Chapter 2
Knowledge Spillovers and Regional Innovation: The Case of Guangdong Province, China

Abstract This chapter aims at analyzing the impact of knowledge spillovers through external channels, namely FDI and trade on the regional innovation and upgrading in Guangdong province, China by using the panel data of 21 municipalities for the period of 2001–2012. The results show strong evidence of external knowledge spillover as effective trigger of local-scale knowledge spillover in the latecomer regions. The external knowledge spillover is primarily working through the mechanism of FDIs rather than import at the investigation period. Furthermore, it demonstrates that the impact of external knowledge spillover is moderated by the degree of industrial diversity at the city scale, which means that more diversified areas benefit from FDI and import to a greater extent. Overall, the empirical investigation suggests that external knowledge spillover is not an automatic process, but is rather closely related to the investment stock, the degree of embeddedness and the absorptive abilities of local firms in the long run. At the end, this chapter points out the future study should go further to explore microeconomic aspects of innovation at the firm-level.

2.1 Introduction

In the field of economic geography and regional development, growing research attention has been paid to the role of knowledge spillovers in generating endogenous growth and determining economic development. Knowledge spillover is a typical urban phenomenon. Going beyond explaining the mere existence of cities, as what static externalities theory does, knowledge spillovers explain the growth of cities (Glaeser 1999). Aside from explaining regional economic growth from the perspective of cost savings on transportation and intermediate inputs (Hoover 1937;

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Carlton 1983; Krugman 1991), knowledge spillovers theory reinterprets externalities in a dynamic way and argues that innovation investment bears increasing returns because it contributes to a general stock of knowledge upon which neighboring firms or latecomer firms can develop (Jacobs 1969; Romer 1986; Lucas 1988; Glaeser 1999).

Two kinds of externalities, namely intra-industry and inter-industry externalities, on the local scale are vital to the growth of cities (Glaeser et al. 1992). However, research findings on knowledge spillovers are heretofore mixed (Feldman 2000). On one hand, it has been proven that specialization stimulates growth, in which knowledge spillover in the same industry is active (Henderson and Cockburn 1996; Henderson 2003). On the other hand, industrial concentration is suggested to hinder growth in some way (Miraky 1994), and the positive impact of diversity has been otherwise proven. Glaeser et al. (1992) discover that knowledge spillovers across industries—rather than within the same industries—boost employment in a period of deindustrialization, particularly in traditional industrial cities. Feldman and Audretsch (1999), and Rosenthal and Strange (2003) also confirm similar benefits of diversity.

The ambiguous pattern of research is somewhat related to different studied objects positioned in different context of time and space (Combes 2000). Comparing the mixed cases, a hidden rule has emerged: knowledge spillovers within the same industry primarily induce incremental innovation, whereas knowledge spillovers across industries are conducive to disruptive innovation. Neffke et al. (2011) latest discourse on the impact of different kinds of knowledge spillovers on the industrial life cycle develops this statement. It is suggested that knowledge spillovers take place across industries when industries are young and rejuvenating, whereas knowledge spillovers within the same industry is more prevalent when industries grow and mature. However, the above literature lacks an open perspective in the era of globalization. Branstetter (2006) finds that Japanese FDIs in the United States result in two-way knowledge spillovers between the two countries. Boschma and Iammarino (2009) conduct a systematic measurement of knowledge spillovers on the local and global scales in Italy, and find that a high variety of traded goods into the region contributes to regional economic growth. Furthermore, knowledge spillovers between developed and developing countries are intensely examined and considered as a key mechanism for conditional convergence in the global economy. The positive relationship between trade and growth is confirmed in studies asserting the knowledge spillovers from the industrial North to the developing South (Coe et al. 1997; Falvey et al. 2004). Javorcik (2004) proves productivity spillovers induced by FDIs across industries in Lithuania, one of the transition economies in Eastern Europe, through forward and backward linkages with foreign affiliated firms. China's fast growing rate during the recent decades has been also suggested by some scholars to be partly attributed to the active integration into the global production networks (Lemoine and Unal-Kesenci 2004; Yeung 2009), although the effect of technology spillover is debated (Wei et al. 2009; Wang and Lin 2013).

