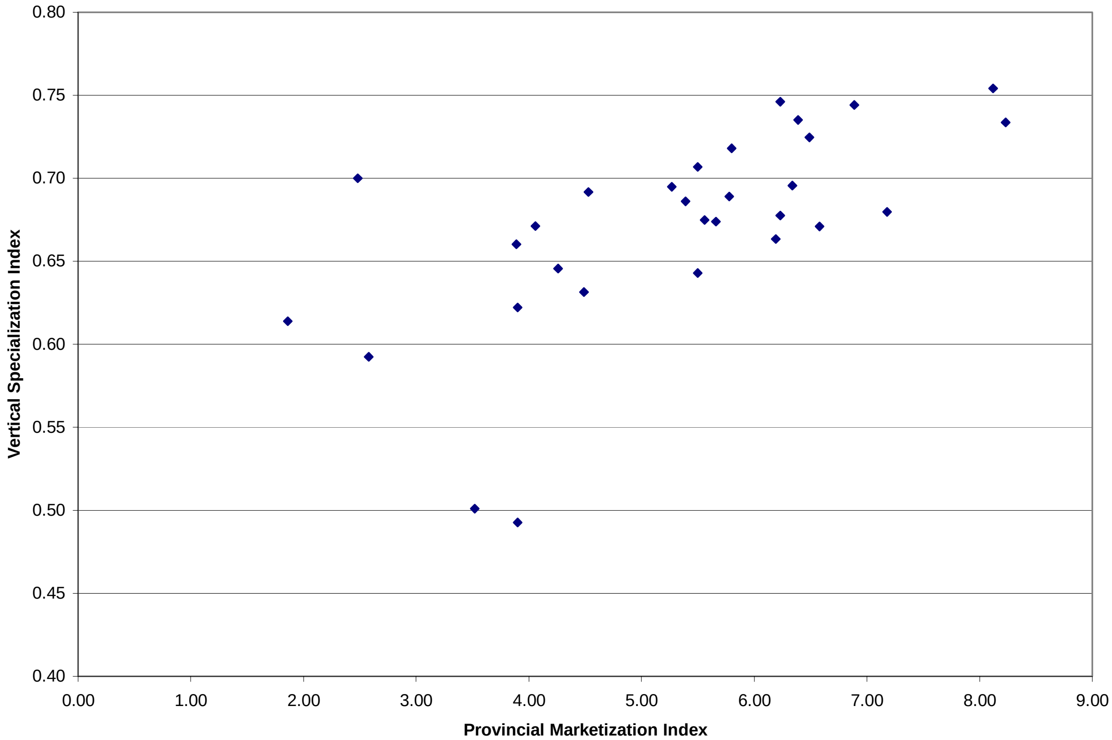
However, no theory indicates that industry size should be a determinant of a firm's productivity. Therefore, we use four-digit industry size as an excluded instrument to estimate (2.22). Panel A of Table 2.12 reports the estimation results of second-stage regression. For specification (1), the second-stage regression results show that the coefficient of *VSI* is significant at the 1 percent level. Compared with OLS, the coefficient is much larger. We add ownership dummies, two-digit industry dummies and province dummies in specification (2). In this case, the coefficient of *VSI* is smaller than specification (1) but still statistically and quantitatively significant. A one-standard-deviation increase in *VSI* is associated with about 1.6 percent increase in output. An increase of 8.1 percentage points in *VSI*, which is the gap between coastal and non-coastal regions in 2000, would imply 0.8 percent higher output after controlling for inputs.

As a robustness check, in specifications (3) and (4) of Table 2.12, we replace four-digit industry size with three-digit industry size as an instrumental variable. The results are almost identical to the baseline estimates. In specifications (5) and (6), we use both four-digit industry size and three-digit industry size. Again, the estimates change very little. The Sargan test of specifications (5) and (6) reported at the bottom of Panel A does not reject the null hypothesis of orthogonality of the IV residuals to the instruments. Subject to the caveats related to the power of the overidentification tests, this gives us additional confidence that industry size is a valid instrument.

Panel B of Table 2.12 reports first-stage estimates.[11] For specifications (5) and (6), the F-statistics for joint significance of four-digit industry size and three-digit industry size are 23.02 and 17.85 respectively. In all six specifications, the excluded instruments are all significant at the 1 percent level, which serves to indicate the strength of these variables as instruments.

[11] In fact if the instruments are weak, even very large samples can yield unreliable estimates (Bound, Jaeger, and Baker, 1995). To test whether instruments are weak, one rule of thumb is that for a single endogenous variable, a first stage F-statistic below 10 is cause for concern (Staiger and Stock, 1997). In a recent study, Stock and Yogo (2004) refine this rule and replace it with simulated critical values. Our first stage F-statistics far exceed the critical values at the 5 percent level reported in Stock and Yogo (2004), so we conclude that our instruments are not weak.

Figure 2.1 Vertical Specialization Index versus Provincial Marketization Index



Note: Provincial marketization index is the value of 2001. See Fan, Wang and Zhu (2003). Vertical specialization index is the value of 2002.
Sources: Provincial marketization index is taken from Fan, Wang and Zhu (2003). Vertical specialization index is calculated based on Table 13-8 of *China Statistical Yearbook* (2003).

Table 2.1 Evolution of Vertical Specialization of China's Industry (1949-2003)

	VSI = 1 – Value Added/Gross Output
2003	0.710
2002	0.702
2001	0.703
2000	0.704
1999	0.703
1998	0.713
1997	0.710
1996	0.713
1995	0.719
1994	0.714
1993	0.677
1992	0.724
	VSI = 1 – Net Value/Gross Output
1992	0.731
1991	0.732
1990	0.724
1989	0.717
1988	0.703
1987	0.692
1986	0.680
1985	0.675
1984	0.670
1983	0.669
1982	0.665
1981	0.659
1980	0.650
1979	0.652
1978	0.649
1975	0.641
1970	0.621
1965	0.640
1960	0.655
1955	0.665
1950	0.686
1949	0.679

Notes: China's statistical system switched from net value to value added in 1992. Value added = net Value + depreciation (China National Statistical Bureau, 1992). Figures of 1949-1997 include all firms with independent accounting system. Figures of 1998-2001 include all state firms and all non-state firms above designated size.

Sources: 1949-1991 Author's calculation based on *China Industrial Economy Yearbook* (1992).
1992-2002 Author's calculation based on *China Statistical Yearbook* (2003).
2003 Author's calculation based on *China Statistical Yearbook* (2004).

Table 2.2 Evolution of Vertical Specialization by Industry (1980-2000)

	1980	1985	1990	1995	2000
Nation	0.626	0.653	0.691	0.726	0.703
Coal Mining & Processing	0.484	0.480	0.551	0.491	0.543
Petroleum & Natural Gas Extraction	0.343	0.326	0.454	0.349	0.294
Ferrous Metals Mining & Processing	0.474	0.443	0.578	0.645	0.622
Non-Ferrous Metals Mining & Processing	0.497	0.478	0.577	0.658	0.655
Nonmetal Minerals Mining & Processing	0.397	0.418	0.587	0.655	0.656
Logging & Transport of Timber & Bamboo	0.393	0.356	0.377	0.541	0.492
Food Processing & Production	0.848	0.834	0.821	0.847	0.758
Beverage Production	0.626	0.643	0.669	0.701	0.647
Tobacco Processing	0.332	0.361	0.411	0.404	0.355
Textile	0.705	0.746	0.762	0.811	0.753
Garments & Other Fiber Products	0.751	0.701	0.739	0.771	0.742
Timber Processing, Bamboo, Cane &Palm	0.668	0.685	0.733	0.786	0.760
Furniture Manufacturing	0.634	0.659	0.705	0.768	0.744
Papermaking & Paper Products	0.662	0.678	0.730	0.777	0.741
Stationery, Educational & Sports Goods	0.596	0.697	0.690	0.761	0.749
Petroleum Processing, Coking Products, & Gas	0.576	0.564	0.708	0.725	0.822
Raw Chemical Materials & Chemical Products	0.658	0.667	0.698	0.757	0.754
Medical & Pharmaceutical Products	0.663	0.692	0.715	0.728	0.644
Chemical Fibers	0.590	0.617	0.675	0.751	0.762
Rubber Products	0.618	0.647	0.712	0.779	0.731
Plastic Products	0.532	0.706	0.730	0.806	0.756
Nonmetal Mineral Products	0.558	0.572	0.645	0.716	0.695
Smelting & Pressing of Ferrous Metals	0.656	0.650	0.724	0.714	0.725
Smelting & Pressing of Non-Ferrous Metals	0.733	0.737	0.781	0.783	0.765
Metal Products	0.630	0.652	0.704	0.776	0.760
Machinery & Equipment Manufacturing	0.594	0.621	0.675	0.734	0.729
Transportation Equipment Manufacturing	0.652	0.649	0.705	0.763	0.753
Electric Equipment & Machinery	0.640	0.665	0.713	0.770	0.745
Electronic & Telecommunications	0.619	0.663	0.725	0.751	0.758
Instruments, Meters, Cultural & Office Equipment	0.523	0.542	0.596	0.716	0.753
Electric Power, Steam & Hot Water	0.338	0.385	0.539	0.505	0.495

Note: Vertical Specialization is defined in Section 2.1.

Sources: 1980 and 1985 Author's calculation based on Industry Volume, *The Data of Industrial Census of People's Republic of China in 1985*.

1990 Author's calculation based on *China Statistical Yearbook* (1991).

1995 Author's calculation based on Industry Volume, *The Data of Third National Industrial Census of People's Republic of China in 1995*.

2000 Author's calculation based on *China Statistical Yearbook* (2001).

Table 2.3 Evolution of Vertical Specialization by Region (1980-2000)

Rank of 2000	Region	1980	1985	1990	1995	2000
1	Zhejiang	0.663	0.684	0.727	0.773	0.764
2	Tianjin	0.664	0.681	0.723	0.732	0.758
3	Jiangsu	0.701	0.711	0.751	0.764	0.751
4	Shanghai	0.617	0.648	0.714	0.726	0.728
5	Guangdong	0.660	0.679	0.701	0.756	0.726
6	Liaoning	0.634	0.639	0.686	0.723	0.719
7	Beijing	0.615	0.636	0.683	0.683	0.718
8	Jiangxi	0.676	0.683	0.709	0.746	0.711
9	Gansu	0.618	0.634	0.644	0.659	0.709
10	Jilin	0.676	0.667	0.674	0.696	0.705
11	Fujian	0.660	0.690	0.687	0.737	0.695
12	Anhui	0.677	0.690	0.714	0.742	0.695
13	Shandong	0.665	0.647	0.713	0.716	0.693
14	Ningxia	0.629	0.652	0.649	0.696	0.692
15	Sichuan	0.649	0.662	0.673	0.722	0.681
16	Henan	0.661	0.669	0.679	0.692	0.681
17	Guangxi	0.662	0.669	0.667	0.707	0.677
18	Hunan	0.669	0.666	0.679	0.708	0.676
19	Hubei	0.685	0.682	0.703	0.721	0.670
20	Hebei	0.637	0.675	0.705	0.687	0.669
21	Qinghai	0.676	0.647	0.625	0.657	0.667
22	Guizhou	0.621	0.629	0.600	0.630	0.656
23	Shaanxi	0.670	0.676	0.671	0.687	0.653
24	Shanxi	0.621	0.650	0.642	0.647	0.648
25	Inner Mongolia	0.669	0.664	0.641	0.653	0.627
26	Xinjiang	0.623	0.623	0.635	0.629	0.581
27	Heilongjiang	0.559	0.625	0.586	0.590	0.507
28	Yunnan	0.627	0.613	0.549	0.524	0.500
29	Tibet	0.666	0.693	0.468	0.474	0.437
	Coast	0.652	0.669	0.709	0.730	0.722
	Non-coast	0.649	0.658	0.642	0.662	0.641

Notes: Coastal regions include Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong and Guangdong. In this table, Hainan and Chongqing are included in Guangdong and Sichuan, respectively.

Sources: 1980 and 1985 Author's calculation based on Region Volume, *The Data of Industrial Census of People's Republic of China in 1985*.

1990, 1995 and 2000 Author's calculation based on *China Statistical Yearbook* (2001).

Table 2.4 China's Ten Youngest and Oldest Industries in 2002

Industry Code	Industry	Age (unit: year)
	Youngest Industries	
4181	Communication Equipment Repairs	2.99
1443	Citrid Acid	4.48
1441	Amino Acid	5.15
4141	Computers	5.46
1912	Heavy Leather	5.61
2625	Trace Element Fertilizer	5.65
3724	Mini-cars	5.80
3685	Medical Apparatus and Instruments Repairs	5.84
4173	Electronic Calculators	6.25
1353	Preserved Aquatic Products	6.31
	Oldest Industries	
3712	Passenger Rail Carriers	71.28
3711	Locomotives	68.48
3761	Ocean Shipping Vessels	56.47
3716	Special Railway Equipment	55.74
3713	Railway Freight Cars	51.15
4251	Photographic and Film Equipment	50.00
1620	Cigarettes	43.42
3781	Railroad Equipment Repairing	41.70
3512	Internal Combustion Engines	39.50
4092	Industrial Electric Furnaces	37.04

Note: Industry age = weighted average of ages of all firms in that industry. The weights are firms' sales shares.
Source: Author's calculation based on NBS Enterprise Dataset (2002).

