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Wan-Hsin LIU

Abstract:
This paper investigates whether knowledge transferred from different sources matter differently for carrying out different innovation outcomes, using a firm-level dataset collected in the Pearl River Delta (PRD) in China. It also investigates whether companies in the PRD in China tend to innovate in a similar way as companies in the Asian Newly Industrialised Economies (NIEs) did decades ago. Our estimation results suggest that companies in the PRD, as companies in the Asian NIEs, strongly rely on sourcing from their OEM customers but not on own R&D activities to implement innovative processes to increase production efficiency. In contrast, they engage in own R&D activities in order to develop innovative products, to realise higher innovation sales and to create new knowledge qualified for patenting. In addition to own R&D activities, they rely on sourcing knowledge from different sets of sources to support them to carry out the last three types of innovation outcomes.

Keywords: innovation, knowledge transfer, knowledge production function, flying geese model, China

JEL classification: O1, O3, R1

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1 Introduction

China has developed rapidly over the past three decades and it turned to be the second largest economy in the world in 2008 with gross domestic product of US$7,903 billion (PPP).[1] After the initiation of the open-door policy in the late 1970s, the economic interactions between China and foreign economies, especially those from Asia, have been intensified with continuous increase in inward foreign direct investments (FDI). Such intensive interactions between China and especially the more advanced Asian economies have been argued to play an essential role for China's rapid economic development. Arguments as such are often related to the "Flying Geese Model (FG Model)" which was firstly proposed by Akamatsu in the 1930s and further developed by Yamazawa, Kojima and Ozawa over the past decades (Akamatsu, 1961 & 1962; Yamazawa, 1990; Kojima, 2000; Ozawa 2009). The FG Model suggests a co-development of countries in a hierarchical form with more advanced countries taking the leading positions and the developing countries acting as followers. As regards the economic development in East Asia, Japan was argued to take the leading position, followed by Hong Kong, Korea, Singapore and Taiwan (Asian NIEs[2]) as the first-tier followers where Japanese companies from the labour-intensive industries started to engage in FDI in the 1960s. With the economic development and the increasing production costs in the Asian NIEs in the 1980s, companies in the Asian NIEs started to relocate more labour-intensive industries into China and some other southeast Asian countries by investing on site just like what Japanese companies did in the 1960s. These new FDI receivers were then included into the co-developing hierarchy as the second-tier followers to take over the most labour-intensive part of the value chains.

The FG Model attributes the co-development of the developing countries strongly to their integration as followers in the hierarchical development pattern to take over the labour-intensive activities. Such integration is made possible mainly due to the FDI engagement of companies from the more advanced countries. However, taking over labour-intensive activities alone may not sustain the development of the follower countries for a long time. With the economic development and increasing labour costs, followers' comparative advantages in carrying out low value-added and labour-intensive activities may gradually disappear. What kinds of efforts the follower countries may make to climb up the upgrading ladder to sustain their market competitiveness against the other (second-tier) followers is not investigated in detail in the FG Model. Take the Asian NIEs as the first-tier followers in Asia

[1] See World Bank (2009).
[2] NIEs refer to Newly Industrialised Economies.

as examples, there are some case studies trying to identify the upgrading efforts made by companies in the Asian NIEs in the past. But empirical literature based on econometric analysis is hardly found. Case studies show that companies in the Asian NIEs, due to the lack of technological capabilities, tended to innovate by relying on using advanced machines and learning technologies provided by their parent companies or OEM customers[3] from Japan or some other more advanced countries so that they can increase their production efficiency (e.g. Hobday, 1995b; Nabeshima, 2004). Moreover, the lack of financial resources and innovation experiences hindered them from devoting themselves to undertaking own R&D activities and reduce their incentives to bear high risks and to develop new products on their own.

Accompanying with the rapid economic development in China, companies in China are facing greater competition than before. Increasing production costs and the changing governmental policies towards innovation and upgrading construct a business environment similar to some extent to that faced by companies in the Asian NIEs decades ago. These two changes seem to act like push and pull factors encouraging companies in China to devote themselves to upgrading to increase their competitiveness in the global markets. Against this background, this paper aims to clarify whether companies in China as the second-tier follower in the FG Model may innovate in a similar way as companies in the Asian NIEs did in the past and whether they use different knowledge sources to support them to carry out different innovation outcomes. Different from the case studies carried out in the Asian NIEs, this paper performs an econometric analysis, using a firm-level dataset collected among electronics companies in the Pearl River Delta (PRD) in China in 2007. It estimates firm-level knowledge production functions (KPF), based on the KPF concept proposed by Criscuolo et al. (2005) and Wagner (2006). This concept, different from the traditional KPF concepts, also considers knowledge and technologies transferred from different sources as innovation inputs. Moreover, in order to more comprehensively capture the new knowledge created by companies in the PRD, this paper considers four different types of innovation outcomes: innovative products, innovative processes, innovation sales and patenting.

This paper is organised as follows. In Section 2 we briefly review literature related to the FG Model and to upgrading activities of companies in the Asian NIEs on the one hand. On the

[3] OEM refers to original equipment manufacturing. Companies engaging in the OEM business are normally asked to follow the production instructions of their OEM customers to produce exactly the products designed by the OEM customers. OEM customers normally provide their producing companies advanced machines, technologies and know-how as well.

other hand, we review literature related to the traditional KPF concepts and the KPF concept of Criscuolo et al. (2005) and Wagner (2006) used for the following analysis. In Section 3 we introduce the background of the survey, from which we obtained the dataset for our analysis. After that, we summarise stylized facts regarding innovation activities of companies in the PRD using some descriptive statistics. In Section 4 we establish baseline and extended estimation models based on the KPF concept and we analyse the estimation results in more detail. Section 5 concludes.