Based on the literature review, this chapter argues that with access to external advanced knowledge and requisite absorptive ability on the local scale, it is very possible for latecomer regions to seize the inflow of external knowledge, thereby triggering knowledge spillovers on the local scale, which are likely to lead to the formation of regional innovation systems to sustain long-term economic growth. In addition, the missing link between external knowledge spillover and localized knowledge spillover in the literature is addressed in the chapter, with theoretical and empirical investigation on the moderating role of urban industrial structure on the effect of FDI and import on innovation. Overall, the chapter contributes to the literature in two respects. First, I put knowledge spillovers on both local and global scales in the latecomer context within an integrated theoretical framework, and discuss how knowledge spillovers on the global scale trigger knowledge spillovers on the local scale, and also interacts with local structure. Second, evidence on knowledge spillovers, which underlies innovation and economic growth in the modern economy, is further collected within the latecomer context. After the global financial crisis and the gradual recovery of East Asian economies[1], it is important to examine whether the local dynamics of economic development, such as active knowledge spillovers, has come into shape to sustain long-term development in the face of a changing and fragile post-crisis global market.

The study area is Guangdong province in South China. The province is selected based on two reasons. First, Guangdong has developed quickly after the opening of the Chinese economy by having successfully attracted labor-intensive production. Latest statistics in 2012 show that FDI in Guangdong accounts for 15 % of the national total, ranking the second among the regional peers, and Guangdong's total import and export volume accounts for about 29 % of the national volume (GPBS 2013). Second, since China's transition from a planned economy to a market economy in 1978, technological activities, such as investments in equipment renewal, process innovation, and product upgrading, have become increasingly prevalent among enterprises in Guangdong (Wang 2008). These factors justify the choice of Guangdong for testing the existence and impact of knowledge spillovers after decades of development.

The chapter has the following structure. Section 2.2 collects stylized facts on technological upgrading and innovation in Guangdong province, China. Section 2.3 provides a theoretical framework for analyzing the overall impact of knowledge spillovers—within the same industry locally, across different industries locally, and through global linkages—on the performance of innovation within the context of a latecomer region, and further elucidates how urban industry structure influences the impact of external knowledge spillover on regional innovation. The section also derives hypotheses for empirical testing. Section 2.4 describes the variable design and the model specification. Section 2.5 reports the results. Finally, Sect. 2.6 provides the conclusion and discusses ways to further extend our understanding of knowledge spillovers.

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[1] See Willem Thorbecke, guest edition "East Asian production networks, global imbalances, and exchange rate coordination". Econbrowser: analysis of current conditions and policy, 19 October 2009. http://econbrowser.com/archives/2009/10/east_asia_the_g. Accessed 13 May 2014.

2.2 Technological Upgrading and Innovation in Guangdong Province, China: Some Stylized Facts

Economic activities in Guangdong province, in particular the core region—the Pearl River Delta (PRD), are characterized as processing and compensation trades (*sanlaiyibu*). In spite of the relatively low added value in the global value chain, content of processing trade in Guangdong province has in actuality upgraded from low-tech products, such as garment and shoes, to high-tech products, such as electronics. The share of high-tech products, mainly the electronics products, in total exports in Guangdong has increased from 19 to 39 % from 2000 to 2012, whereas the share of leather, textile and footwear products decreased from 23 to 11 %. Upgrading of processing trade in industry categories clearly indicates the greater ability of PRD firms to understand, absorb, and process more complex products. Moreover, the share of processing and compensation trade has gradually fallen from 78 to 56 % during the period 2000–2012, implying more independency of industrial production.

