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Technology Spillovers from Multinationals to Local Firms: Evidence from Automobile and Electronics Firms in China

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Abstract

This study compares knowledge spillovers from multinationals to local firms in China between the automobile and electronics industries. In the automobile industry we find that multinationals in the assembly industry affect vertical spillovers to domestic parts supply firms, and horizontal spillovers also exist between domestic parts suppliers. In contrast, we cannot find vertical spillover effects of multinationals in the assembly industry to domestic suppliers in the electronics industry, only horizontal spillover effects from multinationals to domestic supply firms can be found. A different pattern of technology spillover suggests the importance of customization of FDI policy by industry.

Jel Classification: O1; O3; F2; L6
Keywords: R&D; Spillovers; Foreign direct invest; China; Productivity

1. Introduction

Acquiring external technology is an important channel for firms to increase their profits and productivity levels. Therefore, many previous studies argue that acquiring external technology is vitally important for innovation, especially spillovers of foreign direct investment (FDI), which have been drawing a lot of attention. Besides increasing exports and promoting employment in the host country, local firms may benefit from the spillovers of multinationals through imitation, business partner relationships, labor flow and so on. Thus local firms can use these opportunities to catch up with multinationals. Therefore, attracting multinationals is an important economic development strategy for emerging economies, and policies promoting FDI can be commonly found in developing countries.

China is not an exception, and special economic zones were created in its coastal regions to attract FDI in the 1980s. During his southern visit in 1992, Deng Xiaoping promoted further openness and called for speeding up economic reforms. As a result, FDI flows into China increased from $3.5 billion in 1990 to $69 billion in 2006, which in turn made a significant contribution to the rapid economic development of China.

However, recently there have been signs of restrictions on certain types of FDI. As a consequence of rapid economic growth, a shortage of energy has become a major concern of the Chinese government. In addition, air and water pollution can be found in many places throughout the country, so that FDIs of smokestack industries are strictly managed. In addition, the government is keen on spurring the competitiveness of domestic firms and has been particularly promoting indigenous innovation (zizhu chuangxin), i.e., independent research and development (R&D), over borrowing foreign technology. It is clear that the Chinese government requires not only spillovers from production activities of multinationals, but also knowledge spillovers from R&D

activities of multinationals. In the process of shifting China's FDI policy from a quantitative to qualitative orientation, it has become increasingly important to more precisely understand the mechanism of FDI technology spillovers to local economies.

In this paper, we empirically study technology spillovers from FDI to domestic companies by focusing on two industries: automobiles and electronics. We chose these two industries because both make products consisting of many different parts and components requiring long supply chains. A multinational's investment in assembly plants may have a significant impact on local parts and component companies in these industries. In addition, it is interesting to compare the impact of these two industries, because the product architecture between them is completely different. An automobile is a typical example of an integrated product of mutually interdependent components; it should be designed in an integrated manner through the coordination of an assembler and parts suppliers (Takeishi and Fujimoto, 2001). In contrast, an electronics product has a modular architecture in general, which allows an assembler and parts suppliers to work more independently (Baldwin and Clark, 2000; Sturgeon, 2006). Such supply chain characteristics will lead to a different impact from FDI on these two industries, such as vertical technology spillovers between suppliers and assemblers, which can be found particularly in the automobile industry.

There is a large amount of literature on the impact of FDIs on the domestic economy. Some studies have investigated the differences between the effects of vertical and horizontal spillovers (Javorcik, 2004; Blalock and Certler, 2004; Kugler, 2006). However, to our knowledge there is no study that focuses specifically on two industries and compares technology spillover characteristics across industries. In developing countries, FDI and national industry development policies are designed by industry itself. In China, however, the government has introduced different industrial policies for the automobile and electronics industries because industrial development strategy should be compatible with each industry's characteristics. Therefore, we believe that industry-level analysis is quite valuable for policy formulation purposes. In the automobile industry, we find that multinationals in the assembly industry affect vertical spillover to domestic parts supply firms, and horizontal spillover also exists between domestic parts suppliers. In contrast, we find that multinationals in the assembly industry do not affect vertical spillovers to domestic suppliers in the electronics industry, while multinationals in the parts supply industry do affect horizontal spillovers to domestic supply firms.

This paper is structured as follows: Section 2 introduces previous literature; Section 3 surveys the policies and performance of the Chinese automobile and electronics industries, and includes descriptions of the datasets used for this paper; Section 4 explains the methodology of our analysis and the results; Section 5 summarizes major findings and concludes our paper with policy implications.

2. Previous Literature

A large number of studies employ firm-level data to analyze spillovers by focusing on FDI or knowledge (international patenting and multinationals' R&D activities). The economic impact of FDI on local economies has various different aspects.

First, there are many studies that show FDI having a positive effect on local firms' productivity. It has been shown that FDI has a positive effect on the labor productivity of local firms.[1] Furthermore, recent studies show that spillovers of FDI

[1] For instance, Kokko (1994) on Mexico, Chuang and Lin (1999) on Taiwan, Blomstrom and Sjoholm (1999), and Takki (2005) on Indonesia.

have different effects in different markets or through different channels. Gorg and Hijzen (2004) reports that multinationals have positive effects on local firms in export markets, but finds no effect on local firms in national markets. Javorcik (2004) on Lithuania, Blalock and Gertler (2004) on Indonesia, and Kugler (2006) on Columbia all find that spillovers from multinationals affect local firms in the supply industry through business partnerships.

Second, other studies argue that FDI does not lead to spillovers,[2] but does have a negative effect on local firms. Aitken and Harrison (1999) shows the negative effect of FDI by using Venezuela data, and they argue that increasing competition in the local market and stealing the local firms' market share leads to higher costs for local firms.

There are some studies that focus on the knowledge spillovers related to patents and R&D. For instance, Branstetter (2006) focuses on knowledge spillovers using patent citations data and finds that spillovers occur both to and from Japanese firms that have invested in the United States. In addition, Branstetter (2001) and Todo (2006) investigate technology spillover effects by using R&D data. For example, Todo (2006) shows that the industry R&D of multinationals has a positive impact on the productivity level of local firms and argues that intra-industry knowledge spillovers occur through the R&D activities of foreign firms, but not through their production activities. He explains that labor turnover across firms facilitates technology spillovers embodied in human capital because local employees working for multinationals with R&D activities gain much more knowledge than employees of foreign firms without R&D activities. On the other hand, Branstetter (2001) investigates the knowledge spillovers of both Japanese and U.S. firms, and shows that intra-national spillovers are much more important than international spillovers.