2 Literature Background

2.1 FG Model and Industrial Upgrading in the Asian NIEs

While the Japanese economist Akamatsu started to use the phrase "flying geese pattern" in 1930s, he used it to describe a fundamental pattern of industrial development in Japan over time, which he identified after examining the evolution of several Japanese manufacturing sectors. Such a fundamental pattern is characterised with companies' import activities at first, which was followed by growing import-substitution industries and domestic production activities. Over time, production techniques become more mature, which makes mass production and export business possible. In 1960s, Akamatsu went beyond the sole industrial scope of flying geese pattern in a single country and extended it into a multi-country concept by adding in two additional patterns which he observed. The first additional pattern describes a developing phenomenon across industries, namely a developing order from focusing on consumer goods to capital goods and from simple products to more sophisticated products over time. To make a more harmonic development across industries more possible, companies in the more advanced countries need to adequately utilise the strengths of developing countries. This constructs the second additional pattern considered by Akamatsu. More concretely, companies in the more advanced countries may relocate the more labour-intensive production activities into developing countries to sustain their price competitiveness in such labour-intensive industries on the one hand. On the other hand, they may be able to more efficiently allocate the scarce resources at home to focus on advanced or more capital-intensive industries. Through the relocation efforts of the companies from the more advanced countries, developing countries obtain resources and chances to be integrated as followers into the cross-country co-developing pattern (Akamatsu, 1961 & 1962; Yamazawa, 1990; Kojima, 2000; Ozawa, 2009).

The FG Model became well-known for economists outside Japan firstly after the rapid economic development in East Asia. Over time, several studies were carried out to investigate whether the FG Model stays valid in explaining the industrial development and transformation within the East Asian countries. Most studies were carried out at the macroeconomic level, using national-wide statistics regarding gross domestic products (GDP), exports, and imports and using index of revealed comparative advantage based on the former mentioned statistics. Most economists agree on the validity of the FG Model in explaining the economic development pattern in East Asia in the past, in which Japan had the superior leading position, followed by the Asian NIEs as the first-tier followers and China and some other southeast Asian countries as second-tier followers. Differently, findings from the macroeconomic studies in the new decade seem to be inconclusive (e.g. Tung, 2003; Ginzburg and Simonazzi, 2005; Chiang, 2008). However, relying on macroeconomic studies to investigate the validity of FG Model in explaining the economic development in East Asia may have at least two caveats. First, the role of companies which were initially recognised by Akamatsu as the main actors for enabling the industrial transformation across countries can not be adequately investigated. Second, statistics used in the macroeconomic studies such as GDP, exports and imports etc. are output statistics. Relying on such statistics, the industrial transformation processes which companies went through over the last decades can not be figured out.

To better clarify the industrial transformation in individual countries in East Asia, some case studies were carried out. Focusing on the upgrading activities of companies in the Asian NIEs as the first-tier followers during their developing phase, Hobday (1995a, 1995b) finds that electronics companies in these countries lacked human capital, innovation capabilities and experiences when they started to think of upgrading. In order to climb up the upgrading ladder, they need to learn how to innovate by using imported equipments and absorbing technologies and know-how transferred from external players, instead of devoting themselves to own R&D activities directly.[4] Due to the same reasons, they tended to focus, at first, their innovation efforts on improving their production efficiency incrementally. After gaining some more innovation capabilities, they may start to carry out some improvements on their product

[4] Coe and Helpman (1995) and Coe et al. (1997) found that R&D activities undertaken in the more advanced OECD countries may not only affect total productivity growth in these OECD countries. Positive spill-over effects of the R&D activities in the OECD countries on the total productivity growth in the developing countries can also be identified. This finding gives additional evidence on the importance of acquiring foreign technologies and knowledge for upgrading in the developing countries. Moreover, Coe et al. (1997) argued that especially East Asian countries benefited a lot from the foreign R&D activities.

functions or product design. Based on the mechanisms identified by Hobday (1995a, 1995b) [5] which were used by companies in the Asian NIEs to acquire foreign technologies, the following knowledge sources were taken as especially important: parent company and affiliated companies, OEM customers, technical markets and hiring highly-qualified workers. Among these sources, the first two sources seemed to be of higher relevance especially for the beginning of upgrading activities to overcome the barriers due to low capabilities. The findings of Hobday (1995a, 1995b) obtain some supports from the other empirical studies in East Asia. Kim (1991) and Kim and Lee (2001) also argued for, based on their research in Korea, an inevitably high relevance of OEM customers from which technologically laggard companies may more easily obtain advanced equipments and innovation-related technologies. In addition to relying on equipments imported from the OEM customers or other affiliated companies, companies in East Asia tended to strengthen their innovation capabilities through hiring highly-qualified workers who were well educated or trained overseas (e.g. Kim, 1997). With improving innovation capabilities, companies tried to learn new know-how and technologies in form of reverse engineering, i.e. buying finished products from the competitors in the markets and trying to figure out and learn the new technologies used by competitors to produce those products (e.g. Kim and Nelson, 2000; Kang, 2001; Kim, 1998).