Because the organization of electronics product is quite fragmented, suppliers in the emerging countries are distributed in different tiers of the global value chain in terms of skills and technological level. Therefore, deeper investigation into structural changes in primary high-tech trade products is needed. The processing trade involves large volume of components import (particularly the key high-tech component) and final goods export. As shown by the structured trade data in Tabel 2.1, data processing equipment and mobile phones did not appear among the main high-tech export product catalog in 1997. After 2001, export trade of these two electronics commodities has surged, account for 50 % and 34 % of the major exports in 2012, respectively. The rising export of the data processing equipment and mobile phones should complement with, given China's relatively lower technological capabilities, the importation of more semi-finished components, especially the integrated circuit (from 55 to 80 %). On the other hand, the increasing import of other components, primarily part of semiconductor devices and circuit protection fixtures, which are complex electronic components used in integrated circuits, demonstrates the firms' ability to design and produce their own integrated circuit. The processing of these components clearly indicates a deeper understanding of the principle of circuit functions and requires an increasing ability in the field of circuit design adjustments for different purposes. The inference that firms are strengthening their capability to adapt and improve imported technology is further corroborated by the accelerating international competitiveness of the IC products, with its share rising from null to 13 % of the total exports in Guangdong province. In addition, the import of kinescopes—the core technological component of TV sets—has decreased to a great extent. Combining this with the increased export of color TV, it can be concluded that firms in Guangdong are already capable of producing TV sets on their own; this signifies to a certain extent technological upgrading.

New product development is another important aspect of technological upgrading. Under China's statistical standards, new products refer to brand new products

Table 2.1 Structural change of electronics industry trade in Guangdong. (Data Sources: GPBS (1998, 2008 and 2013))

Final and intermediate goods	Value of trade (unit: $ 10,000 US)		
	1997	2007	2012
Imports			
Final electronic goods	49,493	993,009	1,479,630
Data processing equipment	44,547 (90 %)	989,411 (99 %)	1,479,079 (99 %)
Exchange of telephone and telegram	322 (1 %)	–	–
TV sets	4,624 (9 %)	3,598 (1 %)	551 (1 %)
Electronic components	443,483	6,283,113	9,258,958
Integrated circuit (IC) and parts of electronic components	245,155 (55 %)	4,920,595 (78 %)	7,404,316 (80 %)
Part of semi-conductor devices	76,960 (17 %)	640,546 (10 %)	913,381 (10 %)
Protection fixtures of circuit	57,416 (13 %)	545,889 (9 %)	735,005 (8 %)
Kinescope	20,017 (5 %)	13,669 (1 %)	1,660 (0.1 %)
Electric wire & cable	43,935 (10 %)	162,414 (2 %)	204,595 (2 %)
Exports			
Final electronic goods	297,181	6,248,260	10,243,144
Data processing equipment	–	4,110,387 (66 %)	5,176,401 (50 %)
Mobile phone	–	923,567 (15 %)	3,476,778 (34 %)
Electric calculator	32,527 (11 %)	64,765 (1 %)	39,955 (1 %)
Telephone set	81,574 (27 %)	287,209 (4 %)	161,260 (2 %)
Loud speaker	36,515 (12 %)	192,603 (3 %)	330,183 (3 %)
Hi-fi stereo component system	17,510 (6 %)	381,326 (6 %)	290,167 (3 %)
Radio set	28,394 (10 %)	–	–
Color TV sets	29,125 (10 %)	284,235 (4 %)	490,450 (5 %)
Camera	71,536 (24 %)	4,168 (1 %)	277,951 (2 %)
Electronic components	75,831	882,782	2,608,407
Integrated circuit (IC) and parts of electronic components	–	259,199 (29 %)	1,613,685 (62 %)
Static current transformer	75,831 (100 %)	623,583 (71 %)	994,722 (38 %)

Number in brackets indicates the share (%) of this product in sub-category export or import products

that utilize new technology or new design ideas, or greatly improved products in terms of structure, material, or processing methods, all of which would either significantly enhance the performance of the products or expand their functions. Based upon the North-South spillover assumption (Coe et al. 1997), firms in latecomer countries have a large room for learning as well as adapting technology developed by industrialized countries to improve performance. Hence, within the latecomer

