Knowledge Spillovers and Technological Upgrading: Investigation into Guangdong Province, China

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Abstract: This paper aims at analyzing the impact of knowledge spillovers through international channels such as FDI and trade on the technological upgrading in Guangdong province, China by using the panel data of 21 municipalities for the period of 2000-2008. The results show strong evidence of external knowledge spillover as effective trigger of local-scale knowledge spillover in the latecomer regions, which mainly takes place within the industries other than the one between industries. The paper also demonstrates that the impact of external knowledge spillover is closely related to the investment stock, the degree of embeddedness and the absorptive abilities of local firms, and thus differs in different development phase. At the end, this paper points out the future study should go further to explore microeconomic aspects of technological upgrading in the firm-level.

Keywords: Knowledge Spillover; Technological Upgrading; Latecomer

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1. Introduction

The role of knowledge spillover is gaining considerable attention in the literature of economic growth in recent decades in generating endogenous growth and determining world development pattern. Knowledge spillover is particularly effective in cities, and it explains the growth of cities rather than its mere existence compared to static externalities (Glaeser 1999). Other than static externalities, which provide explanation to regional economic growth from the perspective of cost saving such as transportation and intermediate inputs (Hoover 1937; Carlton 1983; Krugman 1991), knowledge spillover refit externalities in a dynamic way and suggests that innovation investment thus bears increasing return because it contributes to a general stock of knowledge upon which neighboring firms or latecomer firms can build (Jacobs 1969; Romer 1986; Lucas 1988; Glaeser 1999).

Glaeser's seminal paper in 1992, which searches evidence of two kinds of externalities in local scale on city growth, has spurred an amount of work afterwards. However, the result of studies on knowledge spillover is so far not clear (Feldman 2000). On the one hand, it is proved that specialization stimulates growth. Henderson et. al (Henderson and Cockburn 1996) report significant knowledge spillover among pharmaceutical firms of both American and European origin. Henderson (Henderson 2003) finds significant knowledge spillover within high-tech industries. On the other hand, specialization is suggested to hinder growth in some way and the positive impact of diversity is proved. Glaeser et. al (Glaeser, Kallal et al. 1992) discover that knowledge spillover across industries rather than within the same industry helps employment growth in a period of deindustrialization, particularly in traditional industrial US cities. Miracky (Miraky 1994) suggests that industry concentration display somehow negative effect on growth. Feldman and Audretsch (Feldman and Audretsch 1999) and Rosenthal and Strange (Rosenthal and Strange 2003) also find the benefits of diversity.

The research results are all different due to different samples in different time and space (Combes 2000; Smit, Groot et al. 2007). Generally speaking, knowledge spillover in the same industry induces primarily incremental innovation, and knowledge spillover between industries is conductive to disruptive innovation. Neffke et al. (Neffke, Henning et al. 2008)'s discourse on the impact of different kinds of knowledge spillover in industry life cycle proves this statement. It suggests that knowledge spillover takes place between industries when industries are young and renewing, while knowledge spillover in the same industry get more prevalent when industries grow and mature. However, the above literature lacks an open perspective in the era of globalization. Branstetter (Branstetter 2006) finds that Japanese firms' FDI in USA brings two-way flow of knowledge spillover between the two countries. Boschma and Iammarino (Boschma and Iammarino 2009) conduct a systematic measurement of knowledge spillover in local scale as well as that in global scale in Italy and find that a high variety of knowledge flowing into the region contributes to regional economic growth. Other than knowledge spillover among developed world, knowledge spillover between developed countries and developing countries is also examined and is considered as a key mechanism to conditional convergence suggested by the theory of endogenous growth. Coe et al. (Coe, Helpman et al. 1997) find substantial knowledge spillover from the industrial North to the developing south by examining the relationship between trade and growth in 77 developing countries. Javorcik (Javorcik 2004) proves productivity spillover by FDI across industries in Lithuania, which realized through forward and backward linkages.

Based on the literature discussion, this paper argues that with the easier accessibility to external advanced knowledge and requisite absorptive ability in the local scale, it is very possible that latecomer regions seize the inflow of external knowledge as the trigger of knowledge spillover in the local scale, and this is likely to shape up a more stronger regional innovation system to sustain long-term economic growth.

The paper would contribute to the literature in the following two aspects: Firstly, I put knowledge spillover in local scale and in global scale in latecomer context within a theoretical framework, and discuss how the knowledge spillover in the global scale triggers the knowledge spillover in the local scale. Secondly, evidence of knowledge spillover, which is most underlying for innovation and economic growth in modern economy, would be further collected in latecomer context. Moreover, after the strike of global financial crisis and the gradual recovery of some developing countries such as East Asian countries[1], it is important to examine whether local dynamics of economic development such as active knowledge spillover has come into shape to sustain the long-term development in the face of changing and fragile global market after the crisis.

The study area is selected as Guangdong province which located in South China, and it is based on the arguments that: 1) Guangdong province developed quickly after the opening of the Chinese economy by successfully attracting labor intensive production. The latest statistic in 2008 shows that FDI in Guangdong takes 23% of the whole China, and the total import and export volume takes about 27% of the whole. 2) Since the transition from planned economy to market economy in 1978, the technological activities such as investing in upgrading machines, processing innovation and product upgrading is

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[1] Willem Thorbecke. Guest Contribution: East Asian Production Networks, Global Imbalances, and Exchange Rate Coordination. October, 2009.

increasingly prevalent in enterprise in Guangdong Province[2]. All of these provide a reasonable condition to test the existence and impact of knowledge spillover after decades of development.

The paper structures as follows: the second part provides a theoretical framework for analyzing the overall impact of knowledge spillover, which takes place in the same industry locally, among the different industries locally, and via global linkages, on the performance of technological upgrading in latecomer context like Guangdong province, China, and derive the hypotheses for empirical testing. The third part collects the stylized facts on the technological upgrading in one of the most developed and opens areas in China. The fourth part builds an econometric model and explains the variable selection and data collection. The fifth part reports the result. The sixth part concludes and discusses how to further extend the understanding of knowledge spillover.

2. Technological Upgrading:
Impact of knowledge spillover in local and global scale

In management literature, technological upgrading is mainly determined in the firm level. For example, firms which set long-term technological development strategies and devote much of its resources to R&D activities are assumed to achieve better technological capabilities. The success of Korean industry proves this assumption. The Korean government drew specific favorable policies in "preferred industries", such as ensuring the efficient scale economies by mergers, project-specific financial support and domestic market protection (Chang 1993). Combining with own R&D efforts, they have finally upgraded to a higher industrial value chain and established modern industry such

[2] Xueliang Wang, Analysis of Guangdong industrial enterprise innovation survey, Guangdong statistical bureau.

as auto and electronics in Korea.