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[2] For instance, Haddad and Harrison (1993) on Morocco

We can also find many studies on FDI spillovers in China. Liu (2008) studies the effect of FDI spillovers to local firms. He points out that it is very important to distinguish between the short-term and long-term effects of spillover. In other words, he finds that an intra-industry increase of FDI lowers the short-term productivity level but raises the long-term rate of productivity growth for local firms. Girma and Gong (2008) focuses on the impact of FDI on state-owned firms. They suggest that foreign finance has a positive effect on state-owned firms in terms of productivity, profitability, and employment, but increased competition caused by FDI has a negative impact on state-owned firms that do not receive foreign capital. Hale and Long (2006) finds that FDI has a positive effect on firms with higher productivity, by means of the labor flow channel and network effect channel, through activities such as attending commercial exhibitions.

These past studies measure spillover effect by the amount of a multinational's production. However, technology spillovers can be better captured by a multinational's R&D activities. In addition, industry characteristics should be taken into account in order to draw more precise implications. These are some points which differentiate our study from the existing literature.

3. The Automobile and Electronics Industries in China

3.1 Automobile Industry

Before the 1980s, auto firms were strictly controlled by the government and most of the auto firms were state-owned with a central focus on the commercial car. In the 1980s, as a result of earlier reforms and greater openness, three partially foreign-owned firms (Beijing Jeep, Guanzhou Peugeot and Shanghai VW) were permitted to enter the Chinese market. In order to strengthen local auto firms' competitiveness, policies specifically designed for auto firms ("qi che gong ye chan ye zheng ce") were implemented in 1994. This was the first time the Chinese government disclosed its automobile policy to the outside world, and it helped international carmakers make investment decisions in China (Wang, 2004). These policies were designed to: (1) consolidate fragmented small domestic automobile companies by entry regulation, (2) foster the automobile components industry by protecting it from international competition, and (3) regulate FDIs. Since then, almost every big auto firm in the world has entered the Chinese market as a joint venture with a Chinese state-owned enterprise. At the same time, several domestic auto firms, such as Jili and Chery, also entered the market but were heavily dependent on foreign technology.

China's automobile production has increased tremendously, reaching 7.38 million units in 2007, which is the third largest volume after the U.S. and Japan. However, foreign-owned companies command a large market share, leaving local companies such as Jili and Chery in a difficult situation. In addition, domestic automobile parts companies are still more vulnerable than their international counterparts (Jin, 2005). It has been pointed out that the transfer of the multinationals' technology to local joint ventures has not been occurring. Commanding the biggest research institute among the top three local auto firms, First Automotive Works (FAW) professed to have developed its new "Hong Qi" car independently, despite the fact that a Chrysler engine, VW transmission, and Audi car body are all used in the "Hong Qi."[3]

Technology transfer from the multinationals to local firms is seemingly controlled strictly by the multinationals. For example, GM and Pan Asia Technology

[3] Moreover, a new car which is produced by local maker Hafei, utilizes the car body design of Pininfarina, install the Mitsubishi Motors' engine, and take the crash-test of Mira. Local auto firms not only order the car parts from outside, but also purchase the module from outside.

Automotive Center Co., Ltd. (hereafter PATAC) jointly developed the “Feng huang” vehicle model, but PATAC did not get the key technology behind “Feng Huang” from GM in the end.

However, at the same time, there is some evidence suggesting that technology transfer did occur in the manufacturing process. For example, Toyota dispatched more than 150 engineers directly to its local partner Tianjin FAW Toyota Motor Co., Ltd. (hereafter TFTM) in order to introduce the Toyota production system to TFTM. Moreover, it seems that technology is transferred through both imitation and job turnover. Chery Automobile's new vehicle model was developed by engineers from a joint venture with VW (Jin, 2005). There are mixed views on the effects of multinationals' technology spillover on domestic companies, but we cannot deny the notion that technology is gradually passed on from multinationals in various forms, such as job turnover in an embodied technology spillover and business partnership in a disembodied one.

3.2 Electronics Industry

The development of the electronics industry in China shows a completely different picture than the automobile industry. There are a large number of past studies showing how international production fragmentation by U.S. and Japanese electronics firms has turned East Asian countries into global manufacturing bases (Borrus et. al, 2000; Bonham et. al, 2007). At first Taiwan became a hub of electronics components suppliers for U.S. and Japanese firms, then China followed in the tracks of Taiwan. There is also a significant influence from Taiwan’s FDI on the development of the electronics industry in mainland China. The Chinese government has applied an open door policy for this industry, in contrast to a managed FDI policy for automobile industries, and multinationals’ investments have been encouraged with tax incentives, lower customs duties and so on.

As well as attracting foreign capital to this industry, the Chinese government has made every effort to improve the competitiveness of domestic companies. In a series of high-tech industry development programs, such as the 863 Plan, Torch Program, and Character "Gold" project, information technology development has always been a priority area. An important difference between domestic electronics companies and automobile companies is ownership structure. Before the 1990s most electronics firms were collective-owned firms, while most auto firms were state-owned firms and more strictly controlled by the government. Recently, private-industry firms have been emerging in this industry, such as Huawei Technology, an internationally competitive communications equipment manufacturer. In the computer industry, Lenovo acquired IBM's personal computer divisions and has now become the third largest PC company in the world. In the consumer electronics industry, Haier has gained the largest share of the domestic economy and now exports its product worldwide. The existence of such world class domestic companies in the electronics industry further differentiates it from the automobile industry.

In comparison to the assembly industry, China's electronics component industry is still lagging behind in terms of international competitiveness. A major part of electronics exports comes from final products, and a substantial trade deficit can be found in the components sector (Motohashi, 2008). However, semiconductor foundry firms, such as SMIC (Semiconductor Manufacturing International Corporation) and Shanghai HuaHong, have invested in 300 mm wafer advanced manufacturing facilities, and BOE-OT (Beijing BOE Optoelectronics technology Co., Ltd.), a Beijing-based flat panel manufacturer, is catching up with Japanese and Korean manufacturers. Again, we can see the technology gap closing faster than compared to the automobile parts industry.

3.3 Comparing the Two Industries with One Another

Finally, we compare the industrial development of automobile and electronics industries by using datasets from China's National Bureau of Statistics. The primary data are taken from the annual Survey of Science and Technology Activities that includes all large- and medium-scale enterprises (LMEs). In 1998-2003 there were roughly 22,000 samples in each year, and there were roughly 28,000 samples in 2004. The percentage of science and technology (S&T) spending by LMEs in 2000 was 67.3% of the total spending by all companies, and the dataset covers a significant share of the S&T activity at manufacturing multinationals in China (Motohashi and Yun, 2007).

In this paper, because we are focusing on electronics firms and auto firms, we extracted only the data of these firms from the dataset. Vehicle body manufacturers and vehicle parts manufacturers are included in the auto supply industry, while auto manufacturers are included in the auto assembly industry. Consumer electronics manufacturers and computer manufacturers are included in the electronics assembly industry, while manufacturers of electronics components, such as semiconductor manufacturers, integrated circuit manufacturers and so on are included in the electronics supply industry. The four-digit industry classification of the automobile and electronics firms is shown in Table 1.