2.2 Concepts of Knowledge Production Function (KPF)

After years of rapid development in China as second-tier follower in the developing hierarchy in East Asia, increasing production costs and changing industrial policy of the Chinese government towards upgrading are expected to drive companies on site to devote themselves to undertaking innovation activities to make themselves be able to produce higher value-added products for the markets. In order to more comprehensively investigate how companies in China innovate, this paper bases its analysis on the KPF concept.

The basic concept of KPF, which was first introduced by the seminal work of Griliches (1979), refers to the relationship between R&D expenditure as innovation inputs and patented inventions as a proxy of knowledge newly created in the knowledge production processes. The first innovation studies of this art analysed different panel datasets at the firm level and found a significant role of R&D activities for the production of patents. However, such

[5] The following mechanisms were identified by Hobday (1995a, 1995b): FDI, joint ventures, licensing, OEM, own-design and manufacture, sub-contracting, foreign and local buyers, informal means (overseas training, hiring returnees), overseas acquisition and strategic partnerships for technologies.

relationship was found to be especially significant in the cross-sectional (firm) dimension but less significant in the time dimension (Pakes and Griliches, 1980).

The basic concept of the KPF has been extended in different ways to better analyse the relationship between R&D activities and innovation outcomes. First, Griliches and Mairesse (1984) extended the basic KPF into an R&D-augmented production function to analyse the role of labour, physical capital and R&D capital for companies' value-added outputs in the U.S. Their finding was similar to the finding of Pakes and Griliches (1980). Second, Jaffe (1986) further developed a system of equations based on the basic KPF, in order to better estimate the spill-over effects of knowledge created by neighbouring companies on companies' performance in the U.S. He found that the R&D activities undertaken by neighbouring companies indeed positively influence companies' production of patents. Also Jefferson et al. (2002) applied a system of equations for their analysis on the R&D performance in the general Chinese context. The system of equations applied by them was, however, built in a recursive way and included a R&D expenditure function, a KPF and a performance function. The performance function considered both usual production factors and innovation outputs resulted from the KPF as inputs. In this way they found robust and significant contributions of companies' R&D activities to companies' new product sales, productivity and profitability.

However, engaging in innovation activities requires not only investment in R&D but also other inputs such as human capital, materials, and internally and externally accumulated knowledge stock. Besides, patents and innovation sales may not sufficiently capture the knowledge newly created. To more comprehensively analyse innovation activities, several attempts have been undertaken to extend the basic KPF in a way, taking some other innovation inputs and innovation outputs into consideration. For example, Hu et al. (2005) analysed the potential effects of technology transfer and foreign direct investment (FDI) on companies' productivity. They found, in addition to a positive role of R&D for companies' productivity, a complementary relationship between R&D and technology transfer either from other domestic innovators or from abroad. Criscuolo et al. (2005) and Wagner (2006) considered a more detailed differentiation of technology and know-how transferred into companies from different sources as innovation inputs for companies' innovation activities in the U.K. and Germany, respectively. They also considered companies' export engagement in addition to (inward) FDI as potential determinants for companies' different innovation behaviour. As innovation outcomes, they consider innovation sales in addition to patents. Wagner (2006) also considered innovative processes as one of the innovation outcomes. As result, they found that knowledge transferred from different sources matter differently for different innovation outcomes considered. The KPF concept of Criscuolo et al. (2005) and Wagner (2006) which, to the best of our knowledge, was not yet applied in the Asian context is used as base for the following analysis.

3 Survey Background and Descriptive Analysis

3.1 Survey Background

This paper aims to investigate whether companies in China may innovate in a similar way like companies did in the Asian NIEs. More concretely, it applies the KPF concept to explain not only whether knowledge and technologies transferred from external players matter for companies' innovation activities in China. But it also investigates whether technologies and knowledge transferred from different sources may matter for carrying out different kinds of innovation outcomes. In order to do so, it analyses an original firm-level dataset collected by our own company survey in the PRD in Guangdong from late 2007 to early 2008.[6] Guangdong is well-known for its relatively high innovativeness among all provinces in China. In addition, Guangdong is in a leading position regarding international trade of high-tech products in general, compared to the other Chinese provinces (MOST, 2007).

Our PRD company survey was only addressed to companies in the electronics industry. The electronics industry has gained in importance for the Asian NIEs during their developing phase since 1960s (e.g. Hobday, 1995b; Tuan and Ng, 1996). Similarly, it has been of increasing importance for the regional economy in Guangdong since 1980s. Its gross output value amounted to 41% of all industries above a designated size in Guangdong in 2006 (GPBS 2007).[7] Our survey questionnaires were sent to 400 electronics companies randomly selected from the comprehensive company catalogue "Guangdong Electronics 2007". Among them, 222 questionnaires were completed and returned.[8]

[6] About 80% of the GDP in Guangdong was carried out directly in the PRD in 2006. 2,620 billion RMB ($328 billion) were produced domestically in Guangdong in 2006 (GPBS 2007).

[7] Gross output value of industry above a designated size consists of the output value of "all state-owned enterprises" and that of "non-state-owned enterprises with annual business revenue of over 5 million RMB". In 2006, the gross output value of industry above a designated size accounted for about 87% of the gross output value of industry for all enterprises (GPBS 2007).