However, internal efforts in the firm-level are not able to explain two phenomena: Firstly, regions with many small firms, which lack the financial ability to support internal R&D, perform quite well in technological upgrading, such as The Third Italy (Storper 1995), and it is argued that mutual trust between the firms constitutes the fundamental basis of long-term cooperation to facilitate knowledge exchange and stimulate growth. Secondly, firms with the same endowment and efforts into technological upgrading usually perform differently in different locations. All of above suggests that external environment plays an important role in determining the technological capabilities of firms.

I focus on three perspectives in knowledge spillover to explain this phenomenon. All these perspectives are concerned about the technological externalities achieved by knowledge spillover, which enables the firms benefit from each other’s internal efforts. The first two knowledge spillover, which takes place within and between industries in the local scale, have been nicely modeled and surveyed by many scholars (Loury 1979; Glaeser, Kallal et al. 1992; Asheim 2000; Neffke, Henning et al. 2008). The third knowledge spillover deals with externalities in the global scale (Grossman and Helpman 1990; Branstetter 2001; Javorcik 2004; Branstetter 2006), which is of most importance for firms in latecomer countries, where the spillover from neighboring firms is quite limited.

The flows of ideas are intrinsic to the new knowledge production which underpins the economic growth (Lucas 1988). Glaeser et al. (1992) suggest that people agglomerate in high-rent cities because they benefit from the learning opportunities. In this respect, it is assumed that physical proximity facilitates the information transmission. MAR externalities and Jacob externalities focus then on the spillover in local scale.

MAR externalities is based on Marshall's (Marshall 1920) agglomeration theory, and then developed by Arrow (Arrow 1962) and Romer (Romer 1986). Marshall's agglomeration theory state that firms in the same industry gather together to gain knowledge spillover as well as cost saving advantage from intermediate goods and searching for skilled workers. Arrow expands further by stressing the role of knowledge spillover between workers with the same working area, in which the experience and learning by doing is important for endogenous technical change. Romer's work asserts that stock of knowledge generates increasing return and thus specialization is conductive to long-run growth. According to Glaeser's (1999) argument on learning in the cities, cities that are full of young people that can only learn from the skilled members of their own industry will tend to be specialized. The concept of proximity further explains the function of specialization, in which geographical proximity 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 the knowledge transmission which is facilitated by geographical proximity. Generally speaking, knowledge spillover within the industries accelerates the generation of know-how and leads to incremental innovation, and it is prevalent in traditional industrial districts (Amin 2000). The success of computer chip industry in Silicon Valley proves the positive relationship between specialization and technological development. By either "meeting, chatting and eavesdropping" among skilled workers or inter-firms labor flow, ideas spread quickly among co-locating firms.

Jacobs (Jacobs 1969) holds different opinion towards the way that knowledge spillover takes place from MAR externalities. Jacobs externalities stress the variety and diversity of industries as an important factor to spur human capital spillover and new ideas formation. Unlike Arrow's statement that human capital enhanced by interaction in the same line of work, Jacobs suggests that cross-fertilization across different lines of work enhance the human capital in the city. The vivid examples given by Jacobs are new forms of adhesive tape 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 (Boschma 2004) further develops this argument by evolutionary thinking and stresses the variety of knowledge as key factor in determining the effective interaction of actors in the territory and avoiding the negative "lock-in" effect of specialization. In a word, diversity brings two benefits: knowledge spillover between different industries and portfolio effect that makes the region resilience to external shock. The negative effect of diversified economy is the lack of focus on general service such as administrative service, advertising, law consultation, etc. (Neffke et. al., 2008). Specialized economy, on the contrary, enables the local government and professional service provider such as marketing and accountancy to make tailor made service.

Neffke et al. (2008) discuss the relationship between industry cycle and externalities. They conclude that MAR externalities are vital to growing and maturing industries when technological activities focuses on improvement, while Jacobs externalities are vital to emergence of new industries when technological activities focuses on innovation and change. Experience and learning by doing in MAR externalities seem to play a considerable role only when specific technological standards and paradigm has been set up in the industry. Glaeser (1999) also argues that diversification tends to be lower in the city when imitation is more feasible. By contrast, in the start of a new industry, various new products emerge in the market to compete fiercely, as the standardization has not yet occurred (Gort and Klepper 1982). Therefore, for an infant industry where technological rapid change is prevalent, the need to absorb different fields of knowledge to spur ideas and innovations is imperative, and Jacobs externalities is of more importance in this case.

Based on the above discussion on knowledge spillover in the local scale, the first hypothesis is drawn as:

Hypothesis 1: In many latecomer regions where technological improvement is focused, knowledge spillover within the industries, which stimulates the process of learning by doing, contributes more to technological upgrading than knowledge spillover between the industries.

In the early phase of industrialization, it is difficult to have knowledge spillover in the local scale due to weak industrial base and unbalanced knowledge distribution among firms, which altogether hinder the function of knowledge spillover mechanisms. Knowledge spillover is realized mainly through four mechanisms: inter-firm collaboration, inter-firm cooperation, spin-off, and talent mobility. In the previous two cases, firms should have developed their own core technological capability to enable the collaboration with customer firms or supplier firms as well as the cooperation with firms producing similar products, because this ensures the reciprocity exchange respective knowledge stock. If the technological capabilities in the firm-level have not fully and consciously developed and the technological capabilities between the firms are not equivalent and supplemented, the firms would be less inclined to exchange knowledge due to the lack of mutual benefit. Similarly, spin-off activities happen only when the parent firm developed a mature technological paradigm and a particular set of technological capabilities which enables some key employees to exploit the existing knowledge by establishing a new organization. For the last mechanism which is transferred by skilled workers and talent, its effective functioning is determined by a high educational and professional level of human capital and skills, which is hard to achieve in the early phase of industrialization due to the higher percentage of agricultural employment.

In this context, external knowledge spillover can act as a trigger of knowledge spillover in the local scale by enabling the mechanisms mentioned above. The importance of external linkage to technological upgrading has been attracting more and more attention in latecomer context (Coe, Helpman et al. 1997; Falvey, Foster et al. 2004; Javorcik 2004; Revilla Diez and Kiese 2006). Revilla Diez and Kiese (2006) conduct a comparision study between south-east countries and European countries, and suggest that the strong orientation to R&D centers of multinational corporations in industrialized countries in Singapore, Penang and Bangkok yields a leapfrogging industrial development.