Table 2 shows a sharp contrast between the two industries. While the share of multinationals in the total number of firms increased from 1994 to 2005 in both industries, its rate of increase is significantly higher for the electronics industry. These findings reflect the difference in FDI policy between the two industries. In the automobile industry, both completely foreign-owned and partially foreign-owned firms increased in the supply industry, but in total they accounted for only 30% share of the industry at the end of 2004. In the assembly industry, partially foreign-owned firms increased their share of the industry to about 25% at the end of 2004, but due to the regulation of the assembly industry only one fully foreign-owned firm is found in our dataset.

On the other hand, both fully foreign-owned and partially foreign-owned electronics firms increased their numbers in the supply industry, with the fully foreign-owned electronics firms showing an especially rapid increase. At the end of 2004, the total number of fully foreign-owned and partially foreign-owned electronics firms accounted for about 50% share of the supply industry. And there is a similar trend for electronics firms in the assembly industry. Moreover, the share of fully foreign-owned firms is relatively larger for the electronics industry.

Figures 1-4 show the value-added share of full foreign-owned firms, partially foreign-owned firms, and local firms for four types of industry category. The figures indicate that the value-added share of foreign firms is increasing rapidly while the value-added share of local firms is decreasing. With the exception of the automobile parts industry, the share of foreign-owned firms' output exceeded 50% of total output in 2004. The value added in the automobile parts industry did not grow as fast as that of the assembly industry, which suggests that highly value-added automobile parts are being supplied by imports and the domestic industry has not been developing very well.

The indices in Table 3 indicate the value added per employee, R&D stock per employee, and number of employees of automobile and electronics firms in China. In both the assembly and supply industries we can find that the multinationals are larger than local firms in every category except the number of employees. In the assembly industry, value added per employee of automobile multinationals is eightfold times that of local firms and the R&D stock per employee is fourfold. That means that automobile multinationals in the assembly industry not only have higher productivity (value added per employee) but also put more effort into R&D than do local auto firms. Auto multinationals in the supply industry are also higher in productivity than the local auto firms, but the differences are not as large as they are for auto firms in the assembly industry. In the electronics industry, local firms are smaller than multinationals in size, but the difference is not as large as the automobile industry.

4. Econometric Analysis

In this section, we focus on the productivity impact of multinationals and the other local companies on local parts supply firms. In order to investigate the productivity impact of these technology spillover routes, we estimate the following Cobb-Douglas type production function.

$$\ln va_{it} = \beta_0 + \beta_1 \ln k_{it} + \beta_2 \ln emp_{it} + \beta_3 \ln R_{it} + \beta_4 \ln spillover_{it} + \beta_5 imdummy_{it} + \beta_6 share_{it} + \upsilon_i + \varepsilon_{it} \quad (1)$$

Where,

va_{it} : value added

k_{it} : capital stocks

emp_{it} : number of employees

R_{it} : R&D stock

$spillover_{it}$: R&D spillover

$share_{it}$: market share of sales of firm i in the industry and the province

$imdummy_{it}$: dummy variable that indicates whether a firm imports technology, if a firm imports in that period, $imdummy_{it}$ equals 1, otherwise

$imdummy_{it}$ equals 0.

υ_i : unobservable firm's specific effect and

ε_{it} : error term

In this paper, we use the following six R&D spillover variables to examine R&D spillovers.

$R_{a,jt}$: R&D stock in assembly sector (f) of province j in year t , and is measured as $R_{a,jt} = \sum_{i \in j} R_{a,it}$

$R_{s,jt}$: R&D stock in supply industry (s) of province j in year t , and is measured as $R_{s,tj} = \sum_{i \in j} R_{s,it} - R_i$

$R^m_{a,jt}$: R&D stock of multinationals (m) in assembly sector (f) of province j in year t , and is measured as $R^m_{a,jt} = \sum_{i \in j} R^m_{a,it}$

$R^l_{a,jt}$: R&D stock of local firms (l) in assembly sector (f) of province j in year t , and is measured as $R^l_{a,jt} = \sum_{i \in j} R^l_{a,it}$

$R^m_{s,jt}$: R&D stock of multinationals (m) in supply industry (s) of province j in year t , and is measured as $R^m_{s,jt} = \sum_{i \in j} R^m_{s,it}$

$R^l_{s,jt}$: R&D stock of local firms (l) in supply industry (s) of province j in year t , and is measured as $R^l_{s,tj} = \sum_{i \in j} R^l_{s,it} - R_i$

Value added is estimated as deflated gross output minus deflated intermediate inputs using a double deflation method. We use the ex-factory output price in the Chinese Statistics Yearbook for the output deflator. Input deflators for intermediate inputs are calculated as a weighted-average of input commodity prices (again using the ex-factory output price) by using the information in the 2002 benchmark Input and Output table. In our dataset, there are two different types of book value capital stock data for structure and machinery. Both data are deflated by the investment price data of the corresponding category in the Chinese Statistical Yearbook. Here, we use the average of end-of-period and beginning-of-period capital stock values.

Because of the technology and knowledge that firms have gained through the accumulation of technology and past experience, we construct R&D stock as follows. First, we deflate nominal R&D expenditure by GDP deflator[4] to get real R&D expenditure. Then following previous studies on China (such as Hu et al., 2005; Hu and Jefferson, 2004), we use the perpetual inventory method to construct R&D stock under the assumption of a 15% depreciation rate[5] and constant growth rate of R&D expenditure. We apply different depreciation rates (18% and 20%) to check the sensitivity of our results to R&D stock, and to get robust estimation results.[6] This R&D capital stock ($\ln R_{it}$) is used as an independent variable because past studies have shown that in-house R&D plays a positive role in shaping the productivity of Chinese manufacturing industries (Hu and Jefferson, 2004; Hu et al., 2005; and Zhang et al., 2003).

This firm-level R&D stock is used for calculating our key variables reflecting the amount of technology spillovers. We focus on the technology spillover effects on domestic parts and components firms, with Figure 5 illustrating the possible routes of technology spillovers, i.e., (1) from assembly firms ($R_{a,}$), (2) from foreign assembly

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4 GDP deflator is taken from the China Statistical Yearbook.

5 Many previous studies on China use an annual depreciation rate of 15% for R&D stock, such as Hu et al. (2005), Hu and Jefferson (2004), Bin (2008) and so on.

6 In addition, Hall and Mairesse (1995) find that choice of depreciation rate for R&D makes little difference.

firms (R_a^m), (3) from local assembly firms (R_a^l),(4) from supply firms (R_s), (5) from foreign supply firms (R_s^m) and (6) from other local supply firms (R_s^l). All of the technology spillover variables are calculated as a sum of R&D stock of firms located in the same city or province and corresponding to each category type.