[8] Survey questionnaire is available upon request.

3.2 Descriptive Analysis

Based on the OSLO Manual, the PRD Survey defined innovative companies as those which introduce new or significantly improved products into markets or implement new or significantly improved processes, organisational modes and market strategies in their business operations (OECD, 2005). Survey results show that there are 158 innovative companies among 221 responding companies in total (71%).[9] These innovative companies were further asked to answer the other innovation-related questions.

In order to carry out innovation activities, survey results show that innovative companies in the PRD not only engage in own R&D activities but also acquire knowledge and technologies from other innovators to expand their innovation capabilities. On average, they invested about 8% of their whole product sales in 2006 in their R&D activities, reflecting a relatively high innovation incentive among the responding companies.[10] However, it is worth noting that four of the innovative companies did not spend any dollar on their R&D activities at all, suggesting their reliance on knowledge and technologies sourced from elsewhere to support their innovation activities. In the survey, seven different sources of knowledge and technologies were considered: "OEM customers (oem)", "suppliers or non-OEM customers (supnoem)", "companies from the same industry (compet)", "universities or research institutes (uni)", "fairs or technical markets (mkt)", "parent company, affiliated companies or joint ventures (group)", and "hiring highly-qualified workers (pers)". While about 69% of the innovative companies in the PRD rely on hiring highly-qualified workers to extend their innovation capabilities, only 40% of them make use of universities or research institutes as their knowledge sources. The shares of innovative companies using the other five knowledge sources lie between these two extremes. Among these five knowledge sources, companies especially rely on their parent company, affiliated companies or joint ventures (56%) to source innovation-related information and technologies.[11]

[9] One of the 222 PRD companies did not answer the question which asked companies to specify whether they carry out innovation activities. The definition of innovation based on the OSLO Manual was explained in detail in the appendix of the survey questionnaire. Companies were reminded to read the definition of innovation before they answered the innovation-related questions in the survey.

[10] We obtained valid information on firm-specific R&D-to-sales ratio in 2006 from 142 innovative companies. The first, second and third quantile value of R&D-to-sales ratio among innovative companies in the PRD in 2006 was 3%, 6% and 10%, respectively. The maximum of the R&D-to-sales ratio amounted to 60%.

[11] We obtained in total 152 (153) valid responses to the sub-questions regarding "OEM customers", "suppliers or non-OEM customers", "universities or research institutes" and "hiring highly-qualified workers" ("companies from the same industry", "fairs or technical markets" and "parent company, affiliated companies and joint ventures") as knowledge sources, respectively.

Although a great part of companies simultaneously makes use of several knowledge sources specified in the survey for their innovation activities, it must not mean that innovative companies may perceive same importance among the knowledge sources used by them. In the survey, innovative companies were asked to assess the importance of knowledge sources used by them, using a five-level scale with "1" indicating very important and "5" not important.[12] Based on companies' responses, pair-wise Wilcoxon Signed Rank Tests (WSRTs) were applied to clarify the relative importance between different knowledge sources perceived by companies.[13] Results show that innovative companies perceive hiring qualified workers as the most important source for them to obtain innovation-related information and technologies. Behind that, they tend to evaluate knowledge sources such as "parent company, affiliated companies or joint ventures", "OEM customers", "fairs and technical markets" and "suppliers or non-OEM customers" with the same importance. In addition, they tend to evaluate the other two knowledge sources such as "companies from the same industry" and "universities or research institutes" with the lowest importance in general.

Innovative companies in the PRD carry out different kinds of innovation outcomes based on their investments in own R&D activities as well as in sourcing knowledge and technologies from other more experienced innovators. About 92% of innovative companies introduced products with new or improved functions into markets in the last three years.[14] A smaller share of innovative companies (81%) implemented new or improved production processes.[15] Irrespective of innovative products or innovative processes, most of the innovative companies tend to improve the existing products or ongoing production processes instead of developing totally new products or new production processes.[16] In addition to introducing innovative products and implementing innovative processes, about 77% of innovative companies in the PRD also applied for patents to protect their products from illegal imitation.[17] And 37% of innovative companies realised more than half of their total product sales with selling innovative products.[18]

[12] Company shares by importance of different knowledge sources are summarised in Table A1 in Appendix.
[13] Results of WSRTs are not presented in tables but directly interpreted here to save space. Results in tables are available upon request.
[14] We obtained in total 134 valid responses to the question regarding innovative products.
[15] We obtained in total 139 valid responses to the question regarding innovative processes.
[16] About 41% of 123 companies with innovative products developed totally new products while 69% of them improved existing products. About 28% of 113 companies with innovative processes implemented totally new production processes, while 78% of them implemented improved ones.
[17] We obtained in total 145 valid responses to the question regarding patenting.
[18] We obtained in total 130 valid responses to the question regarding innovation sales.

In summary, how companies in the PRD in China innovate seems not to be completely the same as that done by companies in the Asian NIEs decades ago when they just started their industrial upgrading processes. On the one hand, innovative companies in the PRD are found to rely on hiring qualified workers and sourcing technologies and knowledge especially from their parent company, affiliated companies, joint ventures or OEM customers to extend their innovation capabilities just like that done by companies in the Asian NIEs. Most of them also implemented new or improved production processes over time as their counterparts in the Asian NIEs. On the other hand, some of the innovative companies in the PRD started to invest a lot in their own R&D activities. And even more companies introduced innovative products into markets than implementing innovative processes. The last two features were not found at the beginning of the industrial upgrading in the Asian NIEs. They were firstly found after the companies already gained some more innovation capabilities and experiences..The observation of the last two features in China in 2007 suggests that the problem of lacking innovation capabilities and financial capital for innovation may not be so severe anymore.

