ERIA-DP-2015-15

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ERIA Discussion Paper Series

China's Semiconductor Industry in Global Value Chains*

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February 2015

Abstract: *This article examines how global production networks have benefited technological upgrading in the semiconductor industry in China. The evidence shows that trade has impacted positively on technological capabilities. The empirical evidence show that 93 percent of firms were engaged in incremental innovation activities, while 87 percent in new product development in 2012. The mean R&D intensity was 6.3 percent. State-owned enterprises showed the lowest mean of 5.3 percent. The mean share of R&D personnel in workforce was 28.2 percent. Government support (90 percent) and collaboration with universities and research institutes (87 percent) has been pertinent in firms' participation in R&D activities.*

Keywords: China, innovation, integrated circuit, semiconductors, technological capabilities

JEL Classification: L62, L22, L14, O31

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* We acknowledge financial support from Economic Research Institute for ASEAN and East Asia (ERIA). We are grateful to two anonymous referees for their incisive comments. The paper is under review for a special issue of *Asia Pacific Business Review* (www.tandfonline.com/fapb).

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1. Introduction

The Chinese semiconductor industry has expanded dramatically with industry output growing on average by 15.8 percent per annum from 56.2 billion yuan in 2000 to 281.4 billion yuan in 2011 (China Electronics Industrial Yearbook, 2013), while the global semiconductor output grew on average only by 8.8 percent per annum over the same period. Rapid growth has enabled the share of China's semiconductor output in world output to rise from 4.8 percent in 2002 to 14.5 percent in 2011. The manufacture of discrete semiconductor appliances grew on average by an impressive 22.1 percent per annum over the period 2002-2011. China has nearly 3,000 semiconductor firms with over 600 of them producing integrated circuits (IC).

Aside from the above glowing account, China's IC industry is very much characterized by low value added activities (Chen and Xue, 2010). For the industry to break out and evolve into a high value added activity, efforts are being taken by the government to stimulate technological upgrading in the industry. However, apart from initiatives to support core technology advancement, the question of whether interactions between government and firms can be strengthened to support technological catch up in the IC industrial ladder – *a la* the strategy pursued by South Korea and Taiwan - remains unclear. Meanwhile, while increased integration into global markets has provided space and scale to Chinese firms, there is still a lacuna in existing works detailing firm-level innovation responses arising from integration in global markets.

Hence, this paper aims to examine how global production networks have benefited national firms' technological upgrading in the semiconductor industry in China. We seek to detail the factors driving the rapid growth of the semiconductor industry, with special focus on how imports and exports have impacted on technological upgrading. In addition, we analyze the instituitional support facing semiconductor firms in their efforts to move up the global value chain.

This paper is organized as follows. The next section discusses government promotion of the semiconductor industry in China followed by a theoretical guide. Section four presents the methodlogy and data used. Section five analyzes the transformation of the industry in China. Section six evaluates technological capabilities using a sample fo 30 firms. The final section presents the conclusions.

2. Government Promotion

Undoubtedly, Chinese semiconductor industrial development has benefited from strong institutional support through national policies. Two distinct stages could be identified, the first before 2000 characterized by specific national programs, while the latter by overall systemic support.

A comprehensive policy framework was established to support development of the semiconductor and supporting industries. Between 2000-2014 witnessed the maturization of the supporting policy, which grew from an abstract national strategy to a concrete policy. Several policy pillars have been set up following issuance by the State Council of the Software and Integrated Circuit Industries in June 2000, the Notification of the Long-term Development Plan for Strategic Emerging Industries over the 12th Five Year Plan in July 7, 2012. The State Council strengthened policy direction further through further encouraging the Development of the Software and Integrated Circuit Industries in 28 January 2011, which provided further support fhrough financial incentive, preferetial investment policies, R&D incentives, import and export subsidies, human resources initiatives and intellectual property rights protection. Human resources initiatives and IPRs protection are both the policy aspects in the docucument issues in January 2011. Human resources aspect includes detailed policies to support the IC related talents attraction and cultivation through industry acdemia collaboration, estabilish the microelectronics institute, reform the educational methods, and talents stimulations policies. IPR aspect includes encourage software companies copyright registration, strictly implement the software and integrated circuit intellectual property protection system.