In addition, we have several other controlling variables for estimation. First, Hu et al. (2005) on China, and Hasan (2002) and Katrak (1989) on India, all show that import technology is important for firms to enhance productivity. Following Katrak (1989), we use a dummy variable ($imdummy_{it}$) to control the impact of import technology on firms' productivity in this paper. Furthermore, it is considered local firms would lose market share to multinationals with the entrance of multinationals into the market. Therefore, in order to control changes in market share, market share is used as a control variable such as in Todo (2006). Here we also use $share_{it}$ as a control variable.

China is a large country, and there is a significant variance in the level of economic and technological development across regions. For example, a local automobile parts firm in a western rural area may be producing totally different products than a local firm in a coastal area collaborating with multinationals. In order to reduce biases associated with such product differentiation, we use only observations for multinationals with R&D activities in both assembly and supply industries in their own province. Table 4 shows the changes in the sample firms and total firms. As multinationals spread their production and R&D locations throughout China, the number of observations in our analysis gradually increases. Table 5 shows the summary statistics of our independent variables.

Table 6 contains the results for the automobile industry. The results by fixed effect model estimations are presented, because the Hausman test rejects the null hypothesis of random individual firm effects for all specifications. We start by (1) testing the vertical spillover effect in model, then (2) looking at the effects of multinationals and domestic firms separately in model. Next, in models (3) and (4) the same types of regressions are conducted for horizontal spillover effects. Finally, in models (5) and (6) both vertical and horizontal spillover effects are included in the production function.

We have found the results to be consistent throughout these models. First, a strong vertical technology spillover effect is found from foreign-owned firms, but the same effect cannot be found from domestic assembly firms. This finding reflects that close coordination between supplier and assembler is needed for automobile products, while technology spillover also takes place in such a vertical coordination process. Since multinational assemblers are technologically superior to domestic firms, horizontal spillover is eminent in the multinational route. On the other hand, local automobile assemblers are not working together with their suppliers very well because they cannot produce a car by their own technology. Instead, they are importing key components from multinationals in order to fill significant technological gaps with multinational assemblers (Jin, 2005).

Second, we have found horizontal spillover effects as well in this industry, but these effect are mainly coming from local parts suppliers. It is natural to find technology spillover effects within the same industry, because labor turnover across firms is one of the important channels of technology spillover. In addition, information communications across firms and imitation are also important means of spillover. However, FDI in the automobile parts industry has been strictly regulated, and the number of multinationals in this industry is still small (Table 2). Therefore, the route between domestic parts suppliers shows up in our estimation results.

In Table 7, the results of corresponding models for the electronics industry are presented. There is a striking difference from automobile industry, that is, we cannot find a vertical spillover effect here. This is consistent with our hypothesis that electronics products have modular architecture, which in general makes close coordination between parts suppliers and assemblers unnecessary. In contrast, horizontal spillover effects are found in the electronics industry as well, but the prominent route in this industry is from foreign-owned parts suppliers. Again, possible channels of horizontal technology spillovers, such as labor turnover, information communications, and imitation, exist with both multinationals and domestic suppliers. On the other hand, we cannot find any spillover effect from local firms in the assembly industry either.

The superiority in the path from multinational to domestic firm as a source of spillover can be explained by its relative technology level. A patent data analysis of the technological capability of Chinese firms shows that electronics firms in China are still lagging behind international competitors in the U.S. and Japan (Motohashi, 2007). As water falls faster from a higher place, technology spillover may occur more from multinationals than from local firms.

Figures 6 and 7 illustrate the results from Tables 6 and 7. First, horizontal spillover effects seem stronger than vertical spillover effects in both industries. This is consistent with existing studies, in a sense that greater technology spillover effects can be found between firms with closer technology proximity (Jaffe, 1986). Within the same industry, both embodied (with human capital) and disembodied (via information communications) technology flows will work more effectively than compared to flows between firms in different industries. Technology spillover effects are also found more in the automobile industry. Particularly the fact that we can find vertical spillover effects in this industry makes it consistent with our hypothesis based on the difference in product architecture (Takeishi and Fujimoto, 2001). According to a Japanese national innovation survey conducted by the Ministry of Education, Science and Technology, 93% of automobile firms perceive clients as a source of information for innovation, and 92% of cite parts suppliers as another source, while the corresponding numbers for the electronics industry are 79% and 77%, respectively (NISTEP, 2004). Therefore, vertical technology spillover is more important for the automobile industry than the electronics industry.

5. Conclusions

This study compares knowledge spillovers from multinationals to local firms between the automobile and electronics industries of China. In the automobile industry, we find that multinationals in the assembly industry have vertical spillover effects to domestic parts supply firms and there are also horizontal spillovers between domestic parts suppliers. In contrast, we cannot find vertical spillover effects from multinationals in the assembly industry to domestic suppliers in the electronics industry, where only horizontal spillover effects from multinationals to domestic supply firms can be found.

We can draw some policy implications from our analysis. First, horizontal technology spillover effects are important for the productivity growth of local firms in both industries. It should be noted that the various channels of technology spillovers, such as labor turnover, informal communications, and imitation occur more for firms within close technological and regional proximity. Therefore, high-tech cluster policies such as the Torch Program are important for the development of domestic local companies.

The second implication is the importance of modifying development strategy by industry. In the electronics industry, which is characterized by modular architecture, closing the technology gap can be achieved by focusing on specific components in the global supply chain. This is a key factor for firms in East Asian countries trying to catch up with their industry counterparts in the U.S. and Japan (Hobday, 1995). Therefore, laissez-faire trade policy is important for the electronics industry.

In contrast, in the automobile industry, which is characterized by integrated architecture, the close coordination of assemblers and parts suppliers is more important. Therefore, FDI policy should be carefully managed, but multinational investments in assembly firms should be welcomed. The formation of clusters with local parts suppliers is also important for this industry.

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Table 1: Definition of supply and assembly industry

Sector name	Total
(Automobile industry)	
Trucks	722
Passenger trains	282
Passenger vehicles	80
Light vehicles	77
	1161
Motor vehicles bodies and trailers	173
Motor vehicles parts and accessories	4908
	5081

Sector name	Total
(Electronics industry)	
Computers	376
Computer accessaries	543
Generator-motors	368
Generator-rotating electrical machines	1059
Electrical machines	404
Washng machines	292
Vacuum cleaners	45
Refrigerators	385
Electric fans	306
Air-conditioners	528
Kitchen wares	125
Other daily electronic products	408
Electric lighting fixtures	234
	5073
Vacuum equipments	932
Semiconductor manufacturing equipments	36
Integrated circuits	157
composite parts	924
Relay switches	437
Rectifiers	379
capacitors	2076
Switching power	190
Electronics parts	499
Switching power supplies and remote control	262
Wiring devices and supplies	78
Insulation products	28
Storage batteries	82
Primary batteries (dry and wet)	383
Electric bulbs	702
Electric lighting fixtures	328
Other lighting fixtures	2893
	10386