4 Econometric Analysis

4.1 Estimation Issues

We apply econometric techniques based on the framework of knowledge production function (KPF) to investigate the relations between different innovation inputs and different kinds of innovation outcomes carried out by the electronics companies in the PRD in China in more detail. In total, we consider four different innovation outcomes: innovative products, innovative processes, innovation sales and patenting. For different innovation outcomes, we expect that, due to their different characteristics, different innovation inputs may matter differently. Above all, we expect, firstly, that companies may rely more on own R&D activities to carry out innovative products and to create qualified knowledge and technologies for patenting, for which they may not easily obtain supports from other knowledge sources such as their OEM customers as suggested by the empirical literature in the Asian NIEs. In contrast, we expect that companies may rely more on sourcing technologies and knowledge from their OEM customers or from their parent company, affiliated companies or joint ventures to improve their production efficiency. The low relevance of sourcing from OEM customers for carrying out innovative products may be further reflected in the low relevance of this knowledge source for higher innovation sales. Secondly, companies may rely strongly on visiting fairs and technical markets to obtain up-to-date information about market needs which is expected to be more relevant for carrying out innovative products than innovative processes. For carrying out innovation processes, firm-specific information is more likely required. Last, but not least, companies may make use of the expertise of universities and research institutes to gain especially advanced new knowledge for creating new technologies which may be qualified enough for patenting.

In order to investigate the role of different innovation inputs for different innovation outcomes, four groups of estimation models with “innovative products”, “innovative processes”, “innovation sales”, and “patenting” as individual outcome variable are estimated, respectively. These four outcomes are codified into four binary variables with “1” representing the corresponding company “introduced products with totally new or improved functions into markets (*prodf_dm*)”, “implemented totally new or improved production methods (*proc_dm*)”, “realised above-average innovation sales (*isales1_2k*) [19]”, and “applied for patents to protect their products from illegal imitation (*patent*)”, respectively. Each group consists of one baseline KPF model and three extended models. Due to the binary characteristics of the outcome variables, the baseline KPF models are estimated using probit:

$$\Pr(Y = 1 \mid X) = \Phi(X'\beta) \qquad (1)$$ [20]

where Y refers to the four innovation outcomes considered separately. X is a vector of explanatory variables and β is a vector of parameters reflecting the effects of X on the probability.[21] $\Phi(.)$ denotes a standard normal distribution. The probit models are estimated with robust standard errors.[22]

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[19] Through the PRD Company Survey 2007 we did not obtain directly information on innovation sales in absolute term. Instead, we obtained categorical information on companies’ sales (six categories: “❑<1 Mio”, “1≤❑<5 Mio”. “5≤❑<10 Mio”, “10≤❑<50 Mio”, “50≤❑<100 Mio”, “❑≥100 Mio”) and on share of sales realised with innovative products (five categories: “☐=0%”, “0<☐≤10%”, “10<☐≤25%”, “25<☐≤50%”, “50<☐≤75%”, “75<☐≤100%”). In order to transform the information on innovation sales from the relative term to the absolute term, we made use of the average value of the upper bound and the lower bound of each available category with respect to sales and share of sales with innovative products. However, the lower bound of the 1st – category sales and the upper bound of the 6th-category sales were not specified in the survey. The former one is set to be 0 for this study. The latter one is determined as follows. The upper bounds of the lower five categories were used to be divided by the number of employees of the corresponding company. The average of the calculated sales per capita was then used to be multiplied by the maximum of the number of employees to obtain the upper bound of the 6th-category sales. The innovation sales of company i with the sales in the “m” category and share of sales with innovative products in the “n” category, for example, was calculated by multiplying the average value of the “m”-category sales with the average value of the “n”-category share of sales with innovative products. After that, innovation sales were transformed into log form. The mean of the innovation sales in log is used as the critical value to separate companies into those with under-average innovation sales and with above-innovation sales

[20] The observation subscript “i” is omitted here. See Greene (2003) p665-666 for more information.

[21] Because probit models are non-linear models, estimated coefficients (β) are not exactly equal to the marginal effects of the explanatory variables but they principally provide sufficient information on the directions of the effects of X on the outcome probability.

[22] More concretely, the Stata module “probit” with variance type “robust” is used for estimation. See Stata Press (2005b) p468-482 and Stata Press (2005c) p493-496 for more information.

All four baseline KPF models consider the following set of explanatory variables:

$$X_i = (X_i^{rd}, X_i^{tt}, X_i^{fc}) \quad (2)$$

They consider both companies' own R&D engagement (X_i^{rd}) measured in their R&D expenditure in log (*lnexprdweu1tr*$_i$)[23] and, more importantly, companies' application of knowledge and technology transferred from different sources (X_i^{tt}) as innovation inputs. In total, the baseline models consider seven different knowledge sources: companies' OEM customers (*oem_dm*$_i$), their suppliers or non-OEM customers (*supnoem_dm*$_i$), companies from the same industry (*compet_dm*$_i$), universities or research institutes (*uni_dm*$_i$), exhibitions or technique markets (*mkt_dm*$_i$), parent company or other affiliated companies (*group_dm*$_i$), and hiring qualified workers (*pers_dm*$_i$). All these variables are codified in dummies and are equal to 1 if companies apply the corresponding knowledge sources.