Table 2.5 Summary Statistics of the Variables

	Mean	Std. Dev.	Minimum	Maximum
VSI (percent)	69.43	15.88	0.01	99.95
Four-digit Industry Size (100 billion Yuan)	0.53	0.70	0.0005	4.00
Three-digit Industry Size (100 billion Yuan)	1.04	1.06	0.0011	5.66
Two-digit Industry Size (100 billion Yuan)	4.07	2.39	0.25	10.96
Four-digit Industry Exports (100 billion Yuan)	0.14	0.31	0	1.35
Three-digit Industry Exports (100 billion Yuan)	0.29	0.56	0	1.89
Neighboring Output: Four-digit industry-City (billion Yuan)	1.47	3.62	0	55.8
Neighboring Output: Three-digit industry-City (billion Yuan)	2.61	6.53	0	93.8
Neighboring Output: Three-digit industry-County (billion Yuan)	0.72	2.63	0	85.7
Four-digit Industry Age (year)	13.16	5.85	2.99	71.28
(Four-digit Industry Age)^2 (1000 year^2)	0.21	0.24	0.009	5.08
Three-digit Industry Age (year)	12.61	3.43	6.58	34.28
(Three-digit Industry Age)^2 (1000 year^2)	0.17	0.11	0.04	1.18
Four-digit Industry Growth Rate (between 1996 and 2002)	1.45	1.43	-0.85	55.97
(Four-digit Industry Growth Rate)^2	4.14	47.9	0.000045	3130.4
Three-digit Industry Growth Rate (between 1996 and 2002)	1.39	1.24	-0.42	24.53
(Three-digit Industry Growth Rate)^2	3.36	22.3	0.0018	601.7
Provincial Marketization Index	6.52	1.26	1.81	8.56
Value Added (million Yuan)	16.2	130.5	0.001	1664.5
Sales Revenue (million Yuan)	57.9	432.0	0.002	4825.3
Employment (person)	283	997	2	137962
Capital (million Yuan)	67.4	524.4	0.003	6821.5
Intermediate Inputs (million Yuan)	42.4	340.5	0.001	3894.3
Share of FDI in Industrial Output	0.21	0.16	0	0.98

Note: All variables are defined in Section 2.4.

Table 2.6 Determinants of Vertical Specialization

Dependent variable: VSI

Specification	(1) VSI	(2) VSI	(3) VSI	(4) VSI
Four-digit Industry Size	0.50*** (0.11)	0.48*** (0.10)	0.55*** (0.11)	0.44*** (0.08)
Neighboring Output: Four-digit industry-City	0.11*** (0.02)	0.11*** (0.02)	0.12*** (0.03)	0.095*** (0.02)
Four-digit Industry Age	0.19*** (0.03)	0.18*** (0.03)	0.08*** (0.03)	
(Four-digit Industry Age)^2	-2.06*** (0.72)	-2.02*** (0.66)	-0.38 (0.28)	
Four-digit Industry Growth Rate				0.14 (0.09)
(Four-digit Industry Growth Rate)^2				-0.0022 (0.0019)
Provincial Marketization Index	1.97*** (0.06)	1.88*** (0.07)	1.34*** (0.09)	1.36*** (0.10)
Collective Ownership		0.87*** (0.11)	0.62*** (0.10)	0.66*** (0.10)
Private Ownership		2.08*** (0.10)	1.65*** (0.10)	1.73*** (0.10)
Foreign Ownership		0.57*** (0.21)	0.41** (0.19)	0.52*** (0.19)
Two-digit Industry Dummies	No	No	Yes	Yes
Coast Dummy	No	No	2.43*** (0.26)	2.44*** (0.26)
R^2	0.0319	0.0346	0.0553	0.0569
		Quantitative Significance		
Four-digit Industry Size	0.35	0.34	0.39	0.31
Neighboring Output: Four-digit industry-City	0.40	0.40	0.43	0.34
Four-digit Industry Age	1.11	1.05	0.47	
(Four-digit Industry Age)^2	-0.49	-0.48	-0.09	
Four-digit Industry Growth Rate				0.20
(Four-digit Industry Growth Rate)^2				-0.11
Provincial Marketization Index	2.48	2.37	1.69	1.71

Notes: Numbers in parentheses are standard errors corrected for two-digit industry-province clustering. Quantitative significance indicates the response of the dependent variable implied by the point estimate of a one-standard-deviation increase in the corresponding explanatory variable. In regressions with ownership dummies, the dummy for state ownership is omitted. * denotes statistical significance at the 0.10 level. ** denotes statistical significance at the 0.05 level. *** denotes statistical significance at the 0.01 level.

Table 2.7 Determinants of Vertical Specialization: Robustness Checks I

Dependent variable: VSI

Specification	(1) VSI	(2) VSI	(3) VSI	(4) VSI
Three-digit Industry Size	0.21** (0.09)			
Two-digit Industry Size		0.29*** (0.04)		
Four-digit Industry Exports			0.93* (0.55)	
Three-digit Industry Exports				0.59* (0.35)
Neighboring Output: Four-digit industry-City	0.10*** (0.036)	0.10** (0.039)	0.12*** (0.040)	0.11*** (0.039)
Four-digit Industry Age	0.058 (0.046)	0.180*** (0.050)	0.039 (0.047)	0.045 (0.044)
(Four-digit Industry Age)^2	-0.32 (1.03)	-1.62 (1.13)	0.23 (2.30)	0.19 (1.19)
Provincial Marketization Index	1.35*** (0.10)	1.26*** (0.19)	1.34*** (0.10)	1.34*** (0.10)
Ownership Dummies	Yes	Yes	Yes	Yes
Two-digit Industry Dummies	Yes	No	Yes	Yes
Coast Dummy	Yes	Yes	Yes	Yes
R^2	0.0568	0.0389	0.0571	0.0570
Quantitative Significance				
Three-digit Industry Size	0.13			
Two-digit Industry Size		0.69		
Four-digit Industry Exports			0.29	
Three-digit Industry Exports				0.33
Neighboring Output: Four-digit industry-City	0.36	0.36	0.43	0.40
Four-digit Industry Age	0.34	1.05	0.29	0.26
(Four-digit Industry Age)^2	-0.08	-0.39	0.05	0.05
Provincial Marketization Index	1.70	1.59	1.69	1.69

Notes: Numbers in parentheses are standard errors corrected for two-digit industry-province clustering. Quantitative significance indicates the response of the dependent variable implied by the point estimate of a one-standard-deviation increase in the corresponding explanatory variable. * denotes statistical significance at the 0.10 level. ** denotes statistical significance at the 0.05 level. *** denotes statistical significance at the 0.01 level.

Table 2.8 Determinants of Vertical Specialization: Robustness Checks II

Dependent variable: VSI

Specification	(1) VSI	(2) VSI	(3) VSI	(4) VSI
Three-digit Industry Age	0.14 (0.13)			
(Three-digit Industry Age)^2	0.58 (0.35)			
Three-digit Industry Growth Rate		0.12 (0.08)		
(Three-digit Industry Growth Rate)^2		-0.0025 (0.0024)		
Four-digit Industry Age			0.087* (0.048)	0.13 (0.10)
(Four-digit Industry Age)^2			-0.80 (1.05)	-0.86 (0.85)
Neighboring Output: Three-digit industry-City			0.044* (0.023)	
Neighboring Output: Three-digit industry-County				0.065** (0.027)
Neighboring Output: Four-digit industry-City	0.092** (0.038)	0.093*** (0.026)		
Four-digit Industry Size	0.40** (0.20)	0.42*** (0.13)	0.62*** (0.20)	0.53*** (0.17)
Provincial Marketization Index	1.35*** (0.10)	1.37*** (0.10)	1.35*** (0.10)	1.36*** (0.10)
R^2	0.0569	0.0572	0.0543	0.0551
Quantitative Significance				
Three-digit Industry Age	0.48			
(Three-digit Industry Age)^2	0.63			
Three-digit Industry Growth Rate		0.15		
(Three-digit Industry Growth Rate)^2		-0.06		
Four-digit Industry Age			0.51	0.76
(Four-digit Industry Age)^2			-0.19	-0.21
Neighboring Output: Three-digit industry-City			0.29	
Neighboring Output: Three-digit industry-County				0.17
Neighboring Output: Four-digit industry-City	0.33	0.34		
Four-digit Industry Size	0.28	0.29	0.43	0.37
Provincial Marketization Index	1.70	1.73	1.70	1.72

Notes: All regressions include ownership dummies, two-digit industry dummies and coast dummy. Numbers in parentheses are standard errors corrected for two-digit industry-province clustering. Quantitative significance indicates the response of the dependent variable implied by the point estimate of a one-standard-deviation increase in the corresponding explanatory variable. * denotes statistical significance at the 0.10 level. ** denotes statistical significance at the 0.05 level. *** denotes statistical significance at the 0.01 level.

Table 2.9 Determinants of Vertical Specialization: Robustness Checks III

Dependent variable: VSI

	(1) VSI	(2) VSI
Firm Size	-0.0013*** (0.0002)	
Share of FDI in Industry Output		0.26** (0.1226)
Four-digit Industry Size	0.51*** (0.0979)	0.32*** (0.0997)
Neighboring Output: Four-digit industry-City	0.13*** (0.0360)	0.15*** (0.0519)
Four-digit Industry Age	0.074*** (0.0254)	0.082*** (0.0295)
$(\text{Four-digit Industry Age})^2$	-0.42 (0.3684)	-0.44 (0.2667)
Provincial Marketization Index	1.41*** (0.0862)	1.31*** (0.0835)
R^2	0.0778	0.0575
Quantitative Significance		
Firm Size	-0.56	
Share of FDI in Industry Output		0.04
Four-digit Industry Size	0.36	0.22
Neighboring Output: Four-digit industry-City	0.47	0.54
Four-digit Industry Age	0.43	0.48
$(\text{Four-digit Industry Age})^2$	-0.09	-0.11
Provincial Marketization Index	1.78	1.65

Notes: All regressions include ownership dummies, two-digit industry dummies and coast dummy. Numbers in parentheses are standard errors corrected for two-digit industry-province clustering. Quantitative significance indicates the response of the dependent variable implied by the point estimate of a one-standard-deviation increase in the corresponding explanatory variable. In regressions with ownership dummies, the dummy for state ownership is omitted. * denotes statistical significance at the 0.10 level. ** denotes statistical significance at the 0.05 level. *** denotes statistical significance at the 0.01 level.

Table 2.10 Determinants of Vertical Specialization

Dependent variable: LOGITVSI

Specification	(1) LOGITVSI	(2) LOGITVSI	(3) LOGITVSI	(4) LOGITVSI
Four-digit Industry Size	0.024* (0.013)	0.022* (0.012)	0.028** (0.012)	0.022* (0.012)
Neighboring Output: Four-digit industry-City	0.0074*** (0.0024)	0.0073*** (0.0023)	0.0071*** (0.0025)	0.0065*** (0.0022)
Four-digit Industry Age	0.010*** (0.0025)	0.010*** (0.0028)	0.0065** (0.0033)	
(Four-digit Industry Age)^2	-0.13* (0.07)	-0.12 (0.07)	-0.05 (0.05)	
four-digit Industry Growth Rate				0.092* (0.053)
(four-digit Industry Growth Rate)^2				-0.17 (0.10)
Provincial Marketization Index	0.088*** (0.005)	0.084*** (0.005)	0.051*** (0.006)	0.051*** (0.006)
Collective Ownership		0.011 (0.010)	0.0026 (0.0867)	0.0026 (0.0087)
Private Ownership		0.069*** (0.009)	0.049*** (0.008)	0.053*** (0.008)
Foreign Ownership		0.026** (0.011)	0.016* (0.009)	0.024** (0.010)
Two-digit Industry Dummies	No	No	Yes	Yes
Coast Dummy	No	No	0.17*** (0.02)	0.16*** (0.02)
R^2	0.0210	0.0219	0.0436	0.0434
		Quantitative Significance		
four-digit Industry Size	0.0168	0.0154	0.0196	0.0154
Neighboring Output: four-digit industry-City	0.0268	0.0264	0.0279	0.0235
four-digit Industry Age	0.0591	0.0585	0.0380	
(four-digit Industry Age)^2	-0.0320	-0.0296	-0.0100	
four-digit Industry Growth Rate				0.0001
(four-digit Industry Growth Rate)^2				0.0000
Provincial Marketization Index	0.1109	0.1061	0.1121	0.0644

Notes: LOGITVSI is defined as LOGITVSI = ln [VSI/(1-VSI)]. Numbers in parentheses are standard errors corrected for Two-digit industry-province clustering. Quantitative significance indicates the response of the dependent variable implied by the point estimate of a one-standard-deviation increase in the corresponding explanatory variable. In regressions with ownership dummies, the dummy for state ownership is omitted. * denotes statistical significance at the 0.10 level. ** denotes statistical significance at the 0.05 level. *** denotes statistical significance at the 0.01 level.

Table 2.11 Vertical Specialization and Productivity: OLS Estimation

Dependent Variable: lnY

Specification	(1) lnY	(2) lnY	(3) lnY
VSI	0.00023** (0.00012)	0.00019* (0.00011)	0.00016 (0.00011)
lnK	0.074*** (0.002)	0.076*** (0.004)	0.075*** (0.005)
lnL	0.034*** (0.002)	0.038*** (0.003)	0.047*** (0.005)
lnM	0.873*** (0.003)	0.867*** (0.004)	0.859*** (0.005)
Collective Ownership		0.035*** (0.008)	0.043*** (0.012)
Private Ownership		0.044*** (0.011)	0.050*** (0.013)
Foreign Ownership		0.088*** (0.017)	0.075*** (0.019)
Two-digit Industry Dummies	No	No	Yes
Province Dummies	No	No	Yes
R^2	0.9409	0.9413	0.9425

Notes: Numbers in parentheses are standard errors corrected for two-digit industry-province clustering. * denotes statistical significance at the 0.10 level. In regressions with ownership dummies, the dummy for state ownership is omitted. ** denotes statistical significance at the 0.05 level. *** denotes statistical significance at the 0.01 level.

Table 2.12 Vertical Specialization and Productivity: IV Estimation

Specification	(1)	(2)	(3)	(4)	(5)	(6)
	Panel A: Second-Stage Regression			*Dependent Variable: lnY*		
VSI	0.0012*** (0.0004)	0.0010** (0.0005)	0.0012*** (0.0004)	0.0010** (0.0005)	0.0012*** (0.0004)	0.0010** (0.0005)
lnK	0.101*** (0.013)	0.050*** (0.013)	0.097*** (0.012)	0.048*** (0.013)	0.100*** (0.012)	0.049*** (0.013)
lnL	0.078*** (0.013)	0.034*** (0.013)	0.073*** (0.019)	0.032*** (0.011)	0.077*** (0.019)	0.032** (0.013)
lnM	0.801*** (0.033)	0.928*** (0.048)	0.810*** (0.030)	0.933*** (0.046)	0.805*** (0.030)	0.930*** (0.048)
Ownership Dummies	No	Yes	No	Yes	No	Yes
Two-digit Industry Dummies	No	Yes	No	Yes	No	Yes
Province Dummies	No	Yes	No	Yes	No	Yes
P-Value of Sargan test					0.4583	0.3985
	Panel B: First-Stage Regression			*Dependent Variable: VSI*		
lnK	-1.61*** (0.04)	-1.22*** (0.05)	-1.63*** (0.04)	-1.21*** (0.05)	-1.63*** (0.05)	-1.22*** (0.05)
lnL	-2.74*** (0.05)	-2.21*** (0.05)	-2.64*** (0.05)	-2.24*** (0.06)	2.71*** (0.05)	-2.25*** (0.06)
lnM	4.22*** (0.04)	3.46*** (0.04)	4.21*** (0.04)	3.53*** (0.05)	4.19*** (0.04)	3.56*** (0.05)
four-digit Industry Size	0.55*** (0.06)	0.27*** (0.05)			0.39*** (0.08)	0.19*** (0.06)
Three-digit Industry Size			0.34*** (0.04)	0.22*** (0.05)	0.17*** (0.04)	0.13*** (0.04)
Ownership Dummies	No	Yes	No	Yes	No	Yes
Two-digit Industry Dummies	No	Yes	No	Yes	No	Yes
Province Dummies	No	Yes	No	Yes	No	Yes
R^2	0.0697	0.1184	0.0696	0.1184	0.0697	0.1185

Notes: Numbers in parentheses are standard errors corrected for two-digit industry-province clustering. * denotes statistical significance at the 0.10 level. ** denotes statistical significance at the 0.05 level. *** denotes statistical significance at the 0.01 level.