Table 2: Number of samples by firm type

Ownership of Auto Firms

type	Supply industry							Assembly industry						
	Full Foreign-Owned	Full Foreign-Owned(%)	Partial Foreign-Owned	Partial Foreign-Owned(%)	Local	Local (%)	Total	Full Foreign-Owned	Full Foreign-Owned(%)	Partial Foreign-Owned	Partial Foreign-Owned(%)	Local	Local (%)	Total
1995	3	0.8%	20	5.3%	351	93.9%	374	0	0.0%	8	7.0%	107	93.0%	115
1996	3	0.7%	35	8.3%	384	91.0%	422	0	0.0%	9	8.2%	101	91.8%	110
1997	7	1.5%	54	11.7%	402	86.8%	463	0	0.0%	10	9.2%	99	90.8%	109
1998	10	2.1%	59	12.3%	411	85.6%	480	0	0.0%	15	12.6%	104	87.4%	119
1999	13	2.6%	81	16.3%	404	81.1%	498	0	0.0%	14	12.3%	100	87.7%	114
2000	18	3.5%	88	17.0%	411	79.5%	517	0	0.0%	14	12.7%	96	87.3%	110
2001	36	6.7%	98	18.1%	407	75.2%	541	0	0.0%	15	13.8%	94	86.2%	109
2002	41	7.5%	105	19.2%	402	73.4%	548	0	0.0%	17	15.7%	91	84.3%	108
2003	38	7.1%	86	16.0%	412	76.9%	536	1	0.9%	28	25.0%	83	74.1%	112
2004	85	12.1%	114	16.2%	503	71.7%	702	0	0.0%	40	25.8%	115	74.2%	155

Ownership of Electronics Firms

type	Supply industry							Assembly industry						
	Full Foreign-Owned	Full Foreign-Owned(%)	Partial Foreign-Owned	Partial Foreign-Owned(%)	Local	Local (%)	Total	Full Foreign-Owned	Full Foreign-Owned(%)	Partial Foreign-Owned	Partial Foreign-Owned(%)	Local	Local (%)	Total
1995	10	1.1%	61	6.5%	862	92.4%	933	8	1.7%	33	7.0%	433	91.4%	474
1996	17	1.7%	74	7.5%	898	90.8%	989	11	2.2%	54	10.7%	438	87.1%	503
1997	23	2.3%	90	9.1%	881	88.6%	994	15	2.9%	63	12.4%	431	84.7%	509
1998	36	3.7%	110	11.2%	839	85.2%	985	23	4.7%	59	11.9%	412	83.4%	494
1999	58	6.1%	124	13.0%	772	80.9%	954	28	6.2%	58	12.9%	365	80.9%	451
2000	65	6.8%	138	14.4%	756	78.8%	959	36	8.3%	62	14.3%	336	77.4%	434
2001	101	9.4%	171	16.0%	800	74.6%	1072	54	11.9%	73	16.1%	326	72.0%	453
2002	137	12.5%	174	15.9%	782	71.5%	1093	74	15.8%	72	15.4%	323	68.9%	469
2003	239	23.2%	166	16.1%	626	60.7%	1031	119	21.4%	76	13.6%	362	65.0%	557
2004	463	30.6%	238	15.7%	812	53.7%	1513	241	33.1%	102	14.0%	386	52.9%	729

Table 3: Performance variables by firm type

	Auto firms in assembly industry								
	All			Multinationals			Local		
Variable	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.
value added/number of employee	1122	114.36	319.70	169	428.26	674.59	953	58.69	139.47
R&D stock/number of employee	1122	16.84	57.10	169	46.61	96.55	953	11.57	44.82
number of employee	1135	3988.45	10826.04	170	3581.32	4059.69	965	4060.17	11616.71
	Electronics firms in assembly industry								
	All			Multinationals			Local		
Variable	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.
value added/number of employee	4993	73.44	393.01	1249	147.40	755.01	3744	48.76	116.21
R&D stock/number of employee	4994	14.10	59.06	1249	18.14	52.79	3745	12.76	60.95
number of employee	5014	1283.03	2047.90	1255	1262.01	2543.29	3759	1290.05	1853.61
	Auto firms in supply industry								
	All			Multinationals			Local		
Variable	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.
value added/number of employee	4990	65.44	258.11	989	179.31	509.46	4001	37.30	122.41
R&D stock/number of employee	4992	10.25	113.16	989	18.22	49.27	4003	8.28	123.89
number of employee	5019	929.72	1310.34	989	663.17	752.07	4030	995.13	1406.43
	Electronics firms in supply industry								
	All			Multinationals			Local		
Variable	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.
value added/number of employee	10258	64.16	153.36	2453	124.61	222.48	7805	45.17	117.69
R&D stock/number of employee	10259	13.19	62.40	2453	23.41	100.13	7806	9.98	43.86
number of employee	10296	959.74	1406.54	2455	900.11	1138.84	7841	978.41	1480.01

Table 4: Number of samples for regression analysis

	Electronics firms		Auto firms	
	Sample firms	Total firms	Sample firms	Total firms
1996	250	676	84	268
1997	336	759	94	333
1998	280	663	110	309
1999	295	652	118	319
2000	314	675	127	363
2001	317	641	128	342
2002	350	696	141	356
2003	208	391	129	248
2004	302	494	142	320
Total	2652	5647	1073	2858

Table 5: Descriptive statistics

Automobile Firms

Variable	Obs	Mean	Std. Dev.	Min	Max	Median
lnva	1375	9.825	1.264	5.352	13.702	9.868
lnk	1034	10.999	0.988	5.763	14.482	10.911
lnemp	1374	6.528	0.848	2.708	9.968	6.554
lnR	1375	5.650	3.685	0.000	13.167	7.050
$\ln R_a$	1375	13.010	1.192	9.445	14.775	13.236
$\ln R_s$	1375	12.381	1.008	9.261	14.510	12.491
$\ln R_a^m$	1375	11.373	1.928	6.628	14.549	11.889
$\ln R_a^l$	1375	12.039	2.062	5.964	14.691	12.705
$\ln R_s^m$	1375	9.904	1.888	6.806	13.540	9.742
$\ln R_s^l$	1375	12.056	1.097	7.090	14.033	12.265
imdummy	1375	0.128	0.334	0.000	1.000	0.000
share	1375	0.003	0.010	0.000	0.215	0.001

Electronics Firms

Variable	Obs	Mean	Std. Dev.	Min	Max	Median
lnva	3406	9.836	1.391	5.045	14.449	9.867
lnk	2503	10.885	1.026	2.655	14.912	10.786
lnemp	3404	6.349	0.825	1.386	10.094	6.306
lnR	3406	5.837	3.906	0.000	13.524	7.179
$\ln R_a$	3406	12.676	1.481	9.699	15.858	12.458
$\ln R_s$	3406	12.891	1.172	8.713	15.182	12.779
$\ln R_a^m$	3406	10.817	2.074	4.382	15.051	10.895
$\ln R_a^l$	3406	11.998	1.817	6.284	15.802	11.885
$\ln R_s^m$	3406	10.776	2.357	4.846	14.743	11.479
$\ln R_s^l$	3406	12.451	1.269	6.988	14.791	12.416
imdummy	3406	0.179	0.384	0.000	1.000	0.000
share	3406	0.017	0.051	0.000	0.882	0.005