With strong policy support through tax exemptions, subsidies and R&D grants, the government has managed to promote technological capabilities, including in indigenous IC design firms. Through reinforcement of the advantages of the IC sector and upgrading into backward packages, a complete industrial value chain is expected to emerge like a “necklace” of “pearls”. The goal of such a scheme is t make China a major player in the global IC industry with domestic brands and national intellectual property rights. This, the government has done through a development roadmap with timeline, development goals, action initiatives and regulations.

The sectoral development policy has stimulated industrial upgrading in the semiconductor industry through two ways. Firstly, the shifting of support from particular segments to the entire value chain, with special emphasis on interaction between different industry players in the value chain has benefited upgrading. One example of upgrading is indicated by the Value Added Tax) reform, which has since benefited all companies in the value chain, including design, manufacturing, assembly, testing and special purpose materials and equipment manufacturing. Secondly, the policy encourages cross regional industrial integration, merger and acquisitions.

3. Theoretical Considerations

This theoretical section seeks to complement the main arguments expounded by Rasiah, Kimura and Oum (2015). Also, we take the underpinnings of evolutionary economics, where industry dynamics matter in explaining the influence of institutions in the development of technological capabilities and the network of regional linkages (Nelson, 2008a; Rasiah, 2010).

Empirically, Chen and Xue (2010) profiled the relationship between firm size and technological level on different value segments of the IC industry, by capturing their position in the global division of IC design, manufacturing and assembly, and test. They argue that Chinese IC industry is very much characterized by low value added activities in the industry value chain. In the meanwhile, Rasiah *et al.* (2010) examined variations in semiconductor catch up strategies of China, Korea, Malaysia and Taiwan to unravel the key drivers among the four late-comers in the origin and catch up of semiconductor firms using the framework of sectoral system of innovations (SSI). The one major similarity across the four countries is the role government played in stimulating entry – either through direct ownership or subsidized credit - to fabricate wafers and support technological catch up. However the nature of state intervention in all four countries differed. Eventually, Rasiah *et al.* (2010) found that government exercised a dual strategy: Firstly, to attract low end firms to expand employment absorption that led to an expansion of export processing zones with strong foreign-led specialization in assembly and test activities. The second strategy is targeted at offering incentives and grants to stimulate firms' located in high tech parks to participate in high technology activities, such as wafer fabrication and designing. Comparing the evolution of IC industry in China with the world, Kong (2009) found that IC development was promoted by active interactions among different levels of government and firms through R&D incentives.

Rasiah (1988, 2009) had argued over the role economic crises has played in the expansion and slowdown of electronics exports from Southeast Asia. From the global production network and a changing geography of innovation system's perspective, Ernst (2006) argued that developing countries need to blend diverse international and domestic sources of knowledge to compensate for weak national production and innovation systems. The work suggests that the key to success are institutions that facilitate the concurrent leveraging of multiple and diverse sources of knowledge, the global production networks of buyers and suppliers of both foreign and domestic origins, as well as the diverse carriers of national innovation systems. The nature and composition of such linkages needs to change over time as a country moves up the technological ladder. In terms of the national strategies and policies supporting semiconductor development, Ernst (2011) argued that the two innovation strategies, which are indigenous innovation and global integration, have little interactions in China.

4. Methodology and Data

The analysis is done using qualitative and quantitative data. The quantitative data was extracted from various secondary sources, for instant, China Electronics Industrial Yearbook, China High Technology Industry Statistics Yearbook, Gartner Dataquest and PricewaterhouseCoopers database. Also, field work by visiting industrial association, such as China semiconductor industry association, helps authors to gather additional data for the analysis of general sectoral development. Subsequently, data would be processed based on methodology advanced by Rasiah (2004, 2010) as proxies to measure technological capabilities, so that an attempt can be made to quantify the capability status in China's semiconductor industry.

In addition to the quantitative data, the paper also uses qualitative data to strengthen the analysis, with the data being extracted from case study and focus group discussion through firm interviews. A small-scale firm-level survey was conducted by visiting 30 semiconductor firms during 2011 and 2012 in Beijing, Shanghai and Chengdu. A total of 100 questionnaires have been distributed with the supports of local authorities. Response rate is 30 percent with 30 sets being collected back with proper answer. The survey is sampled according to the advice from local Semiconductor Association, so that important players are not omitted from the survey.

5. Transformation of the Semiconductor Industry

The semiconductor industry in China has developed strongly to become the world's largest production and export base by 2010. We focus here on the expansion, structural change and changes in trade indicators.