3. DO DOMESTIC FIRMS BENEFIT FROM FOREIGN DIRECT INVESTMENT? THE CASE OF CHINA

3.1. Overview of FDI Spillover Channels

3.1.1. Horizontal Spillovers

Horizontal spillovers of FDI take place when the presence of FDI increases the productivity of the domestic firms in the same industry. Teece (1977) argues that such spillovers can occur through various channels. The first channel is the demonstration effect. Domestic firms may be able to reduce the innovation costs simply by observing and imitating the foreign firms. The second channel is labor turnover. Workers employed and trained by foreign firms may join domestic firms or create their own firms. The third channel is the competition effect. The entry of foreign firms can force domestic firms to restructure and improve their production techniques and management.

However, the increased intensity of competition may hurt domestic firms at least in the short run by reducing their market share and output. As shown by Aitken and Harrison (1999), the productivity of domestic firms would fall if they have to spread their fixed costs over smaller sales volume. This is usually interpreted as a crowding-out effect. The entry of foreign firms may also raise labor costs of domestic firms. Since foreign firms often pay higher wages, they may raise wages for all firms in competitive labor markets (Aitken, Harrison, and Lipsey, 1996). Theoretically, the net horizontal effect of FDI on domestic firms is inconclusive.

There are two generations of empirical studies on horizontal effects. The first generation is characterized by industry-level studies. A partial list includes Caves (1974) for Australia, Globerman (1979) for Canada, and Blomstrom and Persson (1983) for Mexico. Most of the first generation studies find a positive correlation between FDI and industry productivity. Since they rely on cross-sectional data, it is difficult to distinguish whether FDI actually increases domestic firms' productivity, or whether foreign investors are simply attracted to high-productivity industries.

The second generation of empirical studies is based on firm-level panel data. The advantage of the panel data approach is that it can control for foreign investor selection bias. These studies examine whether foreign presence increases the productivity of the firms in the same industry. The results, however, have been mixed. In a study of Venezuelan factories, Aitken and Harrison (1999) find net negative benefits to domestic firms, a result that they attribute to the crowding-out effect. Other studies that find negative spillovers include Haddad and Harrison (1993) for Morocco, Djankov and Hoekman (2000) for the Czech Republic, Konings (2001) for Bulgaria, Romania, and Poland, and Javorcik (2004) for Lithuania. In contrast, studies on developed countries often find evidence of positive spillovers. They include Haskel, Pereira, and Slaughter (2002) for the United Kingdom, Keller and Yeaple (2003) for the United States, Castellani and Zanfei (2002) for Italy, and Gorg and Strobl (2003) for Ireland.

In the case of China, Cheung and Lin (2003) find positive effects of FDI in China on the number of patents by using a provincial panel dataset. Based on 1995 industrial census data in China, Tong and Hu (2003) find significant horizontal spillovers from FDI.

3.1.2. Vertical Spillovers

Backward spillovers of FDI refer to the technology transfer through supply chains from foreign firms to domestic suppliers. If foreign firms are successful at preventing the leakage of their firm-specific knowledge to domestic competitors in the same industry, there is no scope for intra-industry technology spillovers. It is possible, however, that foreign firms voluntarily or involuntarily help increase efficiency of domestic suppliers through backward linkages. Foreign firms can provide technical assistance, training and other help to their domestic suppliers in order to improve the quality of intermediate purchases.

Similarly, forward spillovers occur when domestic firms gain access to new or less costly intermediate inputs as a result of the foreign investment in upstream industries.

Evidence of technology transfer through vertical supply chains is well documented in case studies. For example, Kenney and Florida (1993) and Macduffie and Helper (1997) provide a rich description of technology transfer to U.S. parts suppliers following the entry of Japanese car makers. Blalock (2002) analyzes Indonesian firms and Javorcik (2004) studies a panel dataset from Lithuanian industries, both of which find positive FDI spillovers through backward linkages. Using both industry level and firm level data, Liu and Lin (2004) find evidence of backward spillovers in China.

3.1.3. Local Spillovers

Given that labor turnover and demonstration effect are among the most important channels for technology spillovers, there are good reasons to expect that any benefits to the domestic firms from foreign investment would be received primarily by the firms located nearby: (1) if a skilled worker leaves a foreign firm to work for a domestic firm, he or she is likely to choose a firm in the same region; (2) if a new technology or a new management technique is introduced by a foreign firm, the domestic firms located close to it have an advantage over more distant firms in observing and imitating the foreign firm. Of course, domestic firms that are closer to foreign firms may also suffer more from the competition.

Note that if the workers' skills, new technologies and management techniques are transferable across industries, local spillovers may still occur even without direct horizontal or vertical linkages between domestic and foreign firms.

In the case of China, the entry of FDI can facilitate the institutional changes and the improvements in the legal system. Thus, a region with a longer history of FDI tends to have better business environment. All these factors may contribute to improving the productivity of local firms.

The geographic dimension of FDI spillovers has been investigated in a number of empirical studies. Using cross-sectional data for Indonesia, Sjoholm (1999) finds no evidence for local spillovers. Aitken and Harrison (1999) also fail to find positive spillovers from the foreign firms to nearby domestic firms in Venezuela. From firm-level panel data, Girma and Wakelin (2002) find evidence for positive spillovers from FDI in the same region and same industry in United Kingdom.

3.2. Foreign Direct Investment in China

For the past 25 years, China has aggressively pursued policies that encourage FDI inflow. For example, China developed the first law governing foreign investment in 1979, while the first laws relevant to domestic firms were not enacted until 1988.

According to Chinese laws, foreign firms can invest in China through joint ventures, cooperative enterprises, and solely owned enterprises. The establishment of solely foreign-owned enterprises was subject to strict restrictions from Chinese government, such as export volume and local procurement. These restrictions were removed in 2001 in accordance with WTO framework. Consequently, solely foreign-owned enterprises became the most popular form of FDI in post-WTO China.

Hong Kong is the most important source of FDI in China. In 2003, Hong Kong invested 17.7 billion dollars in China, accounting for 33 percent of the total.[12] Other sources of FDI include Japan, United States, South Korea, Taiwan and Virgin Islands.[13] In recent years, an increasing share of FDI came from global giants in industrialized countries such as Motorola, SONY and Siemens.

Nearly 70 percent of FDI in China was poured into the manufacturing sector. This is mainly due to the competitive edge of relatively low production cost in China for manufacturing. The other reason is that FDI in service sector has not been fully liberalized.

The geographic distribution of FDI has been quite uneven. China initiated its "open door" policy by establishing four special economic zones in 1980. In 1984, it further opened 14 coastal cities. Then in the early 1990s, China expanded its open regions from the coastal cities to the inland regions and from the east to the west. Due to their convenient location, better infrastructure and legal environment, the coastal regions have been the main recipients of FDI in China. For example, in 2003, the coastal provinces received 88 percent of the total FDI in China.

[12] Part of the investment from Hong Kong is originated from Chinese firms who register in Hong Kong and re-enter China as "foreign investment." This is often called "round-tripping."
[13] Many foreign firms, especially those from Taiwan and Hong Kong, invest in China via such international tax havens as Virgin Islands.

The contribution of foreign invested firms to China's economy has been remarkable. FDI accounted for about 9 percent of total investment in fixed assets, 31 percent of industrial output, and 55 percent of foreign trade in 2003.[14]

When a foreign firm acquires a domestic firm or sets up a joint venture with a domestic firm, it usually brings more advanced technology and managerial techniques to the new firm. In a survey of 127 foreign invested firms by Jiang (2002), 65 percent of the firms adopted some technology that filled in the technological gaps in China. In addition, in a transition economy like China, foreign investment can facilitate the restructuring of state-owned enterprises by cutting government-enterprise relation and hardening the budget constraint. For example, when foreign investors join an existing firm, they usually demand that professional managers take over the decision rights from government-appointed officials.

The technology spillovers from FDI to domestic firms can be found in mobile phone industry. China's domestic firms began to produce mobile phones in 1999. Driven by the rapid growth of the market, domestic firms quickly improve their products by borrowing new technology from foreign invested firms in China. In only a few years, their market share jumped from 2 percent in 1999 to over 60 percent in 2003 (Long, 2005).

The foreign firms often develop close vertical relationships with Chinese firms. For example, Motorola plant in Tianjin is supplied by about 80 supporting firms in Tianjin and 170 firms outside Tianjin. Most of them are domestic firms. Motorola often sends personnel to offer technical guidance to these local suppliers.

[14] Source: Author's Calculation based on *China Statistical Yearbook* (2004).

3.3. Measurement and Data

3.3.1. Measuring Horizontal Spillovers

The variable, $Horizontal_{jt}$, measures the foreign presence in the firm's own industry *j* at time *t*. It is calculated as follows:

$$Horizontal_{jt} = \frac{\sum_{i \in j} ForeignShare_{it} \times Sales_{it}}{\sum_{i \in j} Sales_{it}}, \tag{3.1}$$

where $ForeignShare_{it}$ is define as the share of firm *i*'s total equity owned by foreigners. We define the industry at the four-digit level.

3.3.2. Measuring Backward Spillovers

$Backward_{jt}$ captures the foreign presence in the downstream industries that are supplied by industry *j*. Since the firm-level dataset does not provide information about backward linkage, we use backward linkage values of the firm's industry. In particular, we have

$$Backward_{jt} = \sum_{k \neq j} \alpha_{jk} Horizontal_{kt}. \tag{3.2}$$

α_{jk} is the proportion of industry *j*'s total output that is purchased by industry *k*.[15] We exclude the purchase by its own industry because we have already included $Horizontal_{jt}$ in the regression. The coefficient α_{jk} is calculated using the input-output table of 1997.

[15] For example, suppose industry A sells 10% of its output to industry B, 30% to industry C and 60% to industry D, where *Foreign Share* is 30%, 20% and 25%, respectively. In this example, *Backward* of industry A = 0.1×0.3 + 0.3×0.2 + 0.6×0.25 = 0.24.

3.3.3. Measuring Forward Spillovers

Similarly, $Forward_{jt}$ shows the foreign presence in the upstream industries from which industry *j* purchases its intermediate inputs. We calculate $Forward_{jt}$ in the following way:

$$Forward_{jt} = \sum_{k \neq j} \beta_{jk} Horizontal_{kt}. \tag{3.3}$$

β_{jk} is the proportion of industry *j*'s intermediate inputs that is supplied by industry *k*. The coefficient β_{jk} is calculated based on the input-output table of 1997.

3.3.4. Measuring Local Spillovers

$Local_{rt}$ is a proxy for foreign presence in region *r*. We define the region at city level (four-digit geographic level). The computation of $Local_{rt}$ is similar to $Horizontal_{jt}$:

$$Local_{rt} = \frac{\sum_{i \in r} ForeignShare_{it} \times Sales_{it}}{\sum_{i \in r} Sales_{it}}, \tag{3.4}$$

Tables 3.1-3.4 present basic information about these four spillover variables at the two-digit industry level or at the provincial level. In all these variables, there is large variation across industries or regions. For example, as can be seen from Table 3.1, in 2003 *Horizontal* ranges from 0.2 percent in tobacco processing to 69.1 percent in electronics and telecommunications.

3.3.5. The Data and Basic Patterns

This empirical study is based on a large dataset of Chinese industrial firms built from cross-sectional data collected in regular surveys by China National Bureau of Statistics between 2000 and 2003. The surveys cover all state-owned firms and all non-state firms above designated scale. Only non-state firms with sales under 5 million Yuan are excluded. The firms in our sample accounted for about 65 percent of total industrial value added in 2000 (Table 3.5). This share dropped to 53 percent in 2001 and rose to 72 percent and 79 percent in 2002 and 2003.

Since we only focus on manufacturing sector, the sample size decreases to 140,000 to 180,000 firms per year. The number of observations is further reduced by deleting those with missing values and those that fail to satisfy some basic error checks. The industry section of *China Statistical Yearbook* is complied based on this dataset. *China Markets Yearbook* reports the basic information of each four-digit industry. The dataset contains detailed information of about 100 variables, including ID number, ownership, sales revenue, value added, four-digit industry code, six-digit geographic code, exports, employment, capital stock, and intermediate inputs.

We construct a panel dataset by matching the firms by their ID numbers. Only about 60 percent of the firms in the dataset can be matched throughout the entire period (four years). This is because in addition to normal exit and entry, existing firms often change their ID numbers after restructuring, which significantly reduces the percentage of firms that we can match.

Table 3.6 shows that in our dataset, foreign firms account for about 20 percent of total number of firms in each year. Summary statistics are reported in Tables 3.7 and 3.8.

To compare foreign firms with domestic firms, we estimate the following equation:

$$\ln S_i = \alpha_0 + \beta * ForeignShare_i + \alpha_r + \alpha_j + \varepsilon_i, \tag{3.5}$$

where S_i refers to firm *i*'s characteristics, including TFP, labor productivity defined as value-added per worker, sales, employment, capital intensity, and wage. We estimate (3.5) separately for each year in our sample. In the regression, we also control for two-digit industry and provincial fixed effects.