Table 6: Regression results (1)

Automobile Firms		Dependent variable: log of value added					
		1	2	3	4	5	6
lnk	Log of capital stocks	0.133	0.181*	0.145	0.155	0.147	0.180*
		(0.106)	(0.107)	(0.106)	(0.106)	(0.106)	(0.107)
lnemp	Log of employee	0.647***	0.627***	0.644***	0.638***	0.646***	0.626***
		(0.089)	(0.088)	(0.088)	(0.088)	(0.088)	(0.088)
$\ln R_a$	Log of the assembly industry R&D stocks in the same province	0.078				0.074	
		(0.053				(0.052)	
$\ln R_s$	Log of the supply industry R&D stocks in the same province			0.112**		0.110**	
				(0.053)		(0.053)	
$\ln R_a^m$	Log of the assembly industry R&D stocks of multinationals in the same province		0.118***				0.093**
			(0.038)				(0.042)
$\ln R_a^l$	Log of the assembly industry R&D stocks of local firms in the same province		-0.001				0.004
			(0.031)				(0.031)
$\ln R_s^m$	Log of the supply industry (the same industry) R&D stocks of multinationals in the same province				0.057		0.016
					(0.039)		(0.043)
$\ln R_s^l$	Log of the supply industry (the same industry) R&D stocks of local firms in the same province				0.137***		0.110**
					(0.051)		(0.053)
lnR	Log of firm's own R&D stock	0.013	0.017	0.015	0.02	0.019	0.023
		(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)
imdummy	Firm imports technology 1, otherwise 0	0.016	0.016	0.017	0.018	0.014	0.016
		(0.079)	(0.079)	(0.079)	(0.079)	(0.079)	(0.078)
share	Market share	5.643	4.468	5.116	4.884	5.5	4.666
		(3.698)	(3.688)	(3.683)	(3.689)	(3.69)	(3.699)
Constant		3.256**	2.348	2.774*	1.757	1.708	1.044
		(1.47)	(1.437)	(1.465)	(1.521)	(1.648)	(1.582)
Yeardummy		Yes	Yes	Yes	Yes	Yes	Yes
Observations		1033	1033	1033	1033	1033	1033
Number of coden		368	368	368	368	368	368
R-squared		0.18	0.19	0.18	0.19	0.18	0.19

Standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Table 7: Regression results (2)

Electronics Firms		Dependent variable: log of value added					
		1	2	3	4	5	6
lnk	Log of capital stocks	0.322***	0.323***	0.320***	0.319***	0.321***	0.321***
		(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
lnemp	Log of employee	0.497***	0.506***	0.499***	0.500***	0.497***	0.508***
		(0.052)	(0.052)	(0.052)	(0.052)	(0.052)	(0.052)
$\ln R_a$	Log of the assembly industry R&D stocks in the same province	0.019				0.017	
		(0.03)				(0.031)	
$\ln R_s$	Log of the supply industry R&D stocks in the same province			0.015		0.009	
				(0.038)		(0.039)	
$\ln R_a^m$	Log of the assembly industry R&D stocks of multinationals in the same province		0.017				0.016
			(0.013)				(0.013)
$\ln R_a^l$	Log of the assembly industry R&D stocks of local firms in the same province		-0.032				-0.038
			(0.031)				(0.031)
$\ln R_s^m$	Log of the supply industry (the same industry) R&D stocks of multinationals in the same province				0.030*		0.030*
					(0.016)		(0.017)
$\ln R_s^l$	Log of the supply industry (the same industry) R&D stocks of local firms in the same province				-0.022		-0.029
					(0.038)		(0.038)
lnR	Log of firm's own R&D stock	0.013	0.013	0.013	0.01	0.013	0.009
		(0.028)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)
imdummy	Firm imports technology 1, otherwise 0	0.139***	0.140***	0.138***	0.138***	0.138***	0.140***
		(0.042)	(0.042)	(0.042)	(0.042)	(0.042)	(0.042)
share	Market share	1.300**	1.293**	1.317**	1.340**	1.311**	1.328**
		(0.568)	(0.568)	(0.57)	(0.569)	(0.57)	(0.569)
Constant		2.653***	3.006***	2.689***	2.883***	2.568***	3.161***
		(0.624)	(0.605)	(0.682)	(0.674)	(0.719)	(0.753)
Yeardummy		Yes	Yes	Yes	Yes	Yes	Yes
Observations		2503	2503	2503	2503	2503	2503
Number of coden		834	834	834	834	834	834
R-squared		0.19	0.19	0.19	0.19	0.19	0.19