Moreover, the baseline models take several company characteristics into account to control for firm heterogeneity with respect to carrying out innovation activities (X_i^{fc})[24].Company characteristics considered in this study are company size measured by number of total employees in log (*lnsize*$_i$), company age (*age*$_i$)[25], whether they are exporters or not (*exporter*$_i$) and their ownership structure. The ownership structure of companies is considered by using two dummies referring to whether companies are totally foreign-owned companies (*foreignown_to*$_i$) or whether they are joint ventures between Chinese and foreign investors (*foreignown_mi*$_i$), respectively.[26]

Beyond the baseline models, three model extensions are estimated to investigate the robustness of the core findings. First, potential endogeneity problem regarding companies' R&D expenditure in the baseline models is considered. Following the idea of KPF, R&D expenditure is needed to produce innovation outcomes; however, it is also possible that the amounts of R&D expenditure are determined by companies' prior success in carrying out

[23] Through the PRD Company Survey 2007 we did not obtain directly information on R&D expenditure in absolute term. Instead, we obtained information on R&D-to-sales share in percent and categorical information on companies' sales (six categories, see footnote 19). We transformed the information on R&D-to-sales share to R&D expenditure in absolute term by multiplying the R&D-to-sales share of every company with the average value of sales of the corresponding sales category. We obtained the upper boundary of the 6th-category sales and the average sales of every sales category in the same way as described in footnote 19. In order not to lose zero observations on R&D expenditure, we transform R&D expenditure (exprdweu1) before taking logs. More precisely, *logexprdweu1tr* = ln(e*(1+exprdweu1)).

[24] See, for example, Markusen (2002), Criscuolo et al. (2005), Wagner (2006) and Girma et al. (2008).

[25] Company age is calculated in the following way: 2007- "start year of companies' operations in the PRD".

[26] Description of variables and some basic descriptive statistics are summarised in Table A2 in the Appendix.

innovation outcomes. To deal with this issue, valid instrumental variables are identified and they are further used to instrument companies' R&D expenditure for estimation.

Second, importance measures regarding the knowledge sources used by companies are considered in the extended models to substitute for the original source dummies (whether certain knowledge sources are used or not) in the baseline models. We use such importance measures to proxy the usage intensity of different knowledge sources used by innovative companies in the PRD. Given that technologies and know-how transferred from some knowledge sources indeed matter as innovation inputs for carrying out certain innovation outcomes, the probability of carrying out such innovation outcomes is expected to be higher, when these knowledge sources are used more intensively. The importance of each of the seven knowledge sources perceived by companies is codified with two dummies: whether knowledge sources are perceived as a little important or normally important (oem_md_i, $supnoem\_md_i$, $compet\_md_i$, uni_md_i, mkt_md_i, $group\_md_i$, $pers\_md_i$) and whether knowledge sources are perceived as important or very important (oem_st_i, $supnoem\_st_i$, $compet\_st_i$, uni_st_i, mkt_st_i, $group\_st_i$, $pers\_st_i$).[27]

As mentioned above, responding companies in the PRD Company Survey were separated into two groups according to whether they carry out innovation outcomes (innovative companies) or not (non-innovative companies).[28] The estimations from the baseline models and the first two extended models rely solely on the innovation-related data which we obtained among all innovative companies from the PRD Company Survey. Innovation-related data among non-innovative companies were not available, although it is possible that some companies indeed made some innovation efforts but were classified as non-innovative companies because they do not yet carry out any innovative outcomes. If there are indeed such cases, the estimations till now need to be interpreted with more caution. In other words, they may only relate innovation inputs to innovation outcomes among companies which are successful in carrying out innovation outcomes and, thus, overestimate the innovation productivity in general. To cope with this issue and to enable a more generalised interpretation of the estimation results, a second probit equation is considered, in addition to the baseline KPF model, in the third extended model construction. This second probit equation regresses "whether companies are

[27] The abbreviation "md" ("st") here refers to moderately (strongly) important.
[28] Innovative companies refer to companies which introduce new or significantly improved products into markets or/and implement new or significantly improved processes, organisational modes and market strategies (OECD, 2005).

innovative companies or not (*inno*$_i$)" on several different innovation determinants as suggested in the literature (e.g. Kamien and Schwartz, 1975; Aghion et al., 2005; Scott, 2009): company size in log as considered in the baseline model ($lnsize_i$), competition intensity ($mktcompet_i$) and whether companies are manufacturing companies or not ($manuf_i$). The competition intensity faced by companies is further classified, due to its ordinal characteristics, into 2 dummy variables: facing moderately (strongly) increasing competition pressure or not ($mktcompet\_md_i$ & $mktcompet\_st_i$,). This second probit equation is estimated simultaneously with the baseline KPF model for each of the four innovation outcomes by using a full-information maximum likelihood method.[29]