External knowledge spillover in latecomer countries takes place in three ways: trade, FDI and overseas talent. Figure 1 illustrates the logic of how external knowledge spillover triggers local-scale knowledge spillover. They can trigger the mechanism of local knowledge spillover either in a direct or in an indirect way, and the underlined words indicate the four mechanisms of local knowledge spillover that we have mentioned above. Firstly, trade transmits knowledge that is embedded in import goods. Imported goods from industrialized countries serve as advanced product samples for reverse engineering, and boost intra-firm learning as a process of shaping particular firm technological capabilities. The enhancement of firm technological capabilities would further enable the inter-firm collaboration and cooperation to induce knowledge spillover, as well as the spin-off activities to reutilize its value. One point needed to stress is that, the impact of import of intermediate goods and capital outweighs that of final goods and thus it needs careful indicator selection and explanation in the model establishment. Secondly, FDI generate a large production network in latecomer countries, and helps its related firm - such as their subsidiaries, OEM suppliers and non-OEM suppliers -not only by linking these firms to a fiercely competing place with many firm in other low cost regions, but also by introducing, interpreting and instructing production know-how and product-specific technologies to these firms so as to strengthen their technological capabilities, and the strengthening of technological capabilities enable the functioning of three mechanisms of local knowledge spillover just as shown by figure 1. Besides, FDI demonstrates training effect that increases the technical, market and managerial knowledge of the people who once worked in foreign or foreign-related firms. Employees with improved technical knowledge attracted to other local firms by higher salary offer carry the knowledge to these firms, which triggers the functioning of talent mobility mechanism, while employees with improved market and managerial knowledge might seize one of the technological opportunities in the parent companies and set a new firm to exploit the market potential of the particular technology, which triggers the functioning of spin-off mechanism. Lastly but not least importantly, inflow of overseas talent not only increases the quality of human capital in the local scale, but also induces spin-off activities under effective incentive framework offered by the local government to attract overseas entrepreneurs to bring back latest technology with market potentials. They can even establish dynamism between the developing home countries and developed world by using their personal network in both places, which is first suggested as "technological communities" by Saxenian (Saxenian and Hsu 2001). The overwhelming development of Hsinchu hi-tech cluster in Taiwan is greatly supported by the "technological communities" of US-educated Taiwanese engineers that transfer capital, skill and know-how to Taiwan, as well as facilitates the collaboration between Silicon Valley and Hsinchu by using their personal network in both regions.

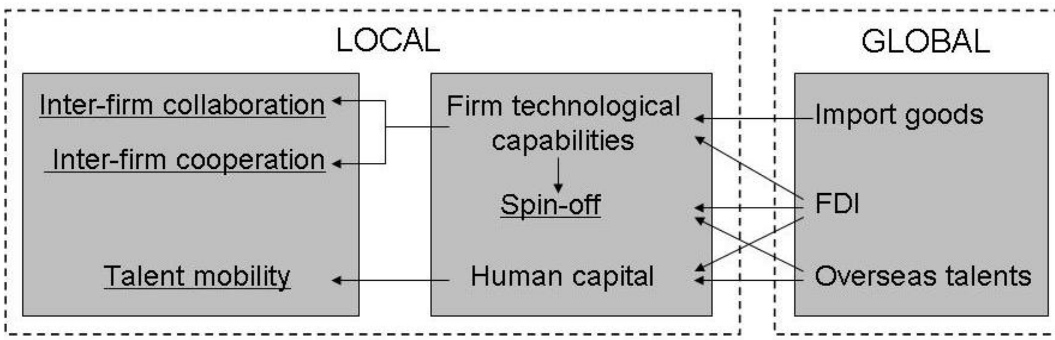

Figure 1 Trigger logic of external knowledge spillover to local knowledge spillover
* the underlined words indicate the four KS mechanisms

Following the above argument and hypothesis 1, we can draw the second hypothesis as:

Hypothesis 2: Knowledge spillover within industries in latecomer regions can be effectively triggered by external knowledge spillover through import goods, FDI and oversea talents.

However, the trigger effect of external knowledge spillover does not take place automatically. In fact, the impact of FDI and import on technological upgrading depends on investment stock, the degree of embeddedness and the absorptive abilities of local firms.

In the early phase of foreign direct investment, global lead firms seek the optimal location to conduct parts of the complex production in order to obtain price advantage and utilize location-specific resources, and their previous investment is aimed at cost reduction which is attracted by low labor prices and favorable policies. In this time, the global firms take a "stand-alone" attitude and exert little impact on local capabilities. In 21^{st} century, globalization is stepping into a new phase. It is transforming from vertical disintegration within an ownership to organizational fragmentation. The production network led by global lead firms took form in many latecomer regions. With the maturing of industries and technological development, more and more activities are outsourced and the local firms grow in this process. Empirical evidences (Kokko 1994; Kinoshita 2001) have proved that FDI can contribute to productivity growth only when the sufficient absorptive ability is available in local firms. On the other hand, foreign investment in this phase are aiming at resource and capabilities utilization so as to explore and utilize the location-specific know-how, and the investment expands from simple production to basic R&D activities (Maskell and Malmberg 2007). Many R&D activities nowadays are becoming standardized and codified, which facilitates the geographical dispersion of R&D units. These R&D units support the effective function of large-scale production activities in the latecomer regions due to geographical proximity. In this phase, the impact of foreign investment on technological upgrading of local industries is becoming larger and larger as the production scale is expanding.

A traditional argument on trade holds that country would at once get the benefits from trade upon liberalization. In fact, the requirement of which import trigger knowledge spillover to latecomer countries is more demanding than what FDI requires, because the learning process through import is active while learning by FDI spillover is rather passive. The learning process by import goods requires the firms to strategically identify and fully assimilate the goods and transform to firm technological capabilities. Cohen and Levinthal (Cohen and Levinthal 1990) argue that firms rely on previous knowledge to understand and absorb new external knowledge, and absorptive ability determines the assimilation of import goods and the effective transformation of knowledge learned from imported goods into firm technological capabilities. Actually, trade would exert different impact in different technological development phase. As investment on technological upgrading is stimulated by anticipated profits, trade would reduce technological efforts in import-competing industries (Lawrence and Weinstein 1999). In this sense, local firms can only benefit from imported goods when their own absorption abilities have developed to a certain level, otherwise it would suppress the incentive of local firms to invest in technological efforts because the market are overtook by the better quality import goods. This constitutes the logic of "import substitution" policy in many developing countries.

Hypothesis 3: The impact of external knowledge spillover on technological upgrading is closely related to the investment stock, the degree of embeddedness and the absorptive abilities of local firms Therefore, the impact of foreign direct investment on technological upgrading increases with growing production, and import goods might harm the incentive of local firms to invest in technological upgrading when their absorptive ability is still low.