5.1. Industrial Expansion

Chinese IC industry has been gradually moving up along the value chain of global production network, witnessed by rapid growth of R&D input and output by domestic firms. The combination of inner strength and external forces significantly promoted the overall advancement of semiconductor industry, where reinforce of inner strengths is featured by the growing number of firms and domestic research institutes, and external forces means the foreign firms with cutting-edge technology synchronize domestic firms to learn and upgrade. Meanwhile, strong domestic demand and national supporting policies provide local semi-conductor firm strong favourable external environment to thrive.

The size of IC industry has been growing rapidly, with production volume increasing from 3500 million items in 1984 to 71.4 billion items in 2012 (the first three quarters). Table 1 profiles a growing IC industry of China with main economic indicator. The number of employees increases 14.7 percent every year, jumping from 74004 people in 2000 to 293023 people in 2010. The growing number of firms brought an increase in industrial gross output, which increased from 27.23 billion yuan in 2000 to 234.02 billion yuan in 2010 with an average annual growth rate of 24 percent throughout the period. A yearly increase of 22.32 percent in the profits lasted over the period, and export grew 25.5 percent every year from 15.95 billion yuan in 2000 to 154.57 billion yuan in 2010.

Table 1: Main indicators, Semiconductor Manufacturing, China, 2000-2010.

Year	Numbers of firms	Employees	Gross output*	Profits*	Export*
2000	172	74004	272.3	17.7	159.5
2005	362	188080	1155.5	32.6	833.7
2007	434	273677	2030.1	89.8	1517.6
2008	500	313441	2342.7	49.6	1903.1
2009	482	275637	1926.5	9.0	1382.5
2010	492	293023	2340.2	132.7	1545.7
Avg. Annual Growth	11.08%	14.75%	24%	22.32%	25.50%

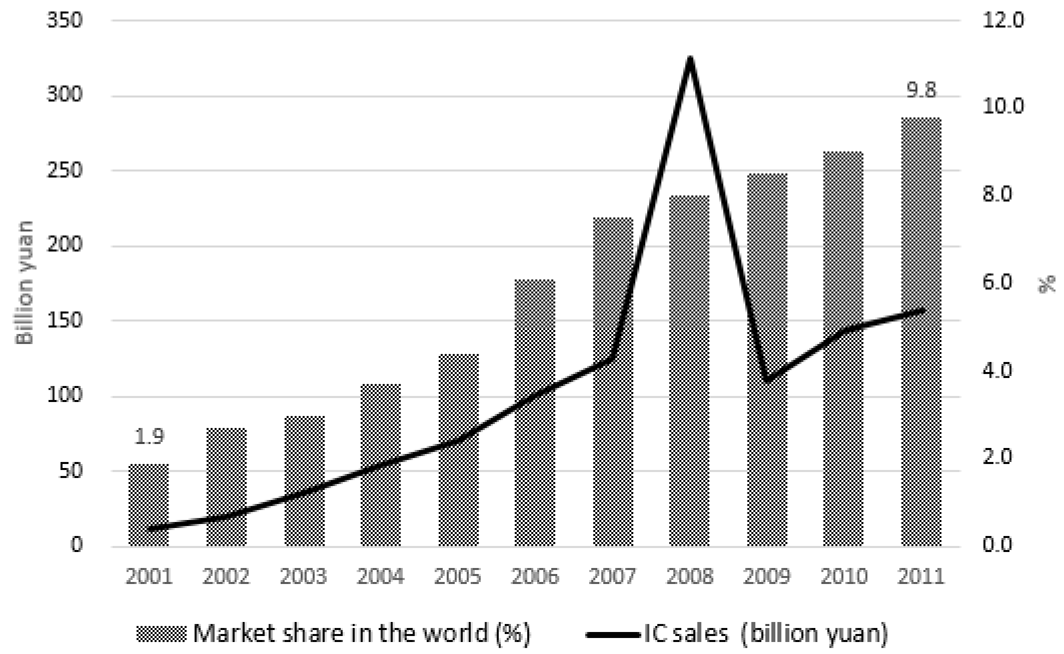
Note: * value is in 100 million yuan.
Sources: China High Technology Industry Statistics Yearbook.