4.2 Estimation Results

4.2.1 Results of Baseline KPF Models

Results of estimated coefficients based on the baseline models are shown in Table 1, with column (1), (2), (3), and (4) for the baseline model with innovative products, innovative processes, innovation sales, and patenting as dependent variable, respectively. It is worth noting that the estimation results of coefficients in probit models give information on in which directions the independent variables may significantly affect the probability of having innovation outcomes considered equal to 1. The estimated coefficients should, however, not be directly interpreted as marginal effects.[30] All four baseline models are well specified, with rejected Wald Chi2 tests at 1% significance level indicating that all regression coefficients considered in the models can not be equal to zero simultaneously. The estimation results support our expectation that different innovation inputs indeed matter for different innovation outcomes differently. Although descriptive analysis above showed that most of the innovative companies in the PRD engage in own R&D activities, such R&D engagement is not found to matter for carrying out all kinds of their innovation outcomes but especially matter for carrying out those innovation outcomes for which companies in the PRD hardly obtain technical supports from other knowledge sources especially OEM customers. As shown in Table 1, the higher the R&D expenditure, the higher the probability that companies may

[29] For estimation the STATA module "cmp", referring to "conditional (recursive) mixed processes" was used. The module „cmp" estimates (recursive) equation systems by using maximum likelihood estimation procedures directly, instead of using multi-stage estimation procedures such as those used in traditional Heckman selection models (Roodman, 2009).

[30] In order to calculate marginal effects in probit models, reference points should be fixed. Normally, the mean values of the explanatory variables are selected to fix the reference point. In our cases, especially the cases with innovative products as innovation outcomes, such a reference company may already have R&D expenditure at a quite high level, crowding out the importance of knowledge transferred from other sources as inputs for innovation. Therefore we prefer to analyse the results of estimated coefficients here to clarify the general importance of different innovation inputs for different innovation outcomes carried out by innovative companies in the PRD. Estimated marginal effects based on the baseline models are reported in Table A4 in the Appendix.

introduce innovative products into markets and they may be capable of carrying out new knowledge sufficiently qualified for patenting. The positive role of R&D expenditure for developing innovative products makes it also more possible that companies with higher R&D expenditure may realise above-average innovation sales. In contrast, R&D expenditure is not found to be significantly relevant for carrying out innovative processes.

In order to carry out innovative processes to improve production efficiency, innovative companies in the PRD are found to rely strongly on the technologies and knowledge transferred from their OEM customers. On the one hand, long-term business experiences between companies in the PRD and their OEM customers make it easier for them to obtain right technologies and know-how which indeed satisfy their technical needs from their OEM customers.[31] On the other hand, helping companies in the PRD to improve their production efficiency is more consistent with OEM customers' own business strategies focusing on sustaining price competitiveness in the markets. In contrast, OEM customers are expected to be reluctant to transfer technologies and know-how to companies in the PRD to help them to develop innovative products or to create new knowledge qualified sufficiently for patenting, because in this way they may help companies in the PRD to become their potential competitors in the future. As suggested in the studies in the Asian NIEs, OEM customers were indeed one of the most substantial knowledge sources for companies in the Asian NIEs. Assumed that OEM customers should play a similar role for the innovative activities of companies in the PRD in general, the finding of a low relevance of OEM customers as knowledge sources for them to carry out innovative products, to realise high innovation sales and to apply for patents is consistent with our argument above that companies which aims at carrying out these three innovative outcomes may need to rely more on own R&D activities.

In addition to own R&D engagement, innovative companies in the PRD which aim at carrying out innovative products, realising high innovation sales and creating new knowledge for patenting may try to search for knowledge sources other than OEM customers from which they can obtain technologies and knowledge they need for innovation. In case of innovative products, "fairs or technical markets" and "parent company, affiliated companies and joint venture companies" are found to be the two knowledge sources which significantly matter. Technical markets may provide them up-to-date information about market needs or about newly available technologies, both of which are relevant for companies to develop innovative

[31] The OEM business mode has been dominantly applied among companies in the PRD over the whole developing processes since late 1970 (FHKI, 2003).

products. Parent company, affiliated companies and joint venture companies may act in some situations like OEM customers and focus more strongly on price competitiveness. However, different from the OEM customers, companies from the same enterprise group tend to follow the same goal to maximise the profit of the whole enterprise group. Therefore, companies from the same enterprise group to which innovative companies in the PRD belong may provide them more know-how and technologies relevant for developing innovative products.

Knowledge sources which are advantageous for carrying out innovative products are expected to be also advantageous for realising higher sales with innovative products. However, the two knowledge sources which are found to matter for carrying out innovative products above are not found to matter for realising higher innovation sales. This suggests, firstly, up-to-date information on market needs and supplies of technologies may be advantageous for developing innovative products. But these products must not be indeed well accepted and sold in the markets. Secondly, although companies from the same group may help innovative companies in the PRD to produce innovative products, these innovative products may rather be used as intermediate goods for production in some other companies from the same enterprise group instead of being sold directly to the markets. In contrast, to realise higher innovation sales, three other knowledge sources are found to be of higher importance: suppliers or non-OEM customers, companies from the same industry, and universities or research institutes. Taking the finding of insignificant roles of these three sources for developing innovative products into account, knowledge which innovative companies obtain from these sources may rather tend to be used to increase the attractiveness and acceptance of their products among customers than to improve the products technically. For example, companies may learn from the marketing strategies of their competitors or from the business research of universities how they can more efficiently market and sell their products.