Before testing the three hypotheses by establishing econometrical models using panel data in Guangdong province, I first collect evidences to demonstrate the technological upgrading in Guangdong province, China in the period of 2000 to 2008 in the next part, so as to justify the selection of the study area as well as to get a overall impression of the characteristic of technological upgrading in Guangdong.

3. Technological Upgrading in Guangdong Province, China:

Trade in Guangdong is characterized as processing trade. But as far as "processing" is concerned, it doesn't necessarily mean low level or stagnating technological development. In the period of 2000 to 2008, the share of high tech products of the total export in Guangdong increases from 19% to 37%, while the share of garment and shoes of the total export decreases from 33% to 18%. The content upgrade of trade from "low-tech" products, such as garment and shoes, to high-tech products, such as electronics, clearly indicates the higher ability of the firms to understand, absorb and process more complex products. However, if the export of high-tech products is just based on simply assembly, it requires no much more skill than processing garments and shoes.

Therefore, I observe deeper into the structural change of main high-tech trade products, and draw a clearer picture of the technological upgrading in Guangdong province (Table 1). Data processing equipment and hand-held telephones didn't appear in the main export high-tech products catalog in 2000, while in 2008 it takes 21% and 7% respectively of the major export commodities. But clearly, the surge of data processing equipment and hand-held telephones exports relies heavily on the import of more complex semi-finished products Integrated Circuit (from 12% to 35% in import catalog), which the firms in Guangdong province still lacks the capability to produce. However, the increasing import share of core parts such as semi-conductor devices and circuit protection device shows that the firms are gradually breaking away the reliance on importing high tech parts to produce and accumulating the capability to adapt and improve imported technology instead of only applying them. This is because that these more complex electronic components are usually used to fit in integrated circuit, and the processing of these components clearly indicates deeper understanding of the principle of circuit running and increasing ability in circuit design adjusting to different purposes. And also, while the export of color TV increases, the import of kinescope – the core technological part in TV set – decreases. Thus it can be concluded that the firms in Guangdong province are now more capable to product TV set all by their own, which signifies a degree of technological upgrading.

Table 1 Structural change of several main high-tech trade products

	Unit: 10 thousand	**in all main export products**		**in all main import products**	
		2001	2008	2000	2008
Finished product	Data Processing Equipment	39328 (15)[1]	87226(21)	4577(4)	23524(7)
	Hand-held or Vehicle-mounted Cordless Telephones	988(2)	20860(7)	—	—
	Color TV Sets	529(0.7)	2129(1)	—	—
	Cameras	6568(1)	7293(2)	—	—
Semi-finished product	Integrated Circuit and Parts of Electronic components	160831(0.6)	794000(1)	1710950 (12)	5735800 (35)
Core parts	Parts of Semi-conductor Devices	—	—	6562167(3)	16183800(5)
	Circuit Protection Devices	—	—	— (2)	— (4)
	Kinescopes	—	—	448(1)	296(0.06)

1. Number in brackets indicates the share (%) of this product in all main export or import products
2. Source: Guangdong statistical yearbook

New products development is an important aspect of technological upgrading. According to China statistical standards, the definition of new products indicates brand new products to the firm, which apply new technological principles or new design idea, or greatly improved products in structure, material or processing methods, all of which would significantly enhance the performance or expand the functions of the products. Having assumed that firms in latecomer countries possessing large room to learn and adapt technology developed by industrialized countries to improve the performance, new product development stands as a more market-oriented indicator than patent in latecomer context for appropriation to technological frontier. In the last ten years, the output value of new products in Guangdong province increases more than 8 times in the period of 2000 to 2008, and the export value of new products increase even 11 times in this period (Figure 2).

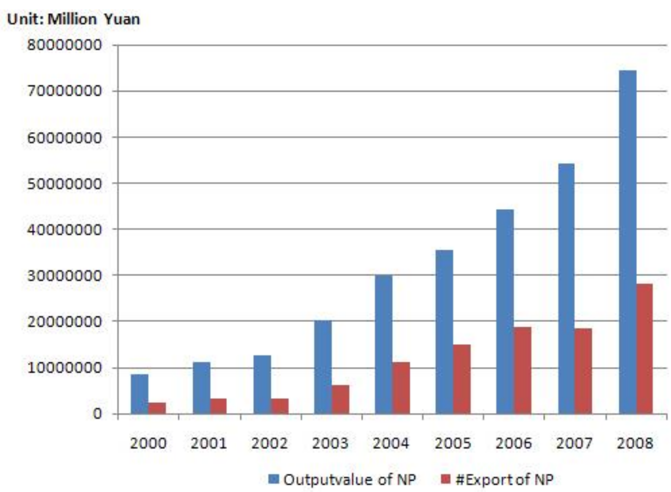

Figure 2 New product development in Guangdong Province
Source: Guangdong statistical yearbook

The significant achievement in new product development can not be achieved without the firms' internal learning effort. Because the R&D expenditure and new product development activities are not normally distributed in Guangdong province, I use Spearman' rho correlation to calculate the correlation of new product value and export and firm R&D expenditure from 2001 to 2008 (except 2004 because of data missing) across 21 municipalities in Guangdong province, and the result shows that new product output value is significantly positive correlated (0.837) with firm R&D expenditure, and new product export is also significantly positive correlated (0.754) with firm R&D expenditure.

Table 2 Spearman's Correlation of new product value and export with firm R&D expenditure

Spearman's rho Correlation		firm R&D expenditure
New product value	Correlation Coefficient	.837**
	Sig. (2-tailed)	.000
New product export	Correlation Coefficient	.754**
	Sig. (2-tailed)	.000

*Correlation is significant at the 0.01 level (2-tailed).
List wise N = 147

R&D activities imply the efforts in improving existing knowledge (develop) and pushing technological frontier (research). International comparison study indicates that R&D share over 1% is the sign of surpassing the phase of basic technological introduction and application and the increasing ability in absorption and assimilation. From 2000, Guangdong province's R&D share in GDP has reached 1.1%, which increased greatly compared to the percentage in 1995 (0.2%), and in 2008, R&D share has reached 1.4%. However, comparing to that of in industrialized countries such as USA (2.7%), Japan (2.7%) and OECD (2.3%), and to that of in newly industrialized countries or regions such as Korea (3.5%), Taiwan (2.6%) and Singapore (2.3), Guangdong still has a long way to catch up. Moreover, R&D activities in Guangdong province mainly involve learning effort in assimilating and improving the technologies in industrialized countries.