The estimation results reported in Table 3.9 suggest that foreign firms differ significantly from domestic firms. The estimated coefficient, β, has a clear economic interpretation, i.e., it shows the percentage differential between a wholly foreign-owned firm and a domestic firm. For example, in 2003, the TFP of a wholly foreign-owned firm was on average 40 percent higher than that of a domestic firm. In general, foreign firms are larger, more productive, more capital intensive, and pay higher wages. Our findings are consistent with previous studies on other countries (e.g., Bellak, 2004)

3.4. Empirical Strategy

To investigate the relationship between FDI and the productivity of domestic firms, we follow an approach that is commonly used in the literature (e.g., Aitken and Harrison, 1999). We estimate a production function that includes spillovers measures as explanatory variables. Our starting point is the following equation:

$$\begin{aligned}\ln Y_{ijrt} &= \alpha_0 + \beta_1 \ln L_{ijrt} + \beta_2 \ln K_{ijrt} + \gamma_1 ForeignShare_{ijrt} + \gamma_2 Horizontal_{jt} \\ &\quad + \gamma_3 Backward_{jt} + \gamma_4 Forward_{jt} + \gamma_5 Local_{rt} + \alpha_t + \alpha_r + \alpha_j + \varepsilon_{ijrt}, \qquad (3.6)\end{aligned}$$

where Y_{ijrt} is the real value-added of firm *i* in industry *j* and region *r* at time *t*, which is deflated by industry-specific ex-factory price index. L_{ijrt} is the number of employees. K_{ijrt} stands for the net value of fixed assets deflated by investment price index.[16]

As an exploratory regression, (3.6) is estimated with OLS on the full sample and the subsample of domestic firms only. Since the spillovers may take time to materialize, we also

[16] According to China's accounting practice, net value of fixed assets of year *t* = net value of fixed assets of year *t*-1 + investment of year *t* – depreciation of year *t*. To get net value of fixed assets of year *t* in constant price, ideally we should only deflate investment of year *t*. Since the price level was almost constant during 2000-2003, deflating net value of fixed assets by investment price index makes little difference.

estimate (3.6) with one-year lagged spillover variables. The model includes a full set of year, two-digit industry, and provincial dummies. The results are reported in Table 3.10. The standard errors reported throughout the chapter are corrected for two-digit industry-province clustering (Moulton, 1990). In all cases, we find positive and statistically significant coefficients on *Backward* and *Local* variables. The variable of *Horizontal* does not appear to be significant. The coefficient on *Forward* is significant only when lagged values are used.

3.4.1. First Differences Estimation

There are two econometric concerns with the estimation of (3.6). The first is the omission of firm-specific unobservable variables. These variables may affect the correlation between firm productivity and FDI presence. Examples include government subsides or strong senior management team.

One solution to this problem is time differencing model. Following Haskel, Pereira, and Slaughter (2002) and Javorcik (2004), instead of (3.6), we estimate the following first differences model:

$$\begin{aligned}\Delta \ln Y_{ijrt} &= \beta_1 \Delta \ln L_{ijrt} + \beta_2 \Delta \ln K_{ijrt} + \gamma_1 \Delta ForeignShare_{ijrt} + \gamma_2 \Delta Horizontal_{jt} \\ &\quad + \gamma_3 \Delta Backward_{jt} + \gamma_4 \Delta Forward_{jt} + \gamma_5 \Delta Local_{rt} + \alpha_t + \alpha_r + \alpha_j + \varepsilon_{ijrt}, \qquad (3.7)\end{aligned}$$

Since differencing also removes time, region and industry effects, unlike (3.6), year, region and industry dummies in (3.7) will control for unobservables that are related to the change in time, region and industry effects.[17]

[17] For example, we control not just for "Shanghai is an attractive city for foreign investment" but also for "the attraction of Shanghai for foreign investment changes over time."

3.4.2. Semi-Parametric Estimation

The second econometric problem is that OLS is biased when estimating the production function in (3.6) because labor and intermediate inputs are not exogenous. Griliches and Mairesse (1998) argue that inputs should be endogenous since they are chosen by firms after productivity is observed. To correct the endogeneity bias, Olley and Pakes (1996) propose a semi-parametric estimation procedure that uses investment as a proxy for the unobservable productivity shock. Since the Olley-Pakes procedure requires the information of investment which is not available in our dataset,[18] we opt for the Levinsohn and Petrin (2003) procedure, which uses intermediate inputs rather than investment to address the underlying endogeneity issues.

There are two advantages for the Levinsohn-Petrin procedure. First, because there is substantial adjustment cost with capital stock, in many firm-level datasets, a large number of observations have zero investment. These observations must be deleted to satisfy the strict monotonicity condition. The Levinsohn-Petrin procedure can avoid this problem because usually the intermediate inputs must be positive. Second, intermediate inputs provide a better proxy for productivity shock than investment because investment does not respond to the productivity shock quickly enough due to the adjustment cost.

The advantage of the Olley-Pakes method is that the original three-stage procedure explicitly controls for selection bias. Although the Levinsohn-Petrin procedure does not account for selection bias, the authors argue that the use of unbalanced panel minimizes such bias. Both Olley and Pakes (1996) and Levinsohn and Petrin (2003) find that controlling for selection has little effect on the final parameter estimates.

[18] In our dataset, the investment in year t can be calculated as the difference in the original value of fixed assets between year t and year t - 1, but we will lose one year data, leaving only three years in our panel.

To briefly discuss the Levinsohn-Petrin procedure,[19] let us consider the following production function:[20]

$$y_{it} = \beta_0 + \beta_l l_{it} + \beta_k \beta_{it} + \omega_{it} + \eta_{it}, \tag{3.8}$$

where y_{it}, l_{it}, and k_{it} denote logarithms of value-added, labor and capital. Note that the error term has two components: (1) productivity shock, ω_{it}; (2) the error term that is uncorrelated with input choices, η_{it}. In the equation, ω_{it} is a state variable and affects the input decision.

Levinsohn and Petrin assume that demand for the intermediate inputs depends on the firm's state variables k_{it} and ω_{it}:

$$m_{it} = m_{it}(k_{it}, \omega_{it}). \tag{3.9}$$

Levinsohn and Petrin show that the demand function is monotonically increasing in ω_{it}. It is possible to invert the intermediate input demand function and express the unobserved productivity shock ω_{it} as a function of k_{it} and m_{it}:

$$\omega_{it} = \omega(k_{it}, m_{it}). \tag{3.10}$$

A further assumption follows Olley and Pakes (1996). Levinsohn and Petrin assume that the productivity shock follows a first-order Markov process:

$$\omega_{it} = E[\omega_{it} \mid \omega_{it-1}] + \xi_{it}, \tag{3.11}$$

where ξ_{it} is a change in productivity uncorrelated with k_{it}.

Equation (3.8) can now be rewritten as

$$y_{it} = \beta_l l_{it} + \phi(k_{it}, m_{it}) + \eta_{it}. \tag{3.12}$$

[19] For complete exposition of the procedure, please refer to Levinsohn and Petrin (2003).

[20] There are two versions of Levinsohn-Petrin procedure: one based on revenue and one based on value-added. In the former case, revenue is a function of labor, capital and intermediate inputs. When revenue is used, Levinsohn-Petrin procedure requires GMM estimation in the second stage. The coefficients will only be weakly identified in GMM estimation with our data because we have a relatively short panel (only four years). Thus the version of value-added is chosen in this study.

where $\phi(k_{it}, m_{it}) = \beta_0 + \beta_k k_{it} + \omega(k_{it}, m_{it})$.

By substituting a third-order polynomial approximation in k_{it} and m_{it} for $\phi(k_{it}, m_{it})$, it is possible to consistently estimate (3.12) using OLS as

$$y_{it} = \delta_0 + \beta_l l_{it} + \sum_{p=0}^{3}\sum_{q=0}^{3-p} \delta_{pq} k_{it}^p m_{it}^q + \eta_{it}. \tag{3.13}$$

Therefore, we can obtain consistent estimates of β_l and ϕ_{it}, which completes the first stage of the procedure.

In the second stage, we first compute the estimated value for ϕ_{it} using

$$\begin{aligned}\hat{\phi}_{it} &= \hat{y}_{it} - \hat{\beta}_l l_{it} \\ &= \hat{\delta}_0 + \sum_{p=0}^{3}\sum_{q=0}^{3-p} \hat{\delta}_{pq} k_{it}^p m_{it}^q - \hat{\beta}_l l_{it}.\end{aligned} \tag{3.14}$$

For any candidate values β_k^*, we can compute a prediction for ω_{it} for all periods *t*, since $\hat{\omega}_{it} = \hat{\phi}_{it} - \beta_k^* k_{it}$. Using these predicted values, a consistent approximation to $E[\omega_{it} \mid \omega_{it-1}]$, $\hat{E}[\omega_{it} \mid \omega_{it-1}]$, is given by the predicted values from the regression

$$\hat{\omega}_{it} = \gamma_0 + \gamma_1 \omega_{it-1} + \gamma_2 \omega_{it-1}^2 + \gamma_3 \omega_{it-1}^3 + \varepsilon_{it}. \tag{3.15}$$

It then follows that the sample residual of the production function can be computed as

$$\eta_{it} + \xi_{it} = y_{it} - \hat{\beta}_l l_{it} - \beta_k^* k_{it} - \hat{E}[\omega_{it} \mid \omega_{it-1}]. \tag{3.16}$$

The estimate $\hat{\beta}_k$ is defined as the solution to

$$\min_{\beta_k} \sum_t \left(y_{it} - \hat{\beta}_l l_{it} - \beta_k^* k_{it} - \hat{E}[\omega_{it} \mid \omega_{it-1}]\right) \tag{3.17}$$

A bootstrap approach is used to calculate the standard errors for $\hat{\beta}_l$ and $\hat{\beta}_k$.

The Levinsohn-Petrin procedure is implemented in this dissertation using the Stata module "levpet" developed by Petrin, Levinsohn and Poi (2004).

We perform the Levinsohn-Petrin procedure for each two-digit industry separately. The measure of ln*TFP* is calculated as follows:

$$\ln TFP_{it} = y_{it} - \hat{\beta}_l l_{it} + \hat{\beta}_k k_{it}. \tag{3.18}$$

3.5. Estimation Results

3.5.1. Baseline Specifications

The estimation of the first differences model, Equation (3.7), produces findings of backward spillovers and local spillovers. The first two columns of Table 3.11 present the estimation results for all firms (full sample) and the subsample of domestic firms, respectively. In both cases, the coefficients on backward spillovers and local spillovers appear to be positive and statistically significant. The third and fourth columns report the results from the regressions with Δln*TFP*, which is calculated through the Levinsohn-Petrin procedure. Again positive and significant coefficients on backward spillovers and local spillovers can be found for both the full sample and the subsample of domestic firms. As shown by the last two columns of Table 3.11, the regressions with labor productivity produce qualitatively similar results. The size of the coefficients does not change very much across specifications. In the case of domestic firms, the coefficient on backward spillovers is larger while the coefficient on local spillovers is smaller. The backward and local spillover effects are also quantitatively significant. A one-standard-deviation (5 percentage points) increase in the foreign presence in the downstream industries is associated with 3.2 percent increase in TFP of the domestic firms in the supplying industry. A one-standard-deviation (13 percentage points) increase in the foreign presence in a city raises the TFP of the domestic firms in the same city by 4 percent.[21]

Little evidence can be found for other channels of spillovers. In most cases, the coefficient on the horizontal spillovers bears a negative sign but appears statistically insignificant. This finding is consistent with previous research that generally fails to find positive horizontal spillovers in developing countries. The variable of forward spillovers has a positive sign but it is not statistically significant.

In order to check the robustness of the results, we estimate a model in second differences. The main cost of differencing is that it can aggravate measurement error in the independent variables. Longer time differences tend to attenuate this problem (Griliches and Hausman, 1986) but they also reduce the sample size. The estimation results of the regressions with second differences are reported in Table 3.12. A positive and significant coefficient on backward spillovers can be found in all regressions except in the case of labor productivity for the subsample of domestic firms. The variable of local spillovers has a significantly positive coefficient in all cases, although the size of the coefficient is smaller compared to first differences. There is no robust evidence of horizontal and forward spillovers in the model of second differences.

3.5.2. HMT firms versus OECD firms

Chinese statistics identify two types of foreign invested firms in China: those invested by overseas Chinese from Hong Kong, Macao and Taiwan (HMT), and those invested by foreign investors mainly from OECD countries. It is not clear which types of foreign firms are more likely to generate spillovers to domestic firms. Hong Kong, Macao and Taiwan are among newly

[21] The calculation is based on the fourth column of Table 3.10.

industrialized economies. The investors from these regions have additional advantages of same culture, same language, geographical proximity, or even family ties. Compared with HMT firms, the advantages of OECD firms lie in their more advanced technology, global production chain and internationally recognized brand names.

To investigate whether there exist different impacts of HMT and OECD firms, we estimate (3.7) separately for these two types of firms. Spillover variables are constructed using a new modified *Foreign Share* variable, which is now defined as the share of firm's equity owned by HMT (OECD) firms.

The results from the regressions with the subsample of domestic firms are reported in Table 3.13.[22] We find robust evidence of backward spillovers and local spillovers from both HMT and OECD firms, which is consistent with our previous findings. The size of the coefficient on *Backward* is smaller in the case of OECD firms, indicating that these firms rely more on their own global supply chain. There is little evidence of spillovers through other channels.

3.5.3. Technological Gap

Recent studies on FDI find that horizontal spillovers depend on the absorptive capacity of the domestic firms. If the technological gap between foreign and domestic firms is large, domestic firms may lack the ability needed to adopt the new technology. Borensztein, Gregorio and Lee (1998) argue that positive FDI spillovers to domestic firms are only generated if the technology gap between the foreign firms and the domestic firm is not too wide. Using a cross-section of firm-level data for Uruguay, Kokko, Tansini, and Zejan (1996) find evidence for productivity

[22] There is no big difference between the results from the full sample and the subsample. Since we are more interested in the spillover effects on domestic firms, we only report the results using the subsample of domestic firms.

spillovers to domestic firms with moderate technological gaps, but not for firms that use considerably lower levels of technology.

Technological gap can also be important for vertical spillovers. Even if the foreign firms outsource locally, their local suppliers may fail to learn and absorb the technology transferred if they are far behind their foreign partners in productivity (Smarzynska, 2002). Thus absorptive capacity of local supplier is an important factors driving technology transfer from FDI to local suppliers.