During the rapid growth, Chinese semiconductor industry has become an important part in the global production network. Countries which have developed the semiconductor industries have set up the industry bases or some research and development centres in China, including USA, EU, Japan, South Korea, and Taiwan region. So far in China, semiconductor industrial clusters have formed in loop Bohai Area, Yangzi River Delta, and Pearl River Delta. Middle and west region has become the base for IC packaging and testing, for instance LED packaging.

Despite of its satus as latecomer in the industry, China semi-conductor sales grew 29.5 percent every year on average from 12 billion yuan in 2001 to 158 billion in 2011, with its market share in the world increasing from 1.9 percent in 2001 to 9.8 percent in 2011 (Figure 1). While the sales shoot up to 325 billion yuan in 2008 from 125 billion in 2007, sales fell back to 110 billion in 2009. The share in the worlds shows a stable rise, suggesting a sudden rising in demand from interntional market in 2008.

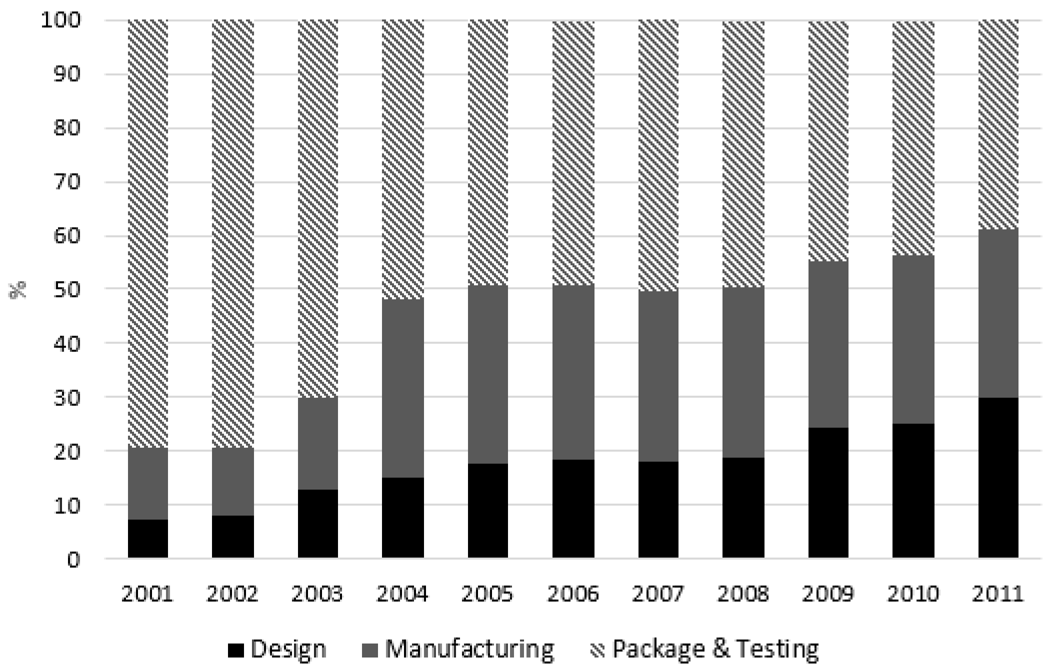
The development of China's IC industry was reflected not only by quantity, but also on its industrial structure to enjoy significant participation in global production activities. The sales of IC design grew 41.2 percent every year from 1.5 billion yuan in 2001 to 47.4 billion yuan in 2011 (Appendix 1). Throughout the period, the share of packing and testing significantly dropped from 79.3 percent to 38.9, while the share of design increased from 7.3 percent to 30.1 percent (Figure 2). This dramatic strucutral change indicates the speeding up of industrailization of China's IC industry. The production activities is shifting away from low-value-added exercise, and is gradually upgrading technological capacity in high-value-added product design.

Figure 1: Semiconductor Sales and Market Share in the world, China, 2001-2011



Source: China Electronics Industrial Yearbook (2013).