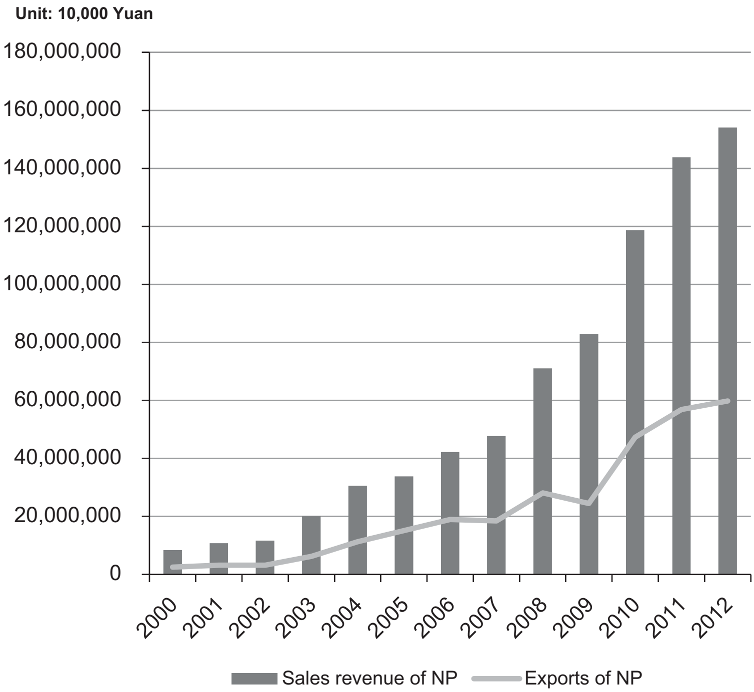

Fig. 2.1 New product development in Guangdong. (Data source: GPBS (2001–2013, annual))

context, new product development is a more market-oriented indicator than patents that represent the technological frontier. Figure 2.1 shows that the sales revenue of new products in Guangdong increased more than 18 times over the decade during 2000–2012, among which the export of new products increased 23 times from 2000 to 2012.

New product development activities are not evenly distributed in Guangdong province; some cities score high in product innovativeness, while some others are lagging behind. The most innovative city, Shenzhen, has achieved about 600 times as many new products as the least one—the mountain city Yunfu. Internal learning efforts of firms constitutes a necessary requisite for achievements in new product development; here, correlation analysis of Spearman's rho is used to calculate the relationship between new product sales and export, and R&D expenditures from 2001 to 2012 across 21 municipalities in Guangdong. It is shown that the new product sales revenue is significantly and positively correlated (0.922) with firm R&D expenditure. Likewise, significant and positive correlation (0.865) is also found between new product export and R&D expenditure (Tabel 2.2).

R&D activities involve both efforts in pushing technological frontiers and improving existing knowledge. International comparative studies indicate that over 1% of R&D expenditure in GDP signifies that a country/region has passed the phase of basic technological introduction and application, and has developed the

Table 2.2 Spearman's correlation of new product performance with R&D expenditure. (Data sources: Calculation based on data compiled from GPBS (2002–2013, annual))

Spearman's rho correlation		Firm R&D expenditure
New product sales	Correlation coefficient	.922[a]
	Sig. (2-tailed)	.000
New product export	Correlation coefficient	.865[a]
	Sig. (2-tailed)	.000

[a] Correlation is significant at the 0.01 level (2-tailed). List wise $N = 147$

ability to absorb and assimilate technology. In 2000, Guangdong's R&D share in GDP sharply increased from just 0.2 % in 1995 to 1.1 %, 2 years earlier than the national average reaching above 1 %. In 2012, R&D expenditure in Guangdong has reached 124 billion Yuan, taking up 2.2 % of the GDP. Compared to the industrialized countries (e.g. the United States, 2.7 %; Japan, 2.7 %; OECD countries, 2.3 %; newly industrialized countries or regions like South Korea, 3.5 %; Taiwan, 2.6 %; and Singapore, 2.3; See OECD 2008), Guangdong is catching up and approaching the high standard. Speaking of the quality, however, R&D activities in Guangdong mainly involve learning efforts in assimilating and improving technologies from industrialized countries.

In order to reveal the character of R&D activities in Guangdong, structural comparison with other developed provinces in China and the national average is made (Tabel 2.3). First, R&D intensity in Guangdong outperforms the national average, but is still much lower than Beijing and Shanghai. This may be attributed to the insufficiency of technological investment in universities and research instituts, as well as the absence of global lead firms devoted to R&D activities, compared to Beijing and Shanghai (Kroll and Tagscherer 2009). Second, technological upgrading in Guangdong is largely market-driven; it is mainly led by private investment other than public one. The percentage of firm investment in R&D in Guangdong is 87 %, which is higher than the national average (74 %) and all other developed regions. Third, technological changes in Guangdong are mainly driven by test and development activities, implying that Guangdong's technological activities are incremental rather than radical.