We reestimate the first differences model with the subsample of the most productive domestic firms. For each two-digit industry, we select those domestic firms whose average TFP over the period 2000-2003 falls into top 25 percent of all domestic firms in that industry.

The results shown in Table 3.14 exhibit patterns that are similar to the baseline specification. In most cases, the coefficients on *Backward* and *Local* have positive signs and are statistically significant. A notable difference is that the coefficient on *Horizontal* is negative and statistically significant in the cases of TFP and labor productivity. This finding is consistent with the observation that foreign firms are often competing head-to-head with elite domestic firms.

3.5.4. Export-Oriented versus Domestic-Market-Oriented FDI

It has been suggested that the market orientation of the foreign firms is likely to affect both horizontal and vertical spillovers (Sgard, 2001; Javorcik, 2004). First, domestic-market-oriented foreign firms take market share directly from domestic firms, while export-oriented foreign firms that target international markets tend to put less pressure on domestic competitors. Second, export-oriented foreign firms are often part of global production network. They usually depend on the suppliers from their parent company or their affiliates in other countries. Therefore, export-oriented foreign firms are more likely to generate horizontal spillovers but not backward spillovers.

To test this hypothesis, we estimate (3.7) using only export-oriented foreign firms as our measure of foreign presence. In our dataset, about 70 percent of foreign firms were engaged in exports between 2000 and 2003. Export-oriented firms are defined as those firms that exported 90 percent of their production.

The estimation results in the last three columns of Table 3.14 indicate that in terms of productivity spillovers, export-oriented foreign firms are not very different from domestic-market-oriented foreign firms. Again we find the same positive backward and local spillovers. The coefficient on *Horizontal* turns positive but remains statistically insignificant.

Table 3.1 Horizontal Spillover Variable by Two-Digit Industry

Unit: %

Code	Industry	2000	2001	2002	2003
6	Coal Mining & Processing	1.0	0.7	0.6	0.6
7	Petroleum & Natural Gas Extraction	2.3	7.2	6.8	5.7
8	Ferrous Metals Mining & Processing	1.2	0.8	0.9	0.7
9	Non-Ferrous Metals Mining & Processing	1.2	1.1	1.4	1.3
10	Nonmetal Minerals Mining & Processing	4.6	4.3	4.1	4.6
13	Food Processing	0.0	0.0	0.0	0.8
14	Food Production	17.8	17.3	18.7	19.1
15	Beverage Production	31.4	34.3	30.2	31.9
16	Tobacco Processing	23.6	24.4	26.1	27.3
17	Textile	0.2	0.2	0.2	0.2
18	Garments & Other Fiber Products	15.3	16.4	16.7	17.9
19	Leather, Fur, Feather and Related Products	36.0	36.0	35.1	36.5
20	Timber Processing, Bamboo, Cane &Palm	44.9	42.6	41.5	40.6
21	Furniture Manufacturing	21.3	22.1	21.0	20.9
22	Papermaking & Paper Products	36.3	37.0	37.1	42.8
23	Printing, Reproduction of Recording Media	24.0	25.5	25.5	25.3
24	Stationery, Educational & Sports Goods	20.8	23.9	23.2	24.6
25	Petroleum Processing, Coking Products, & Gas	51.2	50.9	51.6	52.0
26	Raw Chemical Materials & Chemical Products	4.7	6.6	7.6	6.9
27	Medical & Pharmaceutical Products	15.3	16.6	17.3	19.1
28	Chemical Fibers	16.5	15.4	15.1	15.4
29	Rubber Products	23.2	18.7	18.5	15.3
30	Plastic Products	26.7	27.4	29.3	29.6
31	Nonmetal Mineral Products	35.3	34.5	33.1	35.0
32	Smelting & Pressing of Ferrous Metals	12.9	13.7	13.5	12.1
33	Smelting & Pressing of Non-Ferrous Metals	4.9	6.0	6.4	7.4
34	Metal Products	8.3	8.2	8.2	8.8
35	General Machinery & Equipment Manufacturing	28.8	27.4	27.6	26.8
36	Special Machinery & Equipment Manufacturing	17.3	17.1	17.7	19.5
37	Transportation Equipment Manufacturing	11.8	14.6	15.1	15.9
40	Electric Equipment & Machinery	19.1	20.3	19.0	21.9
41	Electronic & Telecommunications	27.7	28.1	28.1	29.0
42	Instruments, Meters, Cultural & Office Equipment	56.2	59.7	63.1	69.1
43	Manufacture of Artwork and Other Manufacturing	51.4	53.4	55.5	61.5
44	Production and Distribution of Electric Power and Heat	35.0	35.1	35.3	32.8
45	Production and Distribution of Gas	4.5	4.6	4.5	4.4
46	Production and Distribution of Water	11.3	11.1	15.9	20.9

Note: See Section 3.3 for the definition of the horizontal spillover variable.
Source: Author's calculation based on the database.

Table 3.2 Backward Spillover Variable by Two-Digit Industry

Unit: %

Code	Industry	2000	2001	2002	2003
6	Coal Mining & Processing	10.3	10.7	10.1	10.4
7	Petroleum & Natural Gas Extraction	4.7	5.4	6.6	6.1
8	Ferrous Metals Mining & Processing	9.7	9.7	10.0	10.6
9	Non-Ferrous Metals Mining & Processing	9.7	9.7	10.0	10.6
10	Nonmetal Minerals Mining & Processing	14.7	15.3	14.6	15.2
13	Food Processing	31.2	30.3	28.6	29.5
14	Food Production	31.2	30.3	28.6	29.5
15	Beverage Production	31.2	30.3	28.6	29.5
16	Tobacco Processing	31.2	30.3	28.6	29.5
17	Textile	33.4	32.9	31.2	32.1
18	Garments & Other Fiber Products	19.2	20.2	19.4	20.3
19	Leather, Fur, Feather and Related Products	19.2	20.2	19.4	20.3
20	Timber Processing, Bamboo, Cane &Palm	23.3	23.9	23.0	23.8
21	Furniture Manufacturing	23.3	23.9	23.0	23.8
22	Papermaking & Paper Products	21.7	22.4	21.5	22.7
23	Printing, Reproduction of Recording Media	21.7	22.4	21.5	22.7
24	Stationery, Educational & Sports Goods	21.7	22.4	21.5	22.7
25	Petroleum Processing, Coking Products, & Gas	13.1	13.4	12.8	13.3
26	Raw Chemical Materials & Chemical Products	23.9	25.0	24.2	25.5
27	Medical & Pharmaceutical Products	23.9	25.0	24.2	25.5
28	Chemical Fibers	23.9	25.0	24.2	25.5
29	Rubber Products	23.9	25.0	24.2	25.5
30	Plastic Products	23.9	25.0	24.2	25.5
31	Nonmetal Mineral Products	23.3	24.5	24.0	25.9
32	Smelting & Pressing of Ferrous Metals	23.7	23.9	23.1	23.9
33	Smelting & Pressing of Non-Ferrous Metals	23.7	23.9	23.1	23.9
34	Metal Products	21.5	22.6	21.8	23.0
35	General Machinery & Equipment Manufacturing	15.9	16.3	15.1	15.6
36	Special Machinery & Equipment Manufacturing	15.9	16.3	15.1	15.6
37	Transportation Equipment Manufacturing	14.7	15.2	14.8	15.4
40	Electric Equipment & Machinery	24.7	27.0	26.3	28.9
41	Electronic & Telecommunications	26.3	27.2	26.5	28.3
42	Instruments, Meters, Cultural & Office Equipment	15.2	15.7	15.0	15.6
43	Manufacture of Artwork and Other Manufacturing	19.5	20.2	19.5	20.5
44	Production and Distribution of Electric Power and Heat	15.2	15.5	15.0	15.6
45	Production and Distribution of Gas	15.5	15.8	15.4	16.2
46	Production and Distribution of Water	17.2	17.7	17.0	17.7

Note: See Section 3.3 for the definition of the backward spillover variable.
Source: Author's calculation based on the database and 1997 input-output table.

Table 3.3 Forward Spillover Variable by Two-Digit Industry

Unit: %

Code	Industry	2000	2001	2002	2003
6	Coal Mining & Processing	14.9	15.1	14.6	15.1
7	Petroleum & Natural Gas Extraction	17.2	17.8	17.2	17.9
8	Ferrous Metals Mining & Processing	15.8	16.1	15.3	15.8
9	Non-Ferrous Metals Mining & Processing	15.8	16.1	15.3	15.8
10	Nonmetal Minerals Mining & Processing	15.1	15.6	14.7	15.2
13	Food Processing	20.7	21.3	20.3	20.8
14	Food Production	20.7	21.3	20.3	20.8
15	Beverage Production	20.7	21.3	20.3	20.8
16	Tobacco Processing	20.7	21.3	20.3	20.8
17	Textile	19.9	20.0	18.7	19.5
18	Garments & Other Fiber Products	17.0	18.1	17.6	18.5
19	Leather, Fur, Feather and Related Products	17.0	18.1	17.6	18.5
20	Timber Processing, Bamboo, Cane &Palm	18.5	18.7	18.0	18.6
21	Furniture Manufacturing	18.5	18.7	18.0	18.6
22	Papermaking & Paper Products	20.1	20.6	19.7	20.6
23	Printing, Reproduction of Recording Media	20.1	20.6	19.7	20.6
24	Stationery, Educational & Sports Goods	20.1	20.6	19.7	20.6
25	Petroleum Processing, Coking Products, & Gas	2.8	3.3	3.7	3.3
26	Raw Chemical Materials & Chemical Products	12.5	13.2	12.8	13.1
27	Medical & Pharmaceutical Products	12.5	13.2	12.8	13.1
28	Chemical Fibers	12.5	13.2	12.8	13.1
29	Rubber Products	12.5	13.2	12.8	13.1
30	Plastic Products	12.5	13.2	12.8	13.1
31	Nonmetal Mineral Products	13.9	14.3	13.7	14.0
32	Smelting & Pressing of Ferrous Metals	8.7	9.0	8.7	8.9
33	Smelting & Pressing of Non-Ferrous Metals	8.7	9.0	8.7	8.9
34	Metal Products	9.3	9.6	9.7	10.3
35	General Machinery & Equipment Manufacturing	16.7	17.0	16.9	17.9
36	Special Machinery & Equipment Manufacturing	16.7	17.0	16.9	17.9
37	Transportation Equipment Manufacturing	16.4	16.9	16.5	17.3
40	Electric Equipment & Machinery	17.6	18.1	17.7	18.9
41	Electronic & Telecommunications	21.6	21.7	21.1	21.9
42	Instruments, Meters, Cultural & Office Equipment	28.9	30.9	30.6	33.3
43	Manufacture of Artwork and Other Manufacturing	18.6	19.0	18.4	19.1
44	Production and Distribution of Electric Power and Heat	10.2	10.8	10.7	11.2
45	Production and Distribution of Gas	5.4	5.9	5.8	5.8
46	Production and Distribution of Water	13.0	13.2	12.3	12.6

Note: See Section 3.3 for the definition of the forward spillover variable.
Source: Author's calculation based on the database and 1997 input-output table.

Table 3.4 Local Spillover Variable by Province

Unit: %

Rank in 2003	Region	2000	2001	2002	2003
1	Guangdong	44.7	49.4	50.7	55.1
2	Fujian	47.8	49.5	46.8	46.9
3	Shanghai	34.2	35.3	37.7	45.0
4	Tianjin	33.7	40.1	28.8	37.8
5	Jiangsu	21.8	23.4	25.2	28.4
6	Beijing	16.2	29.9	25.5	26.9
7	Liaoning	15.5	15.3	16.0	16.1
8	Zhejiang	13.9	14.4	12.8	12.8
9	Hainan	17.3	14.1	12.3	12.3
10	Chongqing	10.9	10.8	10.4	12.1
11	Guangxi	7.5	9.0	11.6	12.0
12	Shandong	11.4	10.5	9.7	9.7
13	Anhui	8.6	10.9	10.2	9.5
14	Hebei	6.8	6.3	6.5	7.6
15	Hubei	6.0	6.3	6.7	7.5
16	Inner Mongolia		4.3	4.9	6.6
17	Hunan	6.2	5.7	5.5	5.7
18	Jilin		10.9	4.6	5.3
19	Sichuan	4.5	4.8	5.1	5.1
20	Jiangxi	5.2	6.0	4.1	4.4
21	Xinjiang	1.0	0.7	2.8	4.2
22	Guizhou	4.0	3.7	4.5	4.1
23	Henan	5.1	3.7	3.7	3.8
24	Ningxia	3.3	2.9	3.0	3.8
25	Shaanxi	3.4	4.3	3.4	3.4
26	Heilongjiang	2.3	2.7	2.9	3.2
27	Shanxi	2.1	2.5	2.3	2.8
28	Yunnan	1.6	1.7	2.4	1.9
29	Qinghai	1.2	0.4	1.1	1.8
30	Gansu	0.9	1.8	1.9	1.5
31	Tibet	0.7	0.1	0.1	0.1

Note: See Section 3.3 for the definition of the local spillover variable.
Source: Author's calculation based on the database.

Table 3.5 Coverage of the Database

Unit: Trillion Yuan

	(a) Value Added of All Firms in the Database	(b) GDP of Industrial Sector	(a)/(b)
2000	2.54	3.90	0.65
2001	2.23	4.24	0.53
2002	3.30	4.60	0.72
2003	4.20	5.31	0.79

Source: Figures of GDP of industrial sector are from *China Statistical Yearbook* (2004), Table 3-1.

Table 3.6 Number of Foreign Firms in the Database

	2000	2001	2002	2003
Total Number of Firms	129,432	131,631	157,687	178,044
Total Number of Foreign Firms	26,965	28,327	32,766	37,443
— HMT Firms	15,677	16,375	18,056	20,520
— OECD Firms	12,499	13,281	16,452	18,677

Source: China National Statistical Bureau Enterprise Database. HMT firms are partly or fully funded by investors from Hong Kong, Macao and Taiwan. OECD firms are partly or fully funded by investors from OECD countries.