The character of R&D activities in Guangdong province is better revealed by comparison with other developed provinces in China and national average. Firstly, the R&D intensity is comparatively low in the national league. This might attribute to the insufficiency of technological investment of universities and research institutions as well as absence of global lead firms that devote to R&D activities compared to Beijing and Shanghai. Secondly, technological upgrading in Guangdong is mainly led by firm investment other than government and research institutes and thus is more market-driven. The percentage of firm investment in R&D in Guangdong province is 82%, which is higher than national average (73%) other developed regions, except for Zhejiang Province, where the private economy is also developing very well. Thirdly, technological change in Guangdong Province is mainly pushed by test & development activities other than basic research and application research, which shows that technological activities are rather incremental than radical in Guangdong province.

Table 3 National Comparison of Technological Indicators (2008)

	National average	Guangdong	Shanghai	Beijing	Jiangsu	Zhejiang
R&D expense (percentage in GDP)	1.5%	1.4%	2.6%	5.9%	1.9%	1.6%
# Firm investment in R&D (%)	73%	82%	68%	47%	70%	86%
# Investment in Basic Research (%)	5%	1.4%	7%	8%	2%	—
# Investment in Application Research (%)	12.5%	1.6%	14%	22%	—	—
# Investment in Test & Development (%)	82.5%	97%	79%	60%	—	—

Source: China Statistical yearbook and statistical yearbook of the Provinces

To sum up, during the first decade of 21st century, in which the global competition becomes more fierce than in 1990s for low cost regions, Guangdong province shows its learning ability to gradually renew and upgrade the products, which also leads to the sustainable competitiveness of export products. Technological upgrading activities in Guangdong province is characterized as firm-led assimilating and improving activities. Comparatively, the mechanism to conduct rapid technological change is missing due to the absence of excellent universities and research institutions and the basic research activities. Apart from firm internal effort, knowledge spillover that transfers know-how and that induces learning by doing process in the firms is supposed to be important for the dynamic self-sustaining technological progress in Guangdong province according to the discussion in the previous part. This is the point that I turn to in the next part.

4. Econometrical model and Data

Empirical test of knowledge spillover has been conducted mainly in three ways: The first one is to include knowledge spillover effect in technology term in the regional product function using city-industry data (Glaeser et. al., 1992; Feldman and Audretsch, 1999; Neffke et. al, 2008). The second one is to construct knowledge function (patents or new products) to catch the "technological leakage" of private (other firms within or across industries), public and academic research institutions (Jaffe 1989; Feldman 1994b). The third one is to trace the time and spatial scale of patent citation (Trajtenberg 1990; Jaffe, Trajtenberg et al. 1993).

Applying in latecomer context, in which the knowledge assimilation and adaptation is more prevalent than knowledge production, the patent data is not appropriate. Griliches (Griliches 1990) and Feldman et al. (1999) suggest that new product introductions as more direct and market-oriented indicators than patented invention. Thus, I use new product value here to measure technological upgrading. I address the measurement as follows: 1) According to an innovation survey of 8962 firms in Guangdong in 2008[3], product innovation is as important as process innovation for the firms. Schiller (2009) also finds that product innovation is the most important innovation way among electronics firms in the core region of Guangdong province. 2) As city-industry data of external linkage such as FDI or import-export is missing, the first kind of testing

[3] Xueliang Wang, Analysis of Guangdong industrial enterprise innovation survey, Guangdong statistical bureau.

knowledge spillover mentioned above can not be conducted, even if it is suggested by Glaeser (1992) as the most direct way to test spillover. However, the second method can still catch the general effect of knowledge spillover, except examining the difference between industries. Therefore, in order to test the knowledge spillover in China context with available data, I adjust the second method, which examines specifically the impact of knowledge spillover with industries, among industries, and with external actors on the development of new products in Guangdong province.

Construction of data set and the model

For the model building, I use panel data that encompasses data in 21 municipalities in Guangdong province across the time period from 2000 to 2008. This geographical unit is considered to be appropriate scale for knowledge spillover to take place than provincial unit. The starting year 2000 is selected because it was the first year that the data on new product development is available.

As mentioned above, the dependent variable in the model is new product value. The introduction of new products results from many aspects. If discussed in the Guangdong context where technological upgrading are characterized as improvement rather than radical innovation, it would be the result of improving on technologies that is central to the firm, reverse engineering new technological principles, as well as recombination or redesign of existing components by assimilating deeper the existing technological principles (Kogut and Zander 1992). What is worth mentioned here is that I do not accept new product rate in our model as the dependable variable, which might contrast the practice in regional innovation system literature. Yet in the context of an immature regional innovation system, it makes more sense to investigate the factors that drive the emergence of innovation rather than the innovation intensity.

Jacobs externalities have been measured in various ways. Usually, measuring industrial diversity of the city is a common way to test the impact of knowledge spillover between industries on the technological upgrading of the firms. Indexes such as Hirschman-Herfindahl index (HHI) or entropy index are mostly used in the literature. The difference between these two indexes is that HHI calculation is based on the square of the share for respective industries, while entropy index calculation is based on the logarithm of the share for respective industries. Thus, HHI stresses more on the influence of stronger industries. As I aim to measure diversity instead of concentration here, entropy index is chose to enter the model.

Diversification index = $\sum_{i=1}^{N} p_i \log(1/p_i)$

p_i is the percentage of industry i in the whole manufacturing output value.

The index of MAR externalities aims at measuring the degree of specialization of the city. If not using city-industry data (that means location quotient can not be calculated), the measure of specialization can be somehow replaced by the measure of diversity. In order to conduct a robust examination of knowledge spillover in local scale, the model introduces a more accurate measure of specialization, which is the share of the city’s biggest industry according to its output value. The specialization index in the model is defined as:

Specialization index = p_{max}

p_{max} is the percentage of the largest industry in the city according to output value

Besides the measure of knowledge spillover in the local scale, I also aim to assess the impact of external linkage on the technological upgrading in Guangdong province. Here, import value and FDI are all included in the model. Import value aims at measuring spillover of knowledge embedded in foreign commodities, while FDI aims at measuring spillover of know-how by the global production organization. The impact of overseas talents can not be measured here because of missing data. Two issues should be mentioned in the measurement of external knowledge spillover: 1) Foreign direct investment needs time to become embedded in the local environment and become to exert knowledge spillover effect to local firms, therefore, foreign direct investment stock quantity since 1985 is used instead of flow quantity in each year. 2) Data of import value is quite generally in the municipal level of Guangdong province, categorizing information of trade form such as original trade, processing and assembly trade and compensation trade, etc, can not be differentiated. In fact, only a proportion of import such as import for processing trade and imported equipment can actually boost intra-firm learning process and thus increase the technological capabilities of firms. Therefore, general import value would generate bias estimation on the impact of import goods on technological upgrading, so the result of import value should be carefully explained in the model.