Standard errors in parentheses

* significant at 10%; ** significant at 5%; *** significant at 1%

Figure 1

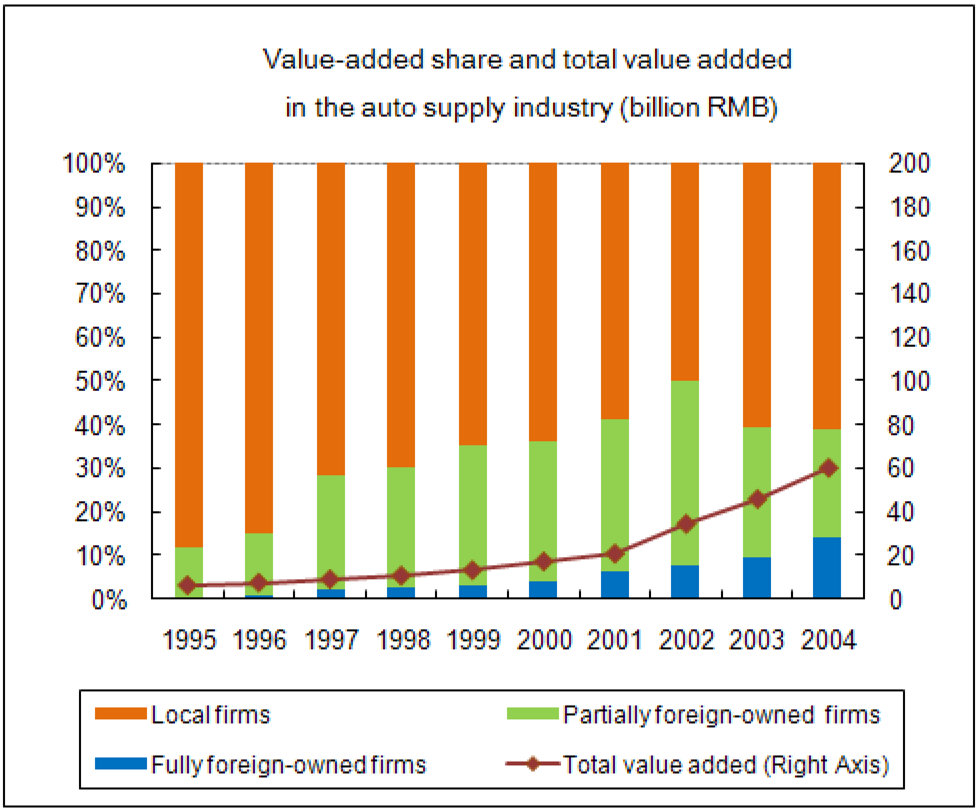


Figure 2

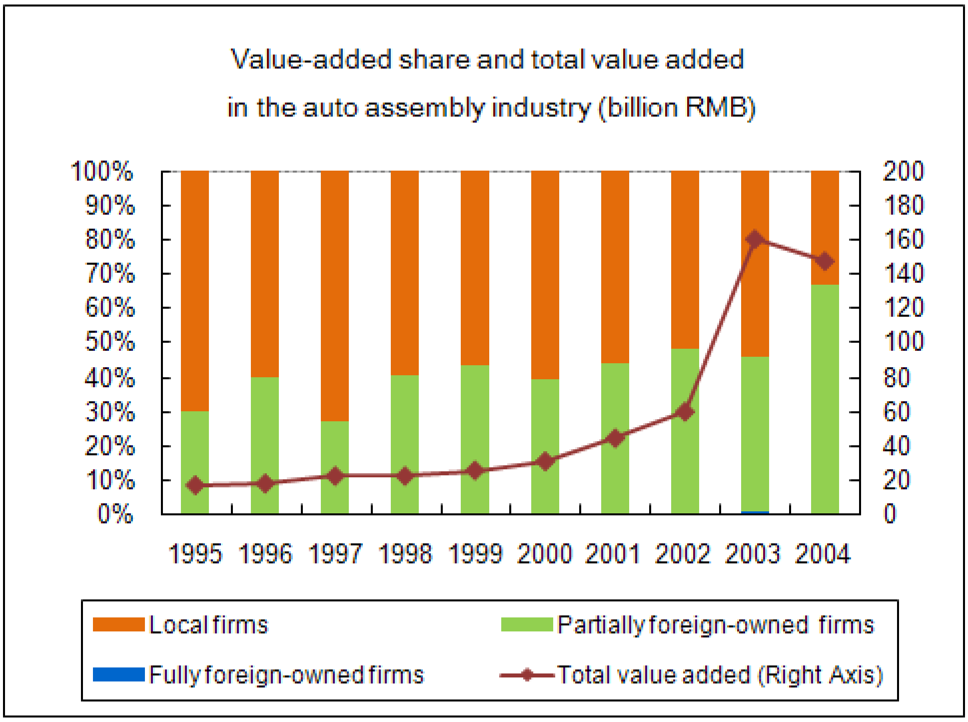


Figure 3

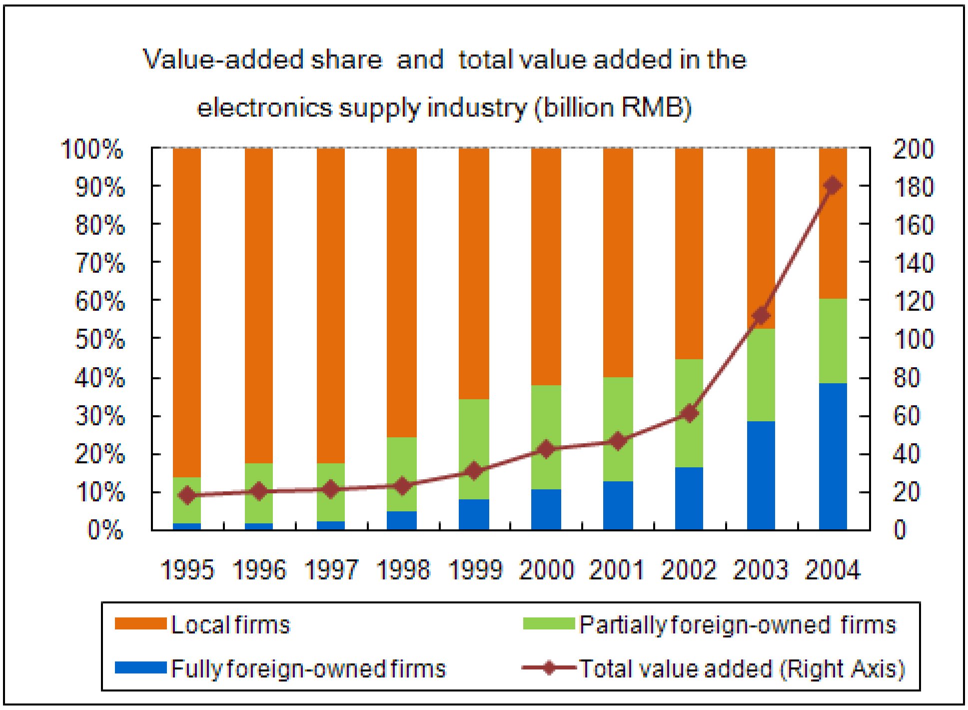


Figure 4

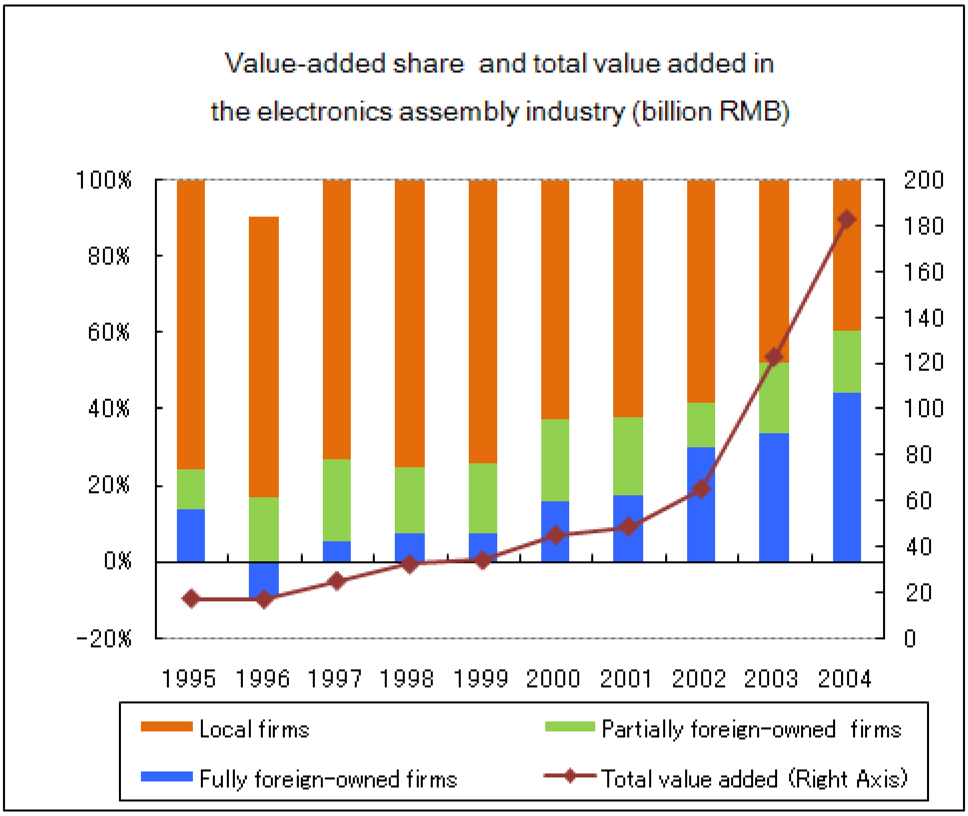