Table 3.7 Summary Statistics

	Summary Statistics for Levels			Summary Statistics for First Differences		
	Number of Observations	Mean	Standard Deviation	Number of Observations	Mean	Standard Deviation
lnY	548,421	8.3536	1.4526	290,122	0.1330	0.9701
lnL	548,421	8.2685	1.7035	290,122	0.0559	0.6465
lnK	548,421	4.8865	1.1321	290,122	0.0151	0.4263
ln(Foreign Share)	545,076	0.1553	0.3297	287,511	0.0015	0.1192
Horizontal	548,421	0.2349	0.1647	290,122	0.0040	0.0608
Backward	548,421	0.2352	0.0503	290,122	0.0032	0.0150
Forward	548,421	0.1661	0.0408	290,122	0.0023	0.0113
Local	548,421	0.2000	0.1890	290,122	0.0078	0.0355

Source: Author's calculation based on the database.

Table 3.8 Additional Summary Statistics of Spillover Variables

Year	*Horizontal*			*Backward*			*Forward*			*Local*		
	Number of Industries	Mean	St. Dev.	Number of Industries	Mean	St. Dev.	Number of Industries	Mean	St. Dev.	Number of Cities	Mean	St. Dev.
2000	520	0.2204	0.1889	29	0.2294	0.0526	29	0.1641	0.0521	364	0.0870	0.1285
2001	521	0.2300	0.1947	29	0.2348	0.0495	29	0.1698	0.0535	357	0.0799	0.1298
2002	530	0.2235	0.1882	29	0.2252	0.0471	29	0.1643	0.0512	351	0.0821	0.1298
2003	525	0.2245	0.1915	29	0.2357	0.0496	29	0.1710	0.0554	351	0.0855	0.1342

Source: Author's calculation based on the database.

Table 3.9 Firm Differentials of Characteristics between Foreign and Domestic Firms

	2000	2001	2002	2003
lnTFP	0.5477 (0.0374)	0.6220 (0.0301)	0.4596 (0.0239)	0.3959 (0.0230)
ln(Value Added per Worker)	0.4570 (0.0638)	0.4904 (0.0507)	0.2919 (0.0412)	0.1804 (0.0398)
ln(Sales)	0.8216 (0.0369)	0.7440 (0.0301)	0.6953 (0.0432)	0.6657 (0.0261)
ln(Employment)	0.2957 (0.0386)	0.3518 (0.0349)	0.3890 (0.0340)	0.4419 (0.0326)
ln(Captial per Worker)	0.7368 (0.0601)	0.7221 (0.0510)	0.6545 (0.0432)	0.5798 (0.0396)
ln(Wage per Worker)	0.4411 (0.0295)	0.4068 (0.0246)	0.3819 (0.0277)	0.3503 (0.0188)
Number of Observations	128,589	130,747	156,450	176,768

Notes: All coefficients are significant at the 1% level. All regressions include a full set of two-digit industry, ownership and provincial dummies. Numbers in parentheses are standard errors corrected for two-digit industry-province clustering.

Table 3.10 OLS with Lagged and Contemporaneous Spillover Variables

Dependent Variable: lnY

	Contemporaneous Spillover variables		Lagged Spillovers Variables	
	All Firms	Domestic Firms	All Firms	Domestic Firms
lnK	0.2522*** (0.0035)	0.2219*** (0.0040)	0.2661*** (0.0042)	0.2312*** (0.0048)
lnL	0.5454*** (0.0064)	0.5625*** (0.0072)	0.5650*** (0.0073)	0.5909*** (0.0084)
Foreign Share	0.2353*** (0.0279)		0.2468*** (0.0293)	
Horizontal	0.0589 (0.0387)	0.0305 (0.0451)		
Horizontal Lagged			0.0365 (0.0404)	0.0353 (0.0575)
Backward	1.3673** (0.6455)	1.6190** (0.6840)		
Backward Lagged			1.0736*** (0.3012)	1.1630*** (0.3580)
Forward	1.3722 (1.3417)	1.5139 (1.3662)		
Forward Lagged			0.4894* (0.2845)	0.8733** (0.3548)
Local	0.1209*** (0.0395)	0.1598*** (0.0457)		
Local Lagged			0.1877*** (0.0494)	0.1689*** (0.0575)
Number of Observations	545,076	425,462	288,743	218,864
R^2	0.9319	0.9241	0.9379	0.9354

Notes: All regressions include time dummies, two-digit industry dummies and provincial dummies. Numbers in parentheses are standard errors corrected for two-digit industry-province clustering. * denotes statistical significance at the 0.10 level. ** denotes statistical significance at the 0.05 level. *** denotes statistical significance at the 0.01 level.

Table 3.11 Regression in First Differences: Baseline Specifications

	ΔlnY		Δln(TFP)		Δln(Labor Productivity)	
	All Firms	Domestic Firms	All Firms	Domestic Firms	All Firms	Domestic Firms
ΔlnK	0.0854*** (0.0040)	0.0827 (0.0041)				
ΔlnL	0.3038*** (0.0082)	0.2913 (0.0091)				
ΔForeign Share	0.1143* (0.0604)		0.1256** (0.0608)		0.0356 (0.0668)	
ΔHorizontal	-0.0014 (0.0354)	-0.0435 (0.0396)	-0.0033 (0.0352)	-0.0459 (0.0395)	0.0115 (0.0380)	-0.0264 (0.0424)
ΔBackward	0.6322** (0.3128)	0.8149** (0.3532)	0.6448** (0.3103)	0.8189** (0.3501)	0.5347* (0.3201)	0.7457** (0.3754)
ΔForward	0.1571 (0.2416)	0.0413 (0.2862)	0.1685 (0.2370)	0.0514 (0.2818)	0.1411 (0.2710)	0.0721 (0.3214)
ΔLocal	0.3949*** (0.1038)	0.2971** (0.1181)	0.3975*** (0.1027)	0.2917** (0.1170)	0.4153*** (0.1139)	0.3296** (0.1297)
Number of Observations	287,511	218,864	287,511	218,864	287,511	218,864
R^2	0.12	0.13	0.10	0.11	0.09	0.10

Notes: All regressions include time dummies, two-digit industry dummies and provincial dummies. Numbers in parentheses are standard errors corrected for two-digit industry-province clustering. * denotes statistical significance at the 0.10 level. ** denotes statistical significance at the 0.05 level. *** denotes statistical significance at the 0.01 level.

Table 3.12 Regression in Second Differences: Baseline Specifications

	ΔlnY		Δln(TFP)		Δln(Labor Productivity)	
	All Firms	Domestic Firms	All Firms	Domestic Firms	All Firms	Domestic Firms
ΔlnK	0.1169*** (0.0049)	0.1118*** (0.0054)				
ΔlnL	0.4216*** (0.0093)	0.4072*** (0.0098)				
ΔForeign Share	0.3408*** (0.0996)		0.3358*** (0.0965)		0.3127*** (0.1056)	
ΔHorizontal	-0.0759 (0.0594)	-0.1185* (0.0654)	-0.0796 (0.0589)	-0.1174* (0.0648)	-0.0659 (0.0639)	-0.0832 (0.0745)
ΔBackward	0.3689* (0.2072)	0.5861** (0.2664)	0.3765** (0.1910)	0.5979** (0.2608)	0.3587* (0.2084)	0.4595 (0.3321)
ΔForward	-0.0822 (0.4063)	0.0014 (0.4219)	-0.0871 (0.4159)	0.0023 (0.4394)	-0.0736 (0.3689)	0.0036 (0.4398)
ΔLocal	0.1346** (0.0635)	0.1548** (0.0731)	0.1456** (0.0677)	0.1626** (0.0730)	0.1226* (0.0705)	0.1775* (0.0986)
Number of Observations	141,516	104,698	141,516	104,698	141,516	104,698
R^2	0.12	0.14	0.09	0.10	0.06	0.07

Notes: All regressions include time dummies, two-digit industry dummies and provincial dummies. Numbers in parentheses are standard errors corrected for two-digit industry-province clustering. * denotes statistical significance at the 0.10 level. ** denotes statistical significance at the 0.05 level. *** denotes statistical significance at the 0.01 level.

Table 3.13 Regression in First Differences: Robustness Checks

	Spillovers from HMT FDI			Spillovers from OECD FDI		
	ΔlnY	Δln(TFP)	Δln(Labor Productivity)	ΔlnY	Δln(TFP)	Δln(Labor Productivity)
ΔlnK	0.0840*** (0.0041)			0.0839*** (0.0039)		
ΔlnL	0.2994*** (0.0090)			0.2971*** (0.0083)		
ΔHorizontal	0.0313 (0.0447)	0.0326 (0.0424)	0.0445 (0.0538)	-0.1006* (0.0593)	-0.1192 (0.0757)	-0.0674 (0.0764)
ΔBackward	0.9171** (0.4497)	0.9090** (0.4332)	0.8116* (0.4505)	0.3304 (0.2065)	0.3419* (0.1987)	0.4904** (0.2071)
ΔForward	0.0241 (0.0417)	0.0195 (0.0388)	0.0124 (0.0488)	-0.2598 (0.2564)	-0.2651 (0.2521)	-0.2194 (0.2851)
ΔLocal	0.2925*** (0.0962)	0.3007*** (0.0978)	0.2958** (0.1278)	0.2187** (0.1094)	0.2209** (0.0995)	0.3210*** (0.1202)
Number of Observations	255,875	255,875	255,875	250,401	250,401	250,401
R^2	0.12	0.10	0.10	0.12	0.12	0.10

Notes: We only report the results from the subsample of the domestic firms. All regressions include time dummies, two-digit industry dummies and provincial dummies. Numbers in parentheses are standard errors corrected for two-digit industry-province clustering. * denotes statistical significance at the 0.10 level. ** denotes statistical significance at the 0.05 level. *** denotes statistical significance at the 0.01 level.

Table 3.14 Regression in First Differences: Robustness Checks (Continued)

	Top 25% Most Productive Domestic Firms			Spillovers from Export-Oriented FDI		
	ΔlnY	Δln(TFP)	Δln(Labor Productivity)	ΔlnY	Δln(TFP)	Δln(Labor Productivity)
ΔlnK	0.0783*** (0.0081)			0.0827*** (0.0041)		
ΔlnL	0.2791*** (0.0126)			0.2913*** (0.0091)		
ΔHorizontal	-0.1803** (0.0780)	-0.1750** (0.0816)	-0.1982** (0.0897)	0.0057 (0.0684)	0.0043 (0.0697)	0.0111 (0.0679)
ΔBackward	0.8185** (0.4505)	0.8082* (0.4667)	0.5936 (0.5013)	0.7919** (0.3526)	0.7951** (0.3499)	0.7292* (0.3739)
ΔForward	0.0115 (0.3625)	0.0131 (0.3641)	0.0239 (0.3914)	0.0232 (0.2861)	0.0325 (0.2821)	0.0606 (0.3207)
ΔLocal	0.2803* (0.1813)	0.2787 (0.1894)	0.3536* (0.2004)	0.1964* (0.1180)	0.2010* (0.1169)	0.2292* (0.1297)
Number of Observations	54,716	54,716	54,716	218,864	218,864	218,864
R^2	0.13	0.11	0.11	0.13	0.11	0.10

Notes: We only report the results from the subsample of the domestic firms. All regressions include time dummies, two-digit industry dummies and provincial dummies. Numbers in parentheses are standard errors corrected for two-digit industry-province clustering. * denotes statistical significance at the 0.10 level. ** denotes statistical significance at the 0.05 level. *** denotes statistical significance at the 0.01 level.

4. EXPORTING AND PERFORMANCE: FIRM LEVEL EVIDENCE FROM CHINA

4.1. Overview of the Literature

4.1.1. Related Theories

With an increasing availability of panel data at the firm level, it has been widely documented that exporters are "better," more productive, larger, survive longer and pay higher wages, than non-exporters (e.g., Bernard, Eaton, Jensen and Kortum, 2003; Pavcnik, 2002). There are basically two theoretical explanations, each emphasizing one direction of the causal relationship.

Self-selection theory stresses the sunk costs of entering foreign markets. Recent theoretical works introduce heterogeneity of firms into standard monopolistic competition models with increasing returns. Melitz (2003) provides a general equilibrium model showing that firms with higher ex ante productivity self-select into export markets, i.e. only more efficient firms can afford the fixed costs of entry into export markets. Helpman, Melitz and Yeaple (2004) extend the model and demonstrate that given equal trade and investment opportunities within sectors, firms sort according to productivity into different organizational forms: the least productive firms serve only the domestic markets, more productive firms export, and most productive firms choose to invest in foreign markets.

Learning-by-exporting theory argues that exporting firms may benefit from the technical expertise of foreign buyers. For the firms in less developed economies in particular, foreign buyers may share knowledge of the latest design specifications and production techniques that might otherwise be unavailable.

4.1.2. Empirical Studies

Most of the empirical studies on exporting and productivity are based on firm-level panel data. The results, however, have been mixed. The first study to make a clear empirical distinction between correlation and causality is Bernard and Jensen (1999). The authors find evidence for the existence of sunk costs in exporting. They also find that productivity increases take place before exporting, suggesting selection rather than technological improvement as result of exporting. Using a slightly different method, Clerides, Lach and Tybout (1998) also find strong evidence for self-selection in their data from Colombia, Mexico and Morocco. They do not find any evidence for learning effects from exporting. Aw, Chung and Roberts (2000) come to the same conclusions for Taiwan and Korea in the late 1980s and early 1990s. Delgado, Farinas and Ruano (2002) consider the case of Spanish firms and find evidence of self-selection into export markets but no evidence for learning from exporting.

In contrast, more recent studies find some evidence to support learning-by-exporting theory. These studies include Wager (2002) for Germany, Girma, Greenway and Kneller (2003) for the United Kingdom, Alvarez and Lopez (2005) for Chile, De Loecker (2005) for Slovenia, and Van Biesebroeck (2005) for sub-Saharan African countries.

In the case of China, using a survey dataset of 2,105 firms between 1989 and 1994, Kraay (1999) confirms that Chinese exporters are more productive. He employes dynamic panel methods and finds that exporting improves labor productivity.

4.2. Growth of China's Exports

Before the reforms began in the late 1970s, almost all trade was carried out through specialized foreign trade companies, whose primary responsibility was implementing central government's mandatory plan. The foreign trade companies purchased goods from manufacturing firms and sold them in the international markets. Manufacturing firms could not negotiate and sign contracts with foreign customers directly because only foreign trade companies were granted the "trading rights for exporting." Since the procurement prices were fixed, the foreign trade companies frequently incurred export losses, which were usually subsidized by the central government. All foreign exchange received was handed over to the central bank at the official rate.