In order to avoid omitted variables bias in the model, two control variables are introduced in the model. They are addressed as follows:

1) Human capital in the firm level: Management literature hold that technological upgrading is mainly decided in the firm level and internal efforts is of major importance. Moreover, internal feature such as the level of human capital determines in a large extent how the firms search, absorb, and internalize the knowledge spillover and transform it into better performance in technological capability. In this model, I use the number of personnel engaged in scientific and technological activities to control for internal efforts

in the firm level.

2) Urban externalities: Compared to “dynamic externalities” (knowledge spillover) brought by MAR externalities and Jacobs externalities, urban externalities bring two major advantages to firms located in larger cities in favor of technological upgrading: Firstly, larger city offers better infrastructure, especially transport infrastructure such as high way and airport which enhances the market access of firms. Secondly, larger city offers larger base and larger odds of interaction (Glaeser, 1999), which indirectly influences the impact of MAR externalities and Jacobs externalities on technological upgrading. However, larger cities can also harm the local industry due to negative externalities such as congestion, too high factor costs and pollution. Therefore, I construct quadratic term for urban population to seize the limit value of urban size, and it is assumed that when under this limit value, the urban population would exert positive effect on technological upgrading and exceeding the limit value would begin to exert negative effect on technological upgrading performance.

Panel data approach

Panel data is a set of data which certain individuals are continuously observed over a period of time, the benefits of using panel data is reflected mainly in three aspects (Baltagi 2005): 1) panel data can control for individual heterogeneity; 2) panel data is able to catch the dynamics of adjustment compared to cross-sectional data, 3) and has less collinearity among variables and adds more variability compared to time-series data.

The general form for panel data model is as follows:

$$y_{it}= \alpha + \beta x_{it}+ \nu_i + \varepsilon_{it}$$

In this model, i=1,2,….N, refers to the cross-sectional unit, and t=1,2,….N refers to the time series, y_{it} is the dependent variable, and x_{it} is the matrix of independent variables, v_i is the unit-specific residual, and it differs between units and is meanwhile constant for any particular unit, which might refer to regional properties in our model. ε_{it} is the error term which is assumed to be homoskedastic.

Instead of pooling all the data together just as in the simple regression model, three techniques are applied to utilize the different scales of variation in panel data: the fix-effects model, the between-effects model and random-effects model. Fix-effects model makes use of the within individual variation in the panel data, between-effects model makes use of the between individual variation in the panel data, and random-effects model makes use of both of it. In between-effects model and random-effects model, no-correlation between v_i and x are required assumption. Fix-effects model looses this limitation and assumes that v_i is correlated with the regressors. In a word, random-effects model is most efficient because it utilized comprehensive information in the panel data which catches cross-section and within variation, but it has a stricter assumption than fix-effects model. Generally speaking, fixed-effects model and random-effects model is more often used than between-effects model.

F statistics is applied to test the appropriateness of fix-effects model compared to pooled regression model, and its null hypothesis is that the fix effect is not significant, which is formalized as:

H_0: $v_1 = v_2 = \ldots v_n$

If the null hypothesis is rejected at a certain level of significance (normally under 5%), then fix-effects exists and fix-effects model outperforms pooled regression model.

The Breusch-Pagan Lagrange multiplier (LM) test is designed to test random effects, and its null hypothesis is that the variance of groups is zero, which is formalized as:

H_0: $\sigma_\nu^2 = 0$ v.s. H_1: $\sigma_\nu^2 \neq 0$

If the null hypothesis is rejected at a certain level of significance (normally under 5%), then random-effects model is more appropriate than pooled regression model.

The above two test can only prove the appropriate form of fix-effects model and random-effects model compared to pooled regression model, however, decision should be made on the estimation effectiveness among fix-effects model and random-effects model. Hausman test is the solution to this problem. Based on the idea of Hausman test, when ν_i is uncorrelated with the regressors, the estimation of fix-effects model is in accordance with the estimation of random-effects model, but the former one is not effective any more. It is formalized as:

$$\text{Cov}\left[b - \hat{\beta}), \beta\right] = \text{Cov}\ [b, \hat{\beta}] - \text{Var}\ [\hat{\beta}] = 0$$

If the null hypothesis is rejected at a certain level of significance (normally under 5%), then ν_i is correlated with the regressors. In this case, we choose fixed-effects model or use instrumental variable to deal with the endogenous problem.

Description of data

In the previous part, I state in details the construction of the variables for estimation purpose. Here, I highlight some features of the data (Table 4). The new product value increases steadily, while the standard deviation increases greatly at the same time, which indicates a uniform upward trend among municipalities in Guangdong province (Figure 3). As shown in figure 1, Shenzhen experiences the largest increase in new product development, especially in the year 2008, the most dramatic increase occurs. Other cities in the core area of Guangdong province such as Guangzhou and Foshan have experienced larger increase, Huizhou experiences a moderate increase, and Zhuhai's increase over time is fluctuating, while other cities all remain in a comparatively low level.

Table 4 Descriptive statistics of several variables over time

	2000	2002	2004	2006	2008
New product value	413669 (826184)*	606765 (1054310)	1423287 (2607879)	2104553 (3957404)	3541318 (7656674)
Industrial diversity	3.8 (0.53)	3.7 (0.57)	3.6 (0.67)	3.7 (0.62)	3.7 (0.56)
Industrial Specialization	0.26 (0.14)	0.27 (0.15)	0.29 (0.17)	0.28 (0.15)	0.27 (0.14)
FDI stock (Unit: billion Yuan)	54.12 (64.85)	69.45 (85.94)	81.64 (101.76)	94.43 (118.98)	111.71 (140.73)
Import value (Unit: billion Yuan)	37.2 (70.9)	48.9 (97.6)	78.8 (162.1)	107.3 (231.9)	133.0 (279.5)
Firm personnel engaged in technological activities (Unit: Thousand)	—	4957.3 (6807.3)	—	9926.5 (17076.1)	16258.8 (35431.4)
Population at the end of the year (Unit: Million)	405.96 (210.03)	421.05 (211.64)	433.84 (212.98)	443.05 (218.62)	454.48 (227.95)

* Numbers outside the brackets indicate average value; numbers in brackets indicate the standard deviation.

The average and standard deviation of diversity and specialization index does not change over time, which indicates a path-dependent pattern of industrial development. Cities tend to do the things that it was good at in the past.