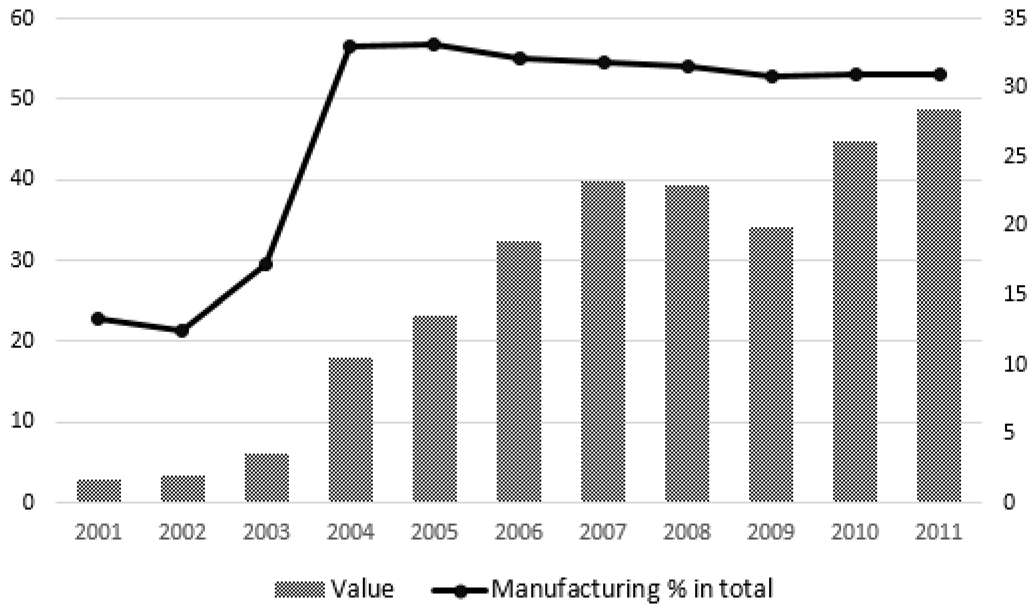
Figure 2: Share of Sales, Semiconductor industry, China, 2001- 2011



Source: China semiconductor industry association (2012).

Zooming the research focus on the IC manufacutring, the sale of manufacturing saw a sudden increase from 6.05 billion yuan in 2003 to 18 billion in 2004 and stablized since then until 2011. The share slightly flucturated between 31 percent to 33 percent from 2005 to 2011, suggesting the strenghth of China as a key manufacuturer was reinforced (Figure 3).

Figure 3: Sales, Semiconductor Firms, China, 2001- 2011



Source: Chinese Electronics Industrial Yearbook (various years).

5.2. Structural Change

Semiconductor manufacturing in China has also undergone strong technological deepening with strong participation of large and foreign firms in export markets. Table 2 presents R&D activities undertaken by semiconductor firms in China. R&D personnel equalivalent working hour demonstrate an average growth rate of 23.8 percent per year from 1321 hours in 2000 to 11149 hours in 2010. R&D expenditure on average grew at 32.6 percent per annum from 0.2 billion Yuan in 2000 to 3.0 billion yuan in 2010. Semiconductor value added grew on average by 18. percent per annum from 3.4 billion Yuan in 2000 to 17.9 billion Yuan in 2010. Consequently, patents filed grew from 4 in 2000 to 2004 in 2010. R&D personnel in the IC industry grew from 9.1 million in 2000 to 99.0 million in 2010 (Table 3).

Large firms dominate export markets in the industry as 26 of the large firms exported

96.6 billion yuan in 2010, which was recording over 26 times the export of 3.6 billion by 316 small firms (Table 4). Also, large firms (115.9 billion Yuan) also sold more than small (88.5 billion Yuan) and medium firms (22.5 billion Yuan). Foreign firms reached enjoyed 3 times higher sales revenue and 20 times export sales than national firms in 2011.

Table 2: R&D Statistics, Semiconductors, China, 2000-2010

Year	R&D personnel equivalent working hour	R&D intra expenditure	New products development expenditure	Industrial value by new products	Sales of new products	Patents applicants	The number of valid patents
2000	1321	17823	19119	338766	336040	12	4
2005	3908	145065	129635	2190918	2150651	457	115
2007	5895	219490	279828	2087254	1994239	1307	291
2008	8263	300850	383349	2820658	2811918	1608	393
2009	13482	279995	290902	4441523	4380166	2129	1808
2010	11149	301329	381026	1792406	1752030	2714	2004
Average Annual Growth (%)	**23.78**	**32.68**	**34.88**	**18.13**	**17.95**	**71.97**	**86.20**

Note: * value is in 10,000 yuan.
Source: China High Technology Industry Statistics Yearbook