In the 2000s, including the tough time in the aftermath of the worldwide financial crisis, competition for low-cost regions had been intensifying compared to the 1990s, but still Guangdong showed its learning ability to renew and upgrade products gradually, leading to the sustainable competitiveness of its export sector. Technological upgrading activities in Guangdong are characterized by firm-led assimilation and improvement undertakings. Nevertheless, the mechanism favoring rapid technological changes is missing due to the absence of research excellence of universities and public institutions. Aside from the internal efforts of firms, knowledge spillovers that transfer know-how and induce learning by doing in firms are supposed to be important for the dynamic self-sustaining technological progress of Guangdong. The following sections would further explore the nature of knowledge spillovers both theoretically and empirically.

Table 2.3 National comparison of technological indicators (2012). (Data sources: Calculation based on data compiled from CSSB (2013), GPBS (2013), SMBS (2013), BMBS (2013), JPBS (2013) and ZPBS (2013))

	National statistics	Guangdong	Shanghai	Beijing	Jiangsu	Zhejiang
R&D expenditure (unit: billion Yuan)	1029.8	123.62	67.93	106.33	128.80	72.26
R&D expense (percentage in GDP) (%)	2.0	2.2	3.4	5.9	2.3	2.1
# Firm investment in R&D (%)	74	87	63	40	62	81
# Investment in basic research (%)	5	2.6	7.2	11.8	2.5[1]	2.4
# Investment in application research (%)	11.2	7.2	13.5	22.8	6.5[1]	5.4
# Investment in test & development (%)	83.8	90.2	79.3	65.4	91[1]	92.2

2.3 Impact of Knowledge Spillover on Innovation: An Integrative Perspective from the Local and the Global Scale

In the management literature, innovation is mainly determined at the firm level. Firms that set long-term technological development strategies and devote much of their resources to R&D activities are assumed to achieve better innovation outcomes. The success of the Korean industry follows the logic of internal capability for technological upgrading and innovativeness. The Korean government has created favorable policies in "preferred industries", which has ensured efficient scale economies through mergers, project-specific financial support, and domestic market protection (Chang 1993). Combined with their own R&D efforts, Korean companies have ultimately upgraded to a higher position in the global value chain and established a modern industrial system led by the automobile and electronics industries.

However, firm-level internal efforts cannot explain two phenomena. First, regions with many small firms, such as the Third Italy, which lack the financial ability and economies of scale to support intense R&D activities, perform fairly well in innovation, particularly in incremental innovation (Storper 1995). Rather, mutual trust among firms constitutes the fundamental basis of long-term cooperation, facilitating knowledge exchange and stimulating growth. Although the ideological concept for "small enterprise spatial system" has been under constant suspicion, especially in the post-2000 period, its success as a geo-historical formation has presented itself as a perfect case for the external sources of firm competitiveness (Bianchi 1998; Boschma and Lambooy 2002). Second, firms with the same endowment and efforts in innovation usually perform differently in different locations. All of these suggest that the external environment plays an important role in determining the innovation performance of firms.

To deal with it, I focus on three perspectives on knowledge spillovers. These perspectives are concerned with innovation externalities achieved through knowledge spillovers that enable firms to benefit from each other's internal efforts. The first two knowledge spillovers, which take place within and between industries on the local scale, have been properly modeled and surveyed by many scholars (Loury 1979; Glaeser et al. 1992; Asheim 2000; Neffke et al. 2011). The third knowledge spillover deals with externalities on the global scale (Grossman and Helpman 1990; Branstetter 2001; Javorcik 2004; Branstetter 2006; Parrado and De Cian 2014), which are highly important for firms in latecomer countries, where spillovers from neighboring firms are quite limited.

The flow of ideas is intrinsic to the new knowledge production system that underpins economic growth (Lucas 1988). Glaeser et al. (1992) suggest that people agglomerate in high-rent cities because they benefit from learning opportunities. In this respect, it is assumed that physical proximity facilitates information transmission. Marshall-Arrow-Romer's (MAR) externalities and Jacobs' externalities focus on spillovers on the local scale.