The FDI stock increases twice on average in Guangdong province over the period of 2000-2008, however, the standard deviation also increases more than twice, which shows the uneven flow and distribution of FDI in Guangdong province. The FDI tracks a path-dependent route because of the sunk cost of capital investment and the increasing return of technical know-how of the local firms developed in the process of doing business with foreign firms.

Import value follows a similar pattern with FDI stock among municipalities in Guangdong province. In 2008, the import value in the core area of Guangdong province (which includes the nine municipalities in Pearl River Delta) accounts for 96% of the whole import value in Guangdong province. This might attribute to the higher consumption level in these areas to import final goods as well as the higher firm absorptive abilities in this areas to import intermediate goods and capital goods to learn.

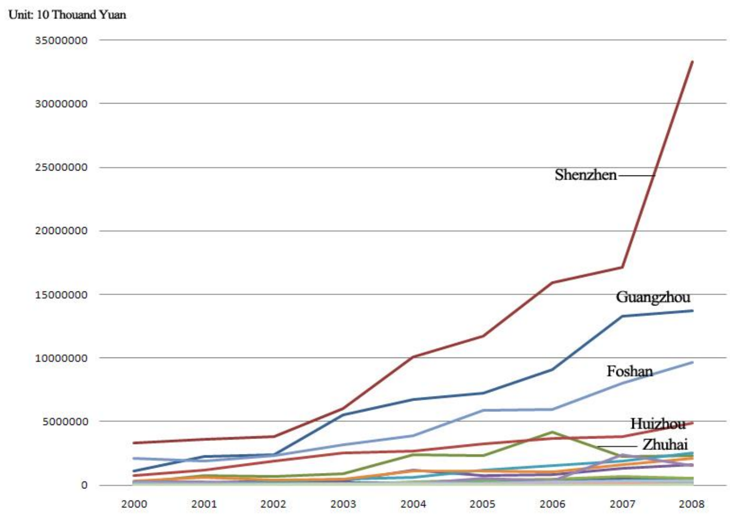

Figure 3 New product output value over time among municipalities

Finally, human capital in the firm-level also increases unevenly among municipalities in Guangdong province over time, while population shows a comparatively stable pattern of distribution during 2000 and 2008. The large variations of most of the indicators justify the application of panel data to include more informative data into the model, and as we can see in the econometrical results in the coming part, the dynamic difference of FDI stock, import value and human capital as well as their interaction effect with specialization explains quite well the great difference of new product development achievement among 21 municipalities in Guangdong province.

5. Report of Empirical Test

As a baseline, I firstly estimate the effect of different scales of knowledge spillover without including the interaction term. Because the diversified index and specialization index are mutually substituted, only one of the two regressors is include in the model at one time. Table 5 presents the result of new product output value in Guangdong province.

Table 5 Regression results of fix-effect models

INDEPENDENT VARIABLE	New Product Output Value （Unit: billion Yuan）				
	(1)	(2)	(3)	(4)	(5)
Constant	-28.37	50.01*	-108.43***	-86**	-90.92***
	(-1.3)	(1.9)	(-3.19)	(-2.59)	(-2.69)
Specialization index	0.58***	—	0.32**	-0.02	0.22
Unit: %	(3.26)		(1.98)	(-0.11)	(1.33)
Diversified index	—	-17.75***	—	—	—
		(-3.82)			
FDI stock	4.02***	4.17***	-0.3	-0.46	1.28
Unit: billion Yuan	(8.11)	(8.53)	(-0.37)	(-0.59)	(1.32)
FDI quadratic term	—	—	0.09***	0.07***	0.08***
(FDI stock*FDI stock)			(6.78)	(5.05)	(5.94)
Interaction term	—	—	—	0.06***	—
(FDI stock*specialization)				(3.58)	
Import value	-0.86***	-0.94***	-1.1***	-1.49***	-2.18***
Unit: billion Yuan	(-4.11)	(-4.48)	(-5.66)	(-6.9)	(-5.04)
Interaction term	—	—	—	—	0.02***
(import value*specialization)					(2.78)
Human capital	1.84***	1.86***	1.59***	1.62***	1.54***
Unit: thousand	(15.44)	(15.76)	(14.42)	(15.28)	(14.17)
Population	-3.16	-2.56	35.62**	29.89**	29.86**
Unit: Million	(-0.61)	(-0.5)	(2.59)	(2.25)	(2.2)
Population quadratic term	—	—	-2.45**	-2.29**	-2.36**
(population*population)			(-2.25)	(-2.19)	(-2.22)
Within Adjusted R^2	0.91	0.91	0.93	0.94	0.93
Number of Observations	168	168	168	168	168
F test	6.52***	6.09***	5.77***	6.76***	6.08***
Hausman test	55.31***	57.54***	114.6***	30.3***	38.94***

Standard errors in parentheses; *p<0.10, **p<0.05, ***p<0.01

Column (1) and (2) show the results. As for the knowledge spillover in the local scale, no matter measured by diversity (entropy index of the city industries) or by specialization (the share of the city's largest industry), the result of our model confirms the first hypothesis, that is, specialization contributes to the product upgrading in Guangdong province. In accordance with MAR externalities, knowledge spillover within the industries tends to generate higher value of new products than knowledge spillover between industries suggested by Jacobs externalities. Also, foreign direct investment stock has a significantly positive impact on new product value as expected, and the impact of import on new product value is significantly negative, which supports hypothesis 3 that argues that import goods can reduce the technological efforts of local firms when their absorptive ability is still low. This view might contrast to other empirical studies on trade impact on productivity. However, considering the data and study context in this model, it is helpful to think about the difference of the trade impact in different development phase. Considered with the positive impact of FDI stock, it can be concluded that the absorptive abilities of Guangdong firms are high enough to avail themselves of the knowledge spillover brought by FDI, but still not high enough to actively transform the knowledge spillover brought by imported goods to their own technological capabilities. As expected by the traditional management literature, internal efforts is of great importance to new product development, which an increase of 1 thousand technological personnel would increase over 1 billion Yuan new product output value. The disadvantage of urban externalities seems to outperform its advantage according to model (1) and model (2), however, this impact is not significant even at the 10% level.