Table 3: R&D Specialization, Semiconductors, China, 2000- 2010

Year	**Firms' R&D Specialization**				**R&D input**		
	For technology import	For assimilation & absorption	For domestic technology	For technology renovation	The number of employees	Expenditure	The number of R&D organizations
2000	33195	118	3	35068	910	14988	9
2005	56049	4375	70	76839	1747	24668	29
2007	59078	12254	337	142918	5461	205760	63
2008	25655	1320	2798	77082	7701	328664	82
2009	15291	469	239	121210	10393	268815	72
2010	16436	2764	33404	62147	9901	283056	87
Average Annual Growth (%)	-6.79	37.08	153.90	5.89	26.96	34.16	25.47

Note: * value is in 10,000 yuan.
Source: China High Technology Industry Statistics Yearbook

Table 4: Semiconductor Manufacturing by Size and Ownership, China, 2010

	By size			By ownership		
Indicator	Large	Medium	Small	Domestic	Foreign	HK, Taiwan & Marco
Numbers of firms	26	150	316	224	164	104
Employees	112041	140146	40836	65878	146033	81112
Industrial gross output	1200.9	909.9	229.4	403.5	1506.6	430.1
Assets	991.2	1039.3	230.4	419.8	1412.3	428.8
Sales revenue	1159.3	885.8	225	389.1	1465.8	415.2
Profits	53	60.2	19.4	31.5	81.6	19.6
Export	966.8	542.4	36.6	51.3	1219.8	274.6

Note: * value is in 10,000 yuan.
Source: China High Technology Industry Statistics Yearbook

While China's semiconductor industry has enjoyed rapid growth and structural change, it faces many challenges. Firstly, domestic firms are still characterized by weak innovation capabilities with less than 20 percent of domestic market supplied by them. Most key technologies, such as, advanced chips and key software are still imported. Consequently, the trade deficit of the IC industry has increased from US$ 8.6 billion in 2003 to over US$100 billion in 2010 (World Bank, 2012). Secondly, domestic firms lack the technological capabilities to compete with Korean and Taiwanese firms.

5.3. Intra-industry Trade and Trade Competitiveness

In this sub-section, we examine international trade as a driving factor to support development of IC industry. Using time-series data, Grubel-Lloyd[1] Index and Trade Balance (TB) index of Chinese semiconductor sector will be calculated and analysed, from which we will have a general picture on the trade status of the industry (Balassa, 1965; Grubel & Lloyd, 1971).

Despite a slight improvement in TB from -0.75 in 2003 to -0.56 in 2012, it is clear that China has yet to achieve comparative advantage in semiconductors (Table 5). The trade imbalance from 2003 to 2012 was caused by weak technology capacity of domestic manufacturing firms, as most of the key component and technology has to be imported

[1] G-L index in an indicator of intra-industry trade, which was calculated by

$$\mathrm{G\text{-}L_i} = \frac{(X_i + M_i) - |X_i - M_i|}{X_i + M_i} = 1 - \frac{|X_i - M_i|}{X_i + M_i}$$

Where Xi denotes the export, and Mi the import of good i.

from overseas, without which the production cannot be completed. In the meanwhile, although semiconductor manufacturing grew quite promisingly in China, the huge demand of high-tech garget from domestic consumer market also explains the massive import of semiconductors. One of the reasons might be insufficient domestic supply of IC item, which has become the largest import commodity in China in 2011 and 2012. According to the data from CCID China, top 10 semiconductor suppliers to Chinese market are all foreign firms or multinational corporations including Intel, Samsung, Toshiba, TI, Hynix, ST, AMD etc. The revenues of total top ten suppliers accounted for 51.7 percent, 50.7 percent of the Chinese IC market in 2010 and 2011 (Table 6). Foreign firms accounted for 46.9 percent and 45 percent of the Chinese semiconductor market in 2010 and 2011.

Meanwhile, the G-L index fluctuated between 0.25 and 0.33 over the period 2003-2011 (Table 5), suggesting weak intra-industry trade because of much higher imports over exports. Nevertheless, this index rose in 2012 to 0.44, suggesting the intra-industry was improved due to big growth in semiconductor exports. However, semiconductor sector still highly relies heavily on overseas market. According to data from Gartner Dataquest 2009-2011, the export market segments of Chinese semiconductor industry are mainly data processing, communications, and consumer electronics, while domestic consumption of the Chinese semiconductor industry are mainly in automotive, industrial, and avionics (Table 6). Among products locally manufactured, very few use the chips made in China, suggesting weak integration between chips manufacturing and assembling companies. Generally speaking, Chinese semiconductor industry has not formed a complete industrial value chain, neither as an ecological well-integrated sectoral innovation system.