China's reforms of its foreign trade system took place in several key aspects, including granting trading rights to manufacturing firms, a reduction and eventual elimination of the mandatory plan, and reforming foreign exchange regime (Lardy, 2001, p. 46). The most dramatic change was the expansion of trading rights. In 1978, only 12 specialized foreign trade companies had the trading rights. By 2001 the government had granted trading rights to 35,000 firms, including many private firms (Lardy, 2005). The direct planning of exports was replaced by decentralized, market-oriented transactions. The mandatory export plan was sharply reduced in the 1980s and abolished in 1991. China established the dual-track system of foreign exchange in the 1980s. The government unified the exchange rate in 1994, which led to substantial depreciation of the official exchange rate.

These trade reforms, combined with other export promotion policies such as rebate of value-added taxes on exports and duty drawback system, have helped transform China into a major trading power. China's exports grew from $18 billion in 1980 to $593 billion in 2004

(Figure 1.3), while over the same period the ratio of exports to GDP rose from 0.06 to 0.31 (Table 4.1). During the period of this study (2000-2003), stimulated by China's entry into WTO in early 2001, the annual growth rate of Chinese exports was as high as 30 percent.

The most impressive export performance in China came from foreign invested firms and Chinese firms that are engaged in export processing. As compared with ordinary trade, export processing plays an increasingly important role in China's exports. Foreign parts and components are brought in, assembled or processed using relatively low-cost Chinese labor, and then exported to the international markets. In 2002, 55 percent of China's exports came from export processing.[23]

A large part of the China's overall success in exports can be attributed to the strong export orientation of foreign invested firms (Huang, 2001). The contribution of foreign invested firms to total exports jumped from only 1 percent in 1985 to 55 percent in 2003 (Table 4.1).[24] In the electronics and telecommunications industry, for example, foreign invested firms accounted for 95 percent of Chinese exports.

According to Chinese trade data, China's five largest export markets in 2003 were the United States, Hong Kong, the European Union, Japan, and South Korea.[25] Regarding the regional pattern of exports within China, the exporting sector is highly concentrated in coastal provinces. In 2003, Guangdong province alone accounted for one third of China's exports.

Table 4.1 also shows the change of the composition of China's exported goods. In the first half of the 1980s, boosted by the exports of crude oil, primary products (mainly agricultural

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[23] Source: Author's calculation based on Table 2-7, *China Foreign Economic Statistical Yearbook* (2003), p. 19.

[24] Source: *China Foreign Economic Statistical Yearbook* (2003), Table 2-26, p. 102.

[25] China's trade data often differ significantly from those of its major trading partners. This is because a large share of China's trade passes through Hong Kong. China treats a large share of its exports through Hong Kong as Chinese exports to Hong Kong, while countries that import Chinese products through Hong Kong generally attribute their origin to China.

products and minerals) comprised about half of China's exports. Primary products are essentially homogeneous goods, therefore little marketing knowledge is needed to sell them. The exporting of manufactured goods requires more sophisticated understanding of consumer preference, quality standard, and so forth. After the mid-1980s, the share of manufactured products rose continuously from 49 percent in 1985 to 92 percent in 2003. The largest exporting sector under Standard International Trade Classification (SITC) is machinery and transport equipment, accounting for 39 percent of the total exports in 2003.

4.3. The Data and Basic Patterns

The data came from the regular surveys by China National Bureau of Statistics between 2000 and 2003. We described the data in Section 3.3.

In this chapter, a firm is defined as an exporter if its exports are positive. Table 4.2 shows that in our dataset, exporters account for about 25 percent of total number of firms in each year. Table 4.3 presents basic information about the export propensity (exports to sales ratio) at two-digit industry level.

To see how exporters and non-exporters differ, following Bernard and Jensen (1999) and others, we estimate the following equation:

$$\ln S_i = \alpha + \beta EXP_i + \gamma_1 Ownership + \gamma_2 Industry + \gamma_3 Province + \varepsilon_i, \tag{4.1}$$

where S_i is firm i's characteristics, including TFP, labor productivity defined as value-added per worker, sales, employment, capital intensity, and wage. The measure of TFP is obtained through the Levinsohn-Petrin procedure, which was discussed in Section 3.4. EXP_i is a dummy variable indicating the export status.[26] In the regression, we also control for ownership, two-digit industry and provincial fixed effects. We estimate (4.1) separately for each year in our sample. The coefficient on EXP_i tells us whether the relevant firm characteristic is different for exporting firms relative to non-exporting firms. More precisely, it reveals the percentage differential between exporters and non-exporters.

The estimation results are reported in Table 4.4. We find significant difference between exporters and non-exporters for all characteristics. Using TFP as a measure for firm performance, exporters were on average 46 percent more productive in 2000, but the TFP gap decreased to 36 percent in 2003. Furthermore, exporters are larger in size and pay higher wages. These results are generally consistent with previous findings. In contrast to the existing studies, we find that exporters are less capital intensive and have lower labor productivity. Given China's comparative advantage in labor intensive goods, it is not surprising that exporters are less capital intensive in China. Exporters tend to have higher TFP but lower labor productivity probably because they are more labor intensive and they utilize capital more efficiently.

4.4. Testing Self-Selection Hypothesis

The self-selection hypothesis suggests that exporting will be profitable only for more productive firms. In this context, initial productivity would be important to explain why some firms begin to export and others only sell in the domestic markets. To examine the empirical validity of this hypothesis, we focus on those firms that do not export initially, which can be further classified into two groups: those that start exporting in the next year and those that stay as non-exporters.

[26] We can also use the export propensity as a measure. When the export propensity is used in the regression, the results are qualitatively the same.

Since our data span 2000-2003, we have three cohorts of export starters and non-exporters: 2000-2001, 2001-2002, and 2002-2003. Pooling these cohorts results in data for 10,391 export starters and 189,358 non-exporters. We estimate the probability of exporting as a function of ex-ante firm performance. In this framework, a positive relationship between ex-ante TFP and probability of exporting would support the self-selection hypothesis. Our probit model is specified as follows:

$$P\{NEWEXP_{it+1} = 1\} = \Phi\{X_{it}, Ownership, Province, Industry, Year\}, \tag{4.2}$$

where $\Phi(\cdot)$ is the normal cumulative distribution function. $NEWEXP \in \{0,1\}$ is an indicator variable of whether the firm entered the export markets. X is a vector of firm characteristics that affect the probability of exporting. Based on previous literature (for example, Bernard and Jensen, 2004), these variables include TFP, firm size measured by sales, firm age, capital intensity, wage rate and the share of new product in sales. The wage rate reflects the skill level of the labor, while the share of new product in sales measures the innovation activity. We also include a full set of ownership, three-digit industry, year and provincial dummies. Since we have three cohorts in the regression, the year dummies capture the effects of events that occur in calendar time.

The results reported in Table 4.5 support the self-selection hypothesis. The estimates, which correspond to the marginal effects, show that the probability of exporting is, as expected, increasing in the initial productivity of the firms. The estimation results also indicate that those firms initially bigger, with foreign ownership, and with larger share of new product in sales, are more likely to enter the export markets. The coefficients on age, capital intensity and wage all bear expected signs, but they are not statistically significant.

4.5. Testing Learning-by-Exporting Hypothesis

4.5.1. Empirical Strategy

Assume a study finds that firms entering the export markets have substantially higher productivity in the following years than non-exporters. That finding does not imply a causal effect of exporting on productivity. If better firms self-select into exporting, we would expect that they should perform better in the future even if they do not start to export. But we cannot observe what they would do had they not started to export because we simply do not observe the counterfactual situation.

Our problem closely resembles the central issue in the program evaluation literature (for example, Heckman, Ichimura, and Todd, 1997): if the treated units are not selected randomly from a population but are self-selected according to certain criteria, the effect of a treatment cannot be evaluated by comparing the average performance of the treated and the non-treated. One solution is to construct a control group such that treated units are matched to untreated units that are as similar as possible at the time before the treatment. Differences after the treatment between the treated groups and the matched non-treated group can then be attributed to the treatment.

In our analysis, let Z_{it} represent the outcome variable that measures the performance of firm *i* at time *t*. Our primary interest lies in TFP, but we will also look at other variables such as labor productivity. The causal effect of starting to export for firm *i* at time period $t+s$ is thus defined as

$$Z_{it+s}^{1} - Z_{it+s}^{0}, \tag{4.3}$$

where Z^1_{it+s} denotes the value of Z at time $t+s$ if firm i started exporting, while Z^0_{it+s} is the value of Z for firm i had it not participated in export markets.

As we discussed earlier, the fundamental problem of causal inference is that Z^0_{it+s} is unobservable. Following the program evaluation literature, we define the average treatment effect on the treated (average effect of exporting on export starters in our case) as

$$E[Z^1_{it+s} - Z^0_{it+s} \mid NEWEXP_{it} = 1] = E[Z^1_{it+s} \mid NEWEXP_{it} = 1] - E[Z^0_{it+s} \mid NEWEXP_{it} = 1]. \quad (4.4)$$

Our causal inference relies on the construction of the counterfactual for the last term in the above equation. It is estimated instead by the average value of non-exporters, $E[Z^0_{it+s} \mid NEWEXP_{it} = 0]$.

An essential feature in the construction of the counterfactual is the selection of a valid control group. We use the method of matching to pair each export starter with a firm with similar characteristics drawn from a sample of non-exporters. Since matching involves comparing a vector of pre-entry characteristics, X, it is difficult to decide along which dimension to match the firms and what weights to use. To solve the dimensionality problem, Rosenbaum and Rubin (1983) show that under the assumption of conditional independence, if we can match on X, we can also match on $P(X) = Pr(NEWEXP_{it} = 1 \mid X)$, the so-called propensity score.

The selection of X comes from the independent variables in (4.2) in Section 4.4. To match an export starter, we choose a non-exporter that is “closest” in terms of its propensity score. The matching is based on “nearest-neighbor,” which selects a non-exporter j on the following criteria:

$$| p_i - p_j | = \min_{k \in \{NEWEXP=0\}} (p_i - p_j), \quad (4.5)$$

where p is the propensity score.

In this study, the matching procedure is implemented with Stata module "psmatch2" developed by Leuven and Sianesi (2003).

The use of a matching approach to search for causal effects of starting to export on productivity was pioneered by Wagner (2002) and later used by Girma, Greenaway and Kneller (2003) and Alvarez and Lopez (2005).

After we have constructed the control group to match the new exporters, we can use the standard matching estimator to evaluate the causal effect of starting to export on performance, which can be written as

$$\delta_M = \overline{Z}_{it+s} - \overline{Z}_{jt+s}, \tag{4.6}$$

where the bar indicates the average over the firms in each group.

Blundell and Costa Dias (2000) argue that matching combined with difference-in-difference (DID) will improve the quality of non-experimental evaluation studies. The difference-in-difference estimator removes effects of common shocks, and provides a more accurate description of the impact of exporting. This approach is a three-step procedure. First, the difference of average value of Z between time t and $t+s$ is calculated for the exporting group, $\overline{Z}_{it+s} - \overline{Z}_{it}$. Second, repeat step 1 for control group and calculate $\overline{Z}_{jt+s} - \overline{Z}_{jt}$. Third, the difference obtained in the step 1 is further differenced with respect to the difference obtained in step 2. Formally, difference-in-difference estimator is given by

$$\delta_{DID} = \left(\overline{Z}_{it+s} - \overline{Z}_{it}\right) - \left(\overline{Z}_{jt+s} - \overline{Z}_{jt}\right). \tag{4.7}$$

Alternatively, the difference-in-difference estimator can be obtained by running the following regression (Meyer, 1995):

$$Z_{it} = \alpha + \beta_1 d_t + \beta_2 d_g + \delta_{DID}(d_t \cdot d_g) + \varepsilon_{it}, \tag{4.8}$$

where the dummy variable, $d_g \in \{1,0\}$, denotes the exporting group and the control group, while $d_t \in \{1,0\}$ denotes post- and pre-exporting periods. To control for possible unobservable factors that may be correlated with the performance, we extend this basic framework by adding more covariates that may affect performance. In particular, we estimate the following equation:

$$Z_{it} = \alpha + \beta_1 d_t + \beta_2 d_g + \delta_{DID}(d_t \cdot d_g) + \gamma_1 d_{ownership} + \gamma_2 d_{industry} + \gamma_3 d_{region} + \gamma_4 d_{year} + \varepsilon_{it}. \quad (4.9)$$

4.5.2. Estimation Results

Table 4.6 reports the results for ln*TFP* from standard matching estimator. For $s = 1$, we created an exporting group of 10,391 firms and a control group of 9,345 firms.[27] When we examine the effect of longer period, the size of both exporting group and control group decreases quickly. Table 4.6 shows that the average treatment effect on the treated is positive and statistically significant in all cases. In the first year of exporting, the causal effect of exporting on TFP is 11.5 percentage points. When $s = 2$, the effect of exporting over the two-year period is estimated to be 14.2 percentage points. In the third year, the cumulative effect is even larger, reaching 16.6 percentage points.

The estimation results from regression (4.9) are presented in Table 4.7. The estimation with difference-in-difference produces similar results. However, the TFP effect estimated from difference-in-difference is larger in all three cases. For example, the causal effect of exporting on TFP is 13.3 percentage points in the entry year. In addition to TFP, we also find robust evidence of the positive effect of exporting on labor productivity, sales and employment. There is little evidence of a wage effect since the coefficient on ln(wage) is significant only when $s = 2$.

[27] Matching is implemented with replacement, so each non-exporter can be matched to more than one export starter.

Since foreign firms come from international markets, it is not clear whether learning-by-exporting theory can be applied to foreign invested firms in China. Therefore, we estimate the exporting effect separately for the subsamples of domestic firms and foreign invested firms. The results reported in Table 4.8 indicate that there is still a significant exporting effect for foreign invested firms but the size of the effect is smaller. Although foreign investors already have international experience, for the foreign invested firms (usually in the form of joint venture), there is some room for learning effects.

In our analyses, we pool all industries in the regression assuming that firms of different industries have the same learning effects of exporting. However, this assumption might be too strong. To see the differences among industries, we estimate (4.9) for selected industries. Those industries with fewer than 200 new exporters are excluded. The new exporters are matched by non-exporters in the same two-digit industry. The results of the estimation are presented in Table 4.9. Although the general pattern is consistent with our main findings, Table 4.9 shows significant heterogeneity among industries. Transport equipment, special machinery, garments and textile industries appear to have largest learning effects.