In column (3), I include the quadratic term of foreign direct investment and population, based on the previous discussion on their nonlinear impact on technological upgrading. Specialization still exerts positive impact on new product development at 5% significant level, while the impact coefficient decreases from 0.58 to 0.32 — which implies that 1 percent increase of the largest industry in the city would increase the new product output value by 0.32 billion Yuan. The impact coefficient and significance of import and firm-level human level remain almost unchanged. What we can clearly see in this model is that the impact of FDI and population is nonlinear. From the coefficient and significance of FDI stock and its quadratic term, it can be drawn that the impact of FDI stock on new product development depends on the amount of the FDI stock, and the relationship between FDI stock and new product value follow a quadratic curve where a>0 (a=0.09). When the FDI stock is in a comparatively low level, the impact is of little importance. With the increase of FDI stock, the impact of FDI on new product development becomes larger, and it implies that the local production network led by global firms has become more mature and the knowledge spillover from foreign investment is becoming larger when it has embedded and the absorptive abilities of local firms have coevolved. As for the urban externalities, the limit value is calculated as 7.26 million population (-b/2a = -35.62/2*2.45=7.26). This means that when the city population is under 7.26 million, then the impact of urban externalities is positive due to better infrastructure and larger odds of interaction to spillover knowledge, however, the positive impact decreases with the growing population and when the city population exceeds 7.26 million, the impact of urban externalities becomes negative and this negative impact increases when the population continue to grow, which attributes to high factor costs, congestion and pollution that brought by big cities.

The central thrust of this article is that external knowledge spillover trigger the knowledge spillover in local scale in latecomer regions. In order to catch these triggering effects, I include the interaction term separately in model (4) and model (5) in order to avoid correlation problem. In column (4), interaction term between FDI stock and specialization is included. The results show that the interaction term is positive at 1% significant level, while the specialization alone does not exert any significant impact on new product development. The estimates imply that the impact of specialization on new product development relies on the value of FDI stock and the larger the FDI stock, the larger the impact specialization can exert. In column (5), interaction term between import and specialization is also significantly positive, while the specialization itself does not have significant impact. This estimation is consistent with the result in column (4), which also implies that the amount of import determines the impact degree of specialization on new product development. It might be kind of surprising to find this positive relationship between import and specialization when import itself would actually harm the new product development (significant at 1% level). As we discussed before, the impact of import is greatly determined by the absorptive ability of the firms, and the cluster literature points out that leading firms act as gatekeepers that determines the effective diffusion of import knowledge to other cluster firms (Owen-Smith and Powell 2004; Giuliani 2005). In this sense, the absorptive ability of the lead firms determines the impact of import goods on the knowledge spillover in the local scale. Due to economies of scale and low transaction and coordination cost in more specialized area, absorptive capacity of the leading firms in more specialized location is stronger and they performs better at utilizing import to yield technological upgrading. Therefore, it is no wonder to see that more specialized area benefit from import while import generally harm the technological efforts of the firms in the whole area.

Test of Model appropriateness and Robustness

The fix-effects model is proved to be appropriate due to the significance of F value and Hauman test parameter, which is shown in the last two lines of table 5. F test in the five models all achieve the 1% significance level, which justifies the application of fix-effects model instead of pooled regression model. The Hausman test shows the correlation between individual-determined standard errors and other regressors, thus indicating the inappropriateness of applying random-effects model.

The new product output value in Shenzhen is much higher than the rest of the municipalities in Guangdong province (Figure 3), especially in 2008. In order to the influence of big fluctuation among the sample, the models are rerun without the Shenzhen data to check the robustness of our results. The overall picture is very much in line with the findings presented in table 5, which supports that the results in table 5 are robust and in line with our theoretical hypotheses.

6. Conclusion and Discussion

The result of this paper shed light on the role of knowledge spillover on technological upgrading of latecomer countries by approaching technological frontier. Consistent with Neffke et al. (2008)'s argument on the relationship between industry cycle and knowledge spillover in the local scale to explain the unclear empirical results in the literature, the results in this paper show that knowledge spillover within the industries matters more when technological activities are incremental and focuses on improvement.

More importantly, the analysis considers the external knowledge spillover, which is suggested by Kuznets (Kuznets 1973) as “advantage of the backwardness”, and demonstrates that external knowledge spillover, especially by the mechanism of foreign direct investment, triggers the knowledge spillover within the industries in the local scale in latecomer regions such as Guangdong province in China. However, it also proves that the external knowledge spillover to latecomer regions does not take place right away, it is in fact closely related to the investment stock, the degree of embeddedness and the absorptive ability of local firms. Another important support to this result is that import actually harms the technological efforts such as developing new products when the absorptive abilities of firms are low.

An important policy implication derived from the results is that efforts to upgrade the technological capabilities of local firms such as enhancing the human capital and providing incentive for small and medium sized firms to invest in technological upgrading should become the next policy focus after the crisis for China. Ever since the financial crisis, China has faced great pressure of RMB appreciation. In March 2009, China Prime Minister Wen proposed that China would further expand the import volume, particularly of high-tech products, in order to balance the trade structure and stabilize the exchange rate. Only with the increasing technological capabilities of the local firms, import can be utilized in a positive way without harming the domestic consumption market, which is now of particular importance to Chinese firms when the western market is shrinking.

In a theoretical term, the results indicate external knowledge spillover is key to the catching up of latecomer countries and conditional convergence between technological leaders and technological followers. However, as indicated by Helpman (Helpman 1993) and Barro and Martin (Barro and Salaimartin 1992), the lower cost of imitation and the absence of intellectual property rights gives the technological followers the incentive to copy in order to gain growth, yet as the technological gap is decreasing and the cost of imitation increases, the growth rate of technological followers tend to decrease. This line of thought sheds two research directions in the future:

Firstly, convergence does not take place as long as the technological gap exists, it requires the firms in the region avail themselves of the external knowledge spillover and convert into its own technological capabilities. Therefore, the first research direction is analyzing the microeconomic aspects of the question. Although the aggregate analysis in this article can provide informative implication on the impact of external knowledge spillover in the latecomer context, it is still far from clear that through which channels technological development in latecomer regions work in its way. In a word, the characteristics of firms and regions should be analyzed as to explore how some of the latecomer regions are successful in availing themselves of the external knowledge spillover to start the catch up process (Budd and Hirmis 2004). Moreover, under the absence of intellectual property rights framework in most of these regions, the informality would be an important aspect in the analysis.

Secondly, the results of this article are valid in a certain development phase. As the imitation cost is increasing, behavioral transition in technological activities should be changed as to insure the sustainable development. Another dimension of further study refers to the trailing of this transformation in latecomer countries and to analyzing the changing impact of knowledge spillover and the responsive strategies of firms and governments.

All in all, this study call into econometric studies that takes a dynamic perspective and considers the impact of knowledge spillover with differentiated development phase. Moreover, a firm-level study is requested to go beyond the general information provided by econometric studies to explore the microeconomic aspect of technological upgrading activities of latecomer countries.

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