Table 5: RCA ratio and G-L index, Semiconductor industry, China, 2003- 2012

Year	Import	Export	RCA	G-L index
2003	40.4	5.7	-0.75	0.25
2004	54.62	10	-0.69	0.31
2005	81.02	13.75	-0.71	0.29
2006	105.48	20.28	-0.68	0.32
2007	128.4	23.9	-0.69	0.31
2008	193.96	36.49	-0.68	0.32
2009	179.92	34.96	-0.67	0.33
2010	235.57	43.89	-0.69	0.31
2011	255.39	48.87	-0.68	0.32
2012	288.20	80.17	-0.56	0.44

Source: China Custom Database (various years).

Table 6: Semiconductor Sales, China, 2011

Firm	Rank	Sales	Market Share
Intel	1	23777	15.7
Samsung	2	9612	6.4
Toshiba	3	5322	3.5
TI	4	5210	3.4
Hynix	5	5087	3.4
ST	6	4742	3.1
AMD	7	4406	2.9
Renesas	8	3452	2.3
Freescale	9	3426	2.3
NXP	10	3003	2
Infineon	11	2782	1.8
ON Semiconductor	12	2701	1.8
Qualcomm	13	2270	1.5
Micron	14	2200	1.5
Media Tek (MTK)	15	2016	1.3

Source: CCID IC Market China 2011 & 2012 Conferences (2011 & 2012).

6. Firm-level Evidence

Based on our arguments above, this section presents the results of field work on the institutional evaluations and firm-level assessment. 30 key semiconductor firms which represent important manufacturing industries have been interviewed. It constitutes the prime empirical platform for examining the firm-level status of innovation and production. The firms were selected on the basis of the importance of the industry to manufacturing, and the recommendation from local officials is also taken into account. In order to assure the complete confidentiality of the participating firm, the information that firms provided us will be used in an aggregate form with no individual firm data and identity

Table 7 shows the general characteristics of 30 firms, of which 4 are state-owned or controlled enterprises (SOE), 14 are local companies, 6 are joint venture and 6 are foreign companies respectively (Table 7). The main business of the firms covers manufacturing, assembling, testing and designing. Total number of business activities (78) which is larger than 30 suggests that many firms engaged in more than merely one activity. Among all the nature of businesses, the firms engaged in design and integrated operations are dominating the total (21 and 19 respectively out of 78), suggesting Chinese IC industry gradually shifts from low value-added manufacturing and assembling to high-value-added design and integrated operations. The facts that 60 percent firms are established after 2000 indicates that IC industry is still a new sector in China, as most of the firms are aged below 14. However, 83 percent firms have employment over than 200, among which the employment of 12 firms is over than 1000. 25 out of 30 firms reported gross sale in 2011 over than 100 million, but only half (17 out of 30) firms export the product to overseas market in 2011.

Table 7: General Characteristics, Sample Firms, China, 2012

Firm Demographic		Ownership				
		SOE[1]	Local Firm[2]	Joint Venture[3]	Foreign[4]	Total
Nature of business[5]	Assembler	4	3	3	4	14
	Manufacturer	0	4	2	1	7
	R&D operations	4	7	3	3	17
	Design	3	11	3	4	21
	Integrated operations	1	10	4	4	19
	Total	12	35	15	16	78
Year Established	<1990	2	0	2	0	4
	1990-2000	2	3	2	1	8
	>2000	0	11	2	5	18
	Total	4	14	6	6	30
Employment 2011	<200	0	7	0	0	7
	200-1000	2	4	3	3	13
	>1000	2	3	3	3	12
	Total	4	14	6	6	30
Gross Sales 2011	<10million yuan	0	0	0	0	0
	10m-100m yuan	0	6	0	0	6
	>100m yuan	4	8	6	6	25
	Total	4	14	6	6	30
Export 2011	<50million yuan	0	6	2	n.	8
	50m-100m yuan	1	1	0	n.	2
	>100m yuan	2	1	4	n.	7
	Total	3	8	6	0	17

Note: 1. SOE refer to state-owned or controlling enterprises;
2. Local firms means the firms with equity above 80 percent but excluded SOE;
3. Joint Venture refers to the firms with foreign investment, but domestic equity of greater than 20 percent but less than 80 percent.
4. Foreign firms refer to the firms with foreign equity greater than 80 percent
5 From authors' survey.