The MAR externalities were developed by Arrow (1962) and Romer (1986) based on Marshall's (1920) agglomeration theory. Marshall's agglomeration theory suggests that firms in the same industry agglomerate to benefit from knowledge spillovers. Moreover, their agglomeration is a cost-saving strategy in their search for intermediate goods and skilled workers. Arrow further expands the theory by stressing the role of knowledge spillovers between workers within the same working area, and argues that experience and learning by doing are vital to endogenous technical changes. Romer's work asserts that knowledge stock generates increasing returns. Thus, specialization is conducive to long-run growth. According to Glaeser's (1999) argument on learning in cities, cities filled with young people who primarily learn from skilled members in their own industries tend to be specialized. The concept of proximity further explains the function of specialization. Geographical and cognitive proximity works in the knowledge spillover process. Cognitive proximity in the same industry assures the basic absorptive ability of firms to assimilate and improve transmitted knowledge, and the exchange of knowledge is facilitated by geographical proximity. Generally, knowledge spillovers within industries accelerate the generation of know-how and lead to incremental innovation, which underlines the success stories of many traditional industrial districts (Amin 2000). The success of the computer chip industry in Silicon Valley corroborates the positive relationship between specialization and knowledge spillover (Saxenian 1994). Skilled workers meet, chat, and eavesdrop, and labor flows across firms, thereby spreading ideas and know-how quickly among co-locating firms.

Meanwhile, Jacobs (1969) holds a different opinion on the way knowledge spillovers take place. Jacobs' externalities stress the diversity of industries as an important factor inducing human capital spillovers and the formation of new ideas. Unlike Arrow's statement that human capital is enhanced by interaction in the same line of work, Jacobs suggests that cross-fertilization across different lines of work enhances human capital in cities. The vivid examples given by Jacobs are new forms of adhesive tapes developed by a sand mining company, brassiere invented by a dress maker in New York, and Japanese bicycle repair shops gradually moving into bicycle manufacturing. Boschma (2004) further develops this argument with evolutionary thinking, stressing that diverse but related knowledge stock is a key factor that determines the effective interaction of actors in locations and prevents the negative "lock-in" effect of specialization. In other words, diversity brings two benefits: knowledge spillovers across different industries, and the portfolio effect that makes regions resilient to external shocks. However, a diversified economy may lead to the lack of focus on general services, such as administrative services, advertising, and legal consultation (Neffke et al. 2011). On the other hand, a specialized economy enables local governments and professional service providers, such as marketing and accountancy firms, to create tailor-made services.

Neffke et al. (2011) discuss the relationship between the industrial cycle and externalities. They conclude that MAR externalities are vital to growing and maturing industries where technological activities focus on improvement and adaptation, whereas Jacobs' externalities are pivotal to emerging industries where technological activities focus on innovation and change. Under MAR externalities, experience and learning by doing play a vital role only when specific technological standards and paradigms are established in the industry. Glaeser (1999) also argues that diversification tends to be lower in cities when imitation is more feasible. In contrast, at the onset of new industries, various new products emerge in the market to compete fiercely because standardization does not yet occur (Gort and Klepper 1982). Therefore, for an infant industry experiencing rapid technological changes, the need to absorb different fields of knowledge to spur ideas and innovations is imperative, and Jacobs' externalities are more important in this case.

Based on the foregoing discussion on knowledge spillovers on the local scale, the first hypothesis is drawn:

Hypothesis 1 In many latecomer regions where improvements and adaptations are prioritized, knowledge spillovers within industries, which stimulate the process of learning by doing, contribute more to innovation than knowledge spillovers across industries.

At the early phase of industrialization, knowledge spillovers on the local scale can be hardly realized due to a weak local industrial base and an unbalanced knowledge distribution among firms. Summarized from the literature, knowledge spillovers are realized mainly through four mechanisms: inter-firm collaboration, inter-firm cooperation, spin-off, and talent mobility (Boschma and Lambooy 2002; Power and Lundmark 2004; Parthasarathy and Aoyama 2006). In the first two mechanisms, firms should have developed their own core technological capabilities, enabling collaboration with customer or supplier, as well as cooperation with firms producing similar products. This ensures the reciprocal exchange of respective knowledge stocks. If firm-level technological capabilities are not fully and consciously developed, and those between firms are not equivalent and supplementary, firms would be less inclined to exchange knowledge due to the lack of mutual benefits.

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