Table 4.1 The Structure of China's Exports

Unit: Billion US Dollars

Year	Exports	Share of Manufactured Products (%)	Share of Foreign Invested Firms (%)	Exports/GDP
1980	18.1	49.7	0.0	0.06
1985	27.3	49.4	1.1	0.09
1990	62.9	74.4	12.4	0.16
1995	148.8	85.6	31.5	0.22
2000	249.2	89.8	47.9	0.23
2001	266.2	90.1	50.0	0.23
2002	325.6	91.2	52.2	0.26
2003	438.2	92.1	54.8	0.31

Sources: *China Foreign Economic Statistical Yearbook* (2003) and *China Statistical Yearbook* (2004).

Table 4.2 Number of Exporting Firms in the Dataset

	2000	2001	2002	2003
Total Number of Firms	129432	131631	157687	178044
Total Number of Exporters	33224	34411	42205	48493
— Domestic Exporters	16778	17043	22236	25333
— Foreign Exporters	16446	17368	19969	23160

Source: China National Statistical Bureau Enterprise Database.

Table 4.3 Export Propensity by Industry (2000-2003)

Unit: %

Code	Industry	2000	2001	2002	2003
6	Coal Mining & Processing	6.96	7.97	6.87	5.12
7	Petroleum & Natural Gas Extraction	3.12	3.07	2.25	1.88
8	Ferrous Metals Mining & Processing	0.27	0.17	0.53	0.29
9	Non-Ferrous Metals Mining & Processing	3.92	7.77	4.60	4.92
10	Nonmetal Minerals Mining & Processing	9.94	8.47	9.67	8.17
12	Logging & Transport of Timber & Bamboo	0.36	0.93	1.52	6.49
13	Food Processing	11.71	11.43	11.78	12.54
14	Food Production	9.92	8.87	9.52	9.87
15	Beverage Production	2.83	2.92	3.34	3.83
16	Tobacco Processing	0.80	0.78	0.85	1.04
17	Textile	30.51	30.14	28.77	28.90
18	Garments & Other Fiber Products	60.70	55.58	56.38	55.63
19	Leather, Fur, Feather and Related Products	63.03	58.82	58.83	56.76
20	Timber Processing, Bamboo, Cane &Palm	15.50	17.29	19.70	21.29
21	Furniture Manufacturing	40.21	38.82	43.50	46.98
22	Papermaking & Paper Products	7.94	8.05	7.80	8.27
23	Printing, Reproduction of Recording Media	6.60	8.07	8.73	11.54
24	Stationery, Educational & Sports Goods	67.64	66.31	68.52	67.55
25	Petroleum Processing, Coking Products, & Gas	2.96	3.19	3.52	3.51
26	Raw Chemical Materials & Chemical Products	10.22	9.60	9.75	9.98
27	Medical & Pharmaceutical Products	10.44	9.72	9.42	10.80
28	Chemical Fibers	5.62	7.33	7.51	7.32
29	Rubber Products	26.60	23.52	22.96	22.72
30	Plastic Products	27.72	25.75	26.86	27.07
31	Nonmetal Mineral Products	9.86	10.22	10.29	10.77
32	Smelting & Pressing of Ferrous Metals	5.77	3.64	3.07	2.80
33	Smelting & Pressing of Non-Ferrous Metals	11.60	8.86	10.82	10.67
34	Metal Products	30.38	27.70	29.27	28.78
35	General Machinery & Equipment Manufacturing	17.30	15.73	15.82	15.25
36	Special Machinery & Equipment Manufacturing	9.58	10.89	8.79	9.41
37	Transportation Equipment Manufacturing	10.76	8.89	9.69	9.80
40	Electric Equipment & Machinery	21.31	21.81	23.78	26.08
41	Electronic & Telecommunications	43.85	44.56	51.08	54.39
42	Instruments, Meters, Cultural & Office Equipment	45.22	51.96	49.70	51.27
43	Manufacture of Artwork and Other Manufacturing	57.05	56.23	58.59	57.74
44	Production of Electric Power and Heat Power	0.05	0.08	0.08	0.26
45	Production and Distribution of Gas	0.54	0.04	0.71	1.40
46	Production and Distribution of Water	0.35	0.34	0.39	0.87

Notes: Export Propensity is defined as export to sales ratio. Source: Author's calculation based on the database.

Table 4.4 Firm Differentials of Characteristics between Exporters and Non-Exporters

Characteristics	2000	2001	2002	2003
lnTFP	0.4635 (0.0203)	0.3998 (0.0180)	0.3828 (0.0171)	0.3590 (0.0170)
ln(Value Added per Worker)	-0.0638 (0.0202)	-0.1158 (0.0160)	-0.1226 (0.0155)	-0.1401 (0.0159)
ln(Sales)	0.6935 (0.0248)	0.6023 (0.0254)	0.5905 (0.0230)	0.5747 (0.0216)
ln(Employment)	0.7497 (0.0199)	0.7242 (0.0187)	0.7062 (0.0173)	0.6900 (0.0169)
ln(Captial per Worker)	-0.0733 (0.0258)	-0.1119 (0.0256)	-0.1286 (0.0252)	-0.1620 (0.0250)
ln(Wage per worker)	0.1048 (0.0096)	0.0686 (0.0091)	0.0677 (0.0076)	0.0730 (0.0081)
Number of Observations	129,368	131,631	157,685	178,044

Notes: See Section 4.3 for the description of the regressions. All coefficients are significant at the 1%. All regressions include a full set of two-digit industry, ownership and provincial dummies. Numbers in parentheses are standard errors corrected for two-digit industry-province clustering.

Table 4.5 Determinants of Starting to Export

Dependent Variable: Export Indicator at time *t* + 1

	Probit (1)	Probit (2)
lnTFP at time *t*	0.0803*** (0.0051)	0.0817*** (0.0052)
Age at time *t*		-0.0002 (0.0005)
Sales at time *t*		0.0236*** (0.0022)
New Product Share in Sales at time *t*		0.2692*** (0.0335)
Capital per worker at time *t*		-0.0266 (0.0399)
Wage per worker at time *t*		0.0005 (0.0004)
Foreign Ownership at time *t*	0.8431*** (0.1374)	0.8321*** (0.1375)
Private Ownership at time *t*	0.2578* (0.1371)	0.2574* (0.1376)
Collective Ownership at time *t*	0.0454 (0.1374)	0.0469 (0.1375)
Number of Observations	199,713	199,713
Pseudo R^2	0.12	0.15

Notes: Both regressions include full sets of three-digit industry, year and provincial dummies. In the regressions, the dummy for state ownership is omitted. * denotes statistical significance at the 0.10 level. ** denotes statistical significance at the 0.05 level. *** denotes statistical significance at the 0.01 level.

Table 4.6 Matching Estimation of Average Treatment Effect on the Treated (ATT)

Outcome Variable: ln*TFP*

	t +1 (entry year)	t + 2	t + 3
ATT	0.1151*** (0.0324)	0.1421*** (0.0425)	0.1662** (0.0731)
Number of Treated	10,391	5,531	1,877
Number of Controls	9,345	4,857	1,671

Notes: Firms are matched using propensity score method. Bootstrapped standard errors are reported in parentheses. * denotes statistical significance at the 0.10 level. ** denotes statistical significance at the 0.05 level. *** denotes statistical significance at the 0.01 level.

Table 4.7 Difference-in-Difference Estimation Results (Full Sample)

Outcome Variables	t +1 (entry year)	t + 2	t + 3
lnTFP	0.1329*** (0.0213)	0.1476*** (0.0279)	0.1926*** (0.0447)
Ln(Labor Productivity)	0.0988*** (0.0196)	0.1123*** (0.0245)	0.1189*** (0.0475)
ln(Sales)	0.1101*** (0.0215)	0.1077*** (0.0288)	0.1334*** (0.0513)
ln(Employment)	0.0549*** (0.0188)	0.0488** (0.0249)	0.0878** (0.0447)
ln(Wage)	0.0179 (0.0120)	0.0289* (0.0159)	0.0101 (0.0282)
Number of Treated	10,391	5,531	1,877
Number of Controls	9,345	4,857	1,671

Notes: Firms are matched using propensity score method. Numbers in parentheses are standard errors based on the White consistent covariance estimates. * denotes statistical significance at the 0.10 level. ** denotes statistical significance at the 0.05 level. *** denotes statistical significance at the 0.01 level.

Table 4.8 Difference-in-Difference Estimation Results (Subsamples)

Outcome Variables	Domestic Firms			Foreign Firms		
	t +1 (entry year)	t + 2	t + 3	t +1 (entry year)	t + 2	t + 3
lnTFP	0.1557*** (0.0244)	0.1606*** (0.0303)	0.2231*** (0.0528)	0.1002*** (0.0368)	0.1089** (0.0480)	0.1673** (0.0728)
ln(Labor Productivity)	0.1179*** (0.0230)	0.1283*** (0.0298)	0.1324*** (0.0557)	0.0659* (0.0352)	0.0814* (0.0446)	0.0958 (0.0647)
ln(Sales)	0.1149*** (0.0257)	0.1101*** (0.0344)	0.1417*** (0.0632)	0.0943** (0.0375)	0.0959* (0.0491)	0.1109 (0.0822)
ln(Employment)	0.0510** (0.0226)	0.0494** (0.0241)	0.0901 (0.0532)	0.0475 (0.0324)	0.0444 (0.0424)	0.0869 (0.0720)
ln(Wage)	0.0187 (0.0139)	0.0296* (0.0169)	0.0105 (0.0316)	0.0216 (0.0224)	0.0075 (0.0289)	0.0042 (0.0458)
Number of Treated	6,893	3,619	1,130	3,442	1,928	753
Number of Controls	6,451	3,287	1,084	2,868	1,592	596

Notes: Firms are matched using propensity score method. Numbers in parentheses are standard errors based on the White consistent covariance estimates. * denotes statistical significance at the 0.10 level. ** denotes statistical significance at the 0.05 level. *** denotes statistical significance at the 0.01 level.

Table 4.9 Difference-in-Difference Estimation by Selected Industries

Code	Industry	Number of Treated	Number of Controls	Average Treatment Effect
13	Food Processing	321	243	0.1174 (0.0902)
14	Food Production	301	264	0.0762 (0.1045)
17	Textile	2314	1914	0.1432*** (0.0412)
18	Garments & Other Fiber Products	1273	965	0.1523*** (0.0575)
19	Leather, Fur, Feather and Related Products	454	386	-0.012 (0.1021)
20	Timber Processing, Bamboo, Cane &Palm	214	157	-0.0454 (0.1179)
24	Stationery, Educational & Sports Goods	324	261	0.1421 (0.1001)
26	Raw Chemical Materials & Chemical Products	612	544	0.1385** (0.0732)
30	Plastic Products	724	672	0.1082 (0.0841)
31	Nonmetal Mineral Products	512	484	0.0611 (0.0716)
34	Metal Products	701	662	0.1231* (0.0637)
35	General Machinery & Equipment Manufacturing	614	571	0.1121 (0.0823)
36	Special Machinery & Equipment Manufacturing	297	281	0.1735* (0.0936)
37	Transportation Equipment Manufacturing	363	315	0.1841* (0.0982)
40	Electric Equipment & Machinery	813	732	0.0904* (0.0521)
41	Electronic & Telecommunications	617	547	0.1390** (0.0671)

Notes: Firms are matched using propensity score method. Numbers in parentheses are standard errors based on the White consistent covariance estimates. * denotes statistical significance at the 0.10 level. ** denotes statistical significance at the 0.05 level. *** denotes statistical significance at the 0.01 level.

5. CONCLUSIONS

As shown by the studies of vertical specialization, FDI and exporting in this dissertation, market forces and globalization forces changed China's economy in a profound way. We find the evidence that market reforms reduced transaction costs, increased vertical specialization, and raising firms' productivity. We also find the spillover effects of FDI and learning effects of exporting.

Chapter 2 contributes to the literature by exploiting rich variation in regional market development and vertical specialization in China's manufacturing sector. Using instrumental variable method, we find a statistically and quantitatively significant relationship between vertical specialization and total factor productivity of firms. Our estimation results also indicate that industry size, neighboring output and provincial marketization index are all determinants of the vertical specialization. Thus, we find evidence that supports Smith's extent-of-market theory, Marshall's input sharing theory and Coase's transaction cost theory. By studying the quantitative significance, we also find that transaction cost theory is more powerful in explaining vertical specialization of firms. This finding implies that market-oriented reform that reduces transaction costs is the major determinant of vertical specialization in China. We fail to find strong evidence that supports Stigler's theory of industry lifecycle.

In Chapter 3 we analyze productivity spillovers from foreign direct investment using firm-level panel data from China manufacturing industries. We investigate whether there exist productivity spillovers from FDI to domestic firms through horizontal, backward, forward and local linkages. We apply the Levinsohn and Petrin (2003) method to the estimation of TFP, which allows us to control for the potential endogeneity of input factors. The estimation results from baseline specifications produce findings that support backward and local spillovers. As was the case with previous studies on developing countries, little evidence of horizontal spillovers can be found. As robustness checks, we distinguish spillovers from HMT investors versus OECD investors, and export-oriented FDI versus domestic-market-oriented FDI. Moreover, we take into account the absorptive capacity of domestic firms. The estimation results are consistent with our main findings.

FDI is often regarded as an engine to economic development, an assumption that has led many governments around the world to attract FDI by offering generous financial incentives. Since we find positive backward and local spillovers, our study provides some support for such policies.

Chapter 4 analyzes the relationship between firm productivity and export behavior in China's manufacturing firms. We find that firms that enter export markets show superior initial performance compared to non-exporters; in other words, we discover evidence consistent with self-selection theory. In order to determine the direction of causality between exporting and productivity, we use propensity score matching technique to construct a counterfactual control group. The matching method controls for the non-random selection of exporting firms in our sample, and allows us to interpret our results as causal effects. Our findings suggest that exporting leads to better performance of the firms. They become on average 13 percent more productive after they start to export, which gives support to the learning-by-exporting hypothesis.

The results of this study are broadly consistent with the idea that increasing access to export markets boosts productivity in developing countries. From an industrial policy perspective, there is a good reason to promote foreign sales over domestic sales because firms become better once they are active in export markets.

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