Source: author survey (2013).

Our survey suggests that innovation activities on firm-level was dynamic with 93 percent of the sampled firms conducting the incremental innovation activities, and 87 percent of them reported new product development in 2012. Meanwhile, 90 percent of the sampled firms reported that they have received government assistance for R&D in 2012 (see Table 8), which shows that the national policies play very important role in the industrial technology upgrading. Also, 56 percent of the samples firms reported conducting contract R&D activities with universities and research institutes. One of the driving force that contribute to the improving level of technology capacity of Chinese IC industry is the close linkages with public research institution, as industrial academia collaboration is one of the important driving factor to innovation capabilities accumulation of domestic firms. National firms reported the highest R&D intensity by expenditure in sales. However, foreign firms showed the highest intensity of R&D personal (34.4 percent) but joint-venture firms show the highest filing of patents followed by national and foreign firms.

Table 8: Technological Indicators by ownership, Sampled Firms, China, 2012

	Total Employment	Average R&D Intensity	Total No. of persons engaged in R&D	R&D Personnel in total (%)	Number of registered Patents
Overall	133,500	6.28	37,695	28.24	1709
SOE	111,340	5.25	30,890	27.74	170
National	7,520	7.28	2,175	28.92	374
JV	9,440	9.6	2,480	26.27	805
Foreign	5,200	7.17	1,790	34.42	360

Source: Compiled from authors survey (2013)

7. Conclusions

The development of China's semiconductor industry could be traced to the time of the establishment of new China. However, only since the new millennium. China has become the largest semiconductor consumption country in the world, and IC has become the largest importation commodity of China. The industry has also enjoyed strongly structural change in this period. Government policies, especially from 2000 have been instrumental in stimulating upgrading. Not have firms become larger in size, both R&D expenditure in sales and R&D personnel in workforce in the industry has since grown strongly. Consequently semiconductor firms have become more innovative with rising numbers of patents files and a rise in incremental engineering activities. While foreign firms and joint-venture firms have increased their R&D intensities and patent filing, national firms have also enjoyed strong technological deepening, though, they are not at the technology frontier yet.

However, the semiconductor industry in China is still highly import-dependent with the TB and GL index showing low performance. While improvements recently in these indices suggest that in 2012 suggest that the technological deepening initiatives are likely to improve the trade performance indices. Financial incentives and grants, and efforts to bring back talents from abroad may help to stimulate further upgrading, and build the stock of tacit knowledge in the industry. Global production networks are clearly important here as personnel trained in multinationals carry important knowledge for leading the upgrading in domestic firms.

To quicken technological upgrading in the global value chain, there are still several key points that ought to be considered. Firstly, there is a need to build an industrial ecosystem around the semiconductor firms. Secondly, the universities should play a greater role to supply the human capital to continuously develop home grown firms and innovation capabilities. Thirdly, efforts must be taken to push domestic firms to integrate globally so as to appropriate systemic synergies (Rasiah, 2010). Fourthly, efforts must be taken to strengthen network cohesion between institutions, meso-organizations and the firms.

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Appendix 1: IC Activities, China, 2001- 2011

Year	IC design*	% in total	IC manufacturing*	% in total	IC package & testing*	% in total
2001	1.48	7.3	2.77	13.4	16.11	79.3
2002	2.16	8.0	3.36	12.5	21.33	79.5
2003	4.49	12.8	6.05	17.2	24.60	70.0
2004	8.18	15.0	18	33.0	28.35	52.0
2005	12.43	17.7	23.29	33.2	34.49	49.1
2006	18.62	18.5	32.35	32.1	49.66	49.3
2007	22.57	18	39.79	31.8	62.77	50.2
2008	23.52	18.86	39.27	31.5	61.89	49.55
2009	26.99	24.33	34.14	30.77	49.82	44.8
2010	36.39	25.27	44.71	31.04	62.92	43.59
2011	47.37	30.13	48.69	30.97	61.16	38.9

Note: * sale is in billion yuan

Source: Chinese Electronics Industrial Yearbook (various years) and China semiconductor industry association.

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