Figure 5

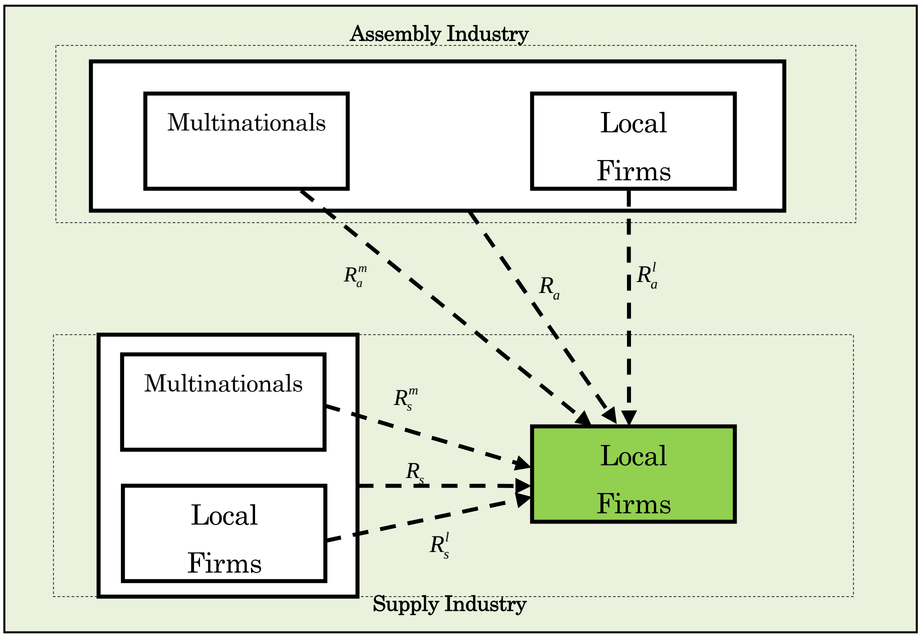


Figure 6

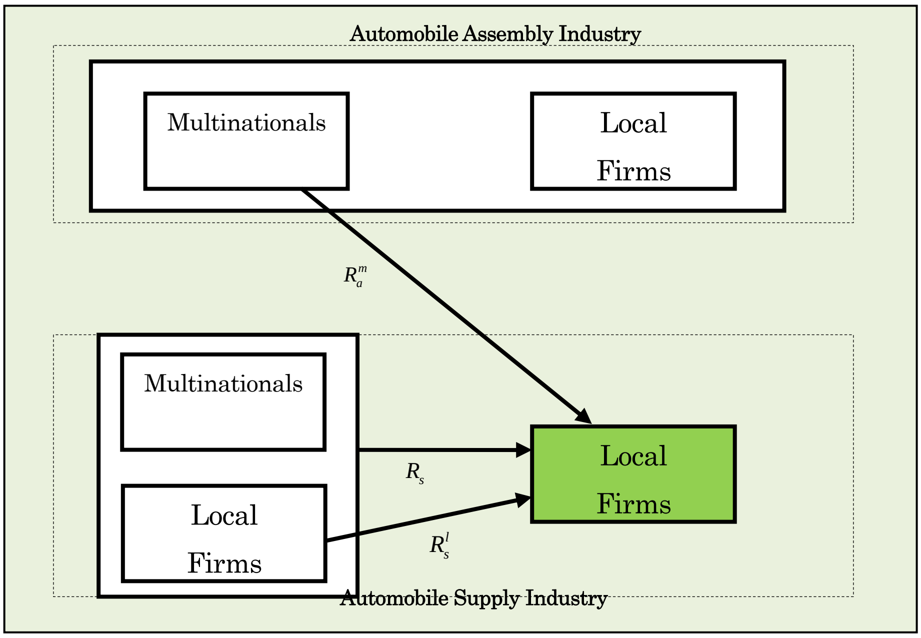
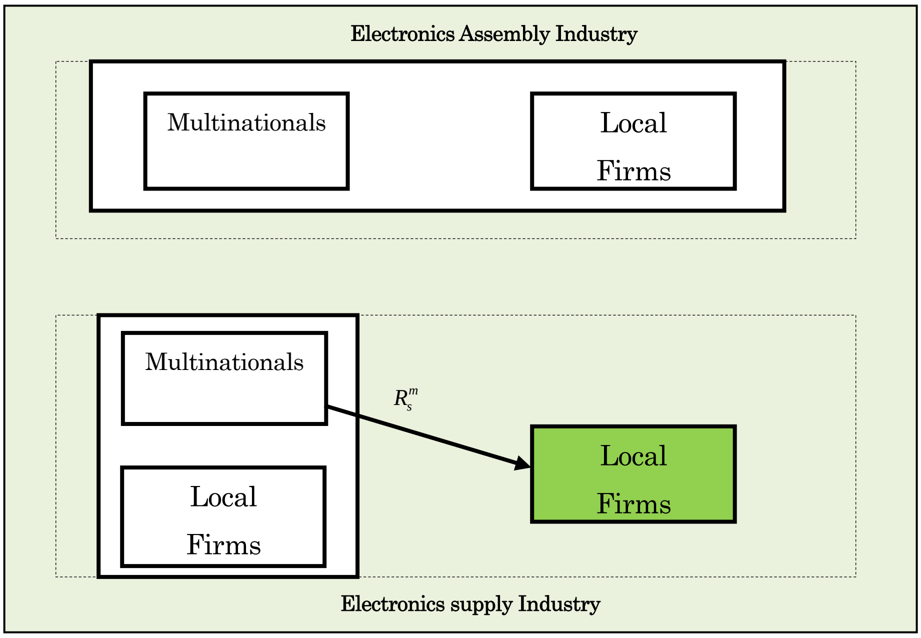


Figure 7



Electronics Assembly Industry
Multinationals
Local
Firms
Multinationals
R_s^m
Local
Firms
Local
Firms
Electronics supply Industry