Universities and research institutes, however, may not only provide results of business research to help innovative companies to better market and sell their products. As suggested by the positive finding of this knowledge source for patenting in Table 1, they may also provide innovation-related technologies and knowledge which can be used by innovative companies in the PRD as innovation inputs to produce new knowledge qualified enough for patenting. In addition to universities, fairs or technical markets seem to provide such innovation-related technologies to innovative companies in the PRD as well. However, it is worth noting that the variable "patenting" was derived from a question which asked innovative companies, whether they apply for patents to protect them products from piracy. Based on this question, it is possible that especially those companies which trust formal institutions such as transaction rules in the technical markets tend to utilise the other formal institutions such as patent laws to protect their products. Therefore, the positive relationship found between market as knowledge source and patenting may be partially due to the preference of such companies for making use of formal institutional rules for innovation. In contrast to these two knowledge sources, sourcing from suppliers or non-OEM customers is found to be significantly and negatively relevant for the patenting activities of the innovative companies in the PRD. Suppliers, especially, may provide more advanced products which can be further used as inputs into innovation activities of the innovative companies in the PRD. However, they may tend to provide only those products which are already well-patented to protect their products from being imitated by innovative companies in the PRD.

Table 1 Estimation results (estimated coefficients of baseline models)

	prodf_dm (1)	proc_dm (2)	isales1_2k (3)	patent (4)
lnexprdewu1tr	0.822*	-0.074	1.952***	0.232*
	(0.423)	(0.148)	(0.414)	(0.128)
oem_dm	-1.314**	0.846**	-0.997**	-0.156
	(0.537)	(0.373)	(0.418)	(0.380)
supnoem_dm	0.632	0.286	0.895**	-0.862**
	(0.391)	(0.409)	(0.449)	(0.398)
compet_dm	-0.348	-0.590	0.890*	-0.274
	(0.359)	(0.384)	(0.475)	(0.352)
uni_dm	0.496	-0.003	0.881***	0.615*
	(0.406)	(0.374)	(0.329)	(0.357)
mkt_dm	0.905**	0.549	-0.541	0.868**
	(0.368)	(0.347)	(0.435)	(0.367)
group_dm	0.606*	0.232	-1.097***	0.466
	(0.363)	(0.337)	(0.393)	(0.325)
pers_dm	-0.658	-0.344	-0.656*	0.081
	(0.436)	(0.355)	(0.397)	(0.323)
lnsize	-0.033	0.151	0.036	-0.045
	(0.231)	(0.169)	(0.175)	(0.163)
age	0.031	0.034	0.033	0.027
	(0.033)	(0.023)	(0.042)	(0.031)
exporter	-0.485	-0.225	0.766*	-0.112
	(0.525)	(0.408)	(0.428)	(0.365)
foreignown_to	0.383	0.915**	-0.311	0.083
	(0.488)	(0.402)	(0.430)	(0.344)
foreignown_mi	-0.883	0.371	0.188	-1.525***
	(0.733)	(0.584)	(0.534)	(0.416)
_cons	0.616	-0.340	-4.193***	0.301
	(1.306)	(0.709)	(0.976)	(0.630)
Obs.	117	120	116	122
Wald Chi2	27.72***	28.41***	50.15***	30.98***
Pseudo R2	0.299	0.225	0.554	0.224

Note: ***, **, * significant at 1%, 5% and 10% level, respectively; robust standard error in parentheses.

Estimation results of the baseline models also suggest that different firm characteristics, especially how innovative companies are involved in the global affairs, may matter for their knowledge production behaviour. First, exporting companies are found to be capable of realising higher innovative sales but must not be more capable of developing innovative products. This seems to suggest that exporting companies may profit more from their better established distribution networks worldwide than from obtaining access to up-to-date information about customer needs and technologies supplied in the global technical markets. Second, innovative companies which are partially owned by foreign investors are found to be less capable of producing new knowledge qualified enough for patenting. Foreign investors may be reluctant, due to the control difficulty based on the partial ownership and the relatively deficient IPR regime in China, to transfer more advanced but also more sensitive knowledge into the invested companies on site which companies in the PRD may need as innovation inputs for producing new knowledge for patenting. In contrast, innovative companies which are totally owned by foreign investors tend to be more capable of patenting. The estimated coefficient regarding patenting behaviour of totally foreign-owned companies is found to be positive, though not significant. Such totally foreign-owned companies are also found to be significantly more capable of carrying out innovative processes.

4.2.2 Results of Extended Models

As mentioned in Section 4.1, three extended models for all four innovation outcomes are considered in this study. First, we aim to cope with the potential endogeneity problem of R&D expenditure by using instrumental-variable estimation techniques. Taking the limitation of data availability into account, we use the following two variables as potential instruments for R&D expenditure: *predict* and *careerceo*. The first variable ($predict_i$) is a binary variable with "1" indicating that companies could at least a little bit predict the policy changes over the last five years in China. Since the beginning of the new century, the Chinese government turns to emphasise the importance of innovation and upgrading for sustaining the economic growth in China more strongly than before. Some policy studies in the Asian NIEs suggest positive effects of innovation policies on industrial innovations at home (e.g. Eriksson, 2005). Based on these findings, we expect that innovation policies in China may also be positively influential for companies' willingness in engaging in R&D activities. Therefore, we expect that companies which can better predict such policy changes may also be more willing in investing more in R&D activities. The second variable ($careerceo_i$) is also a binary variable with "1" indicating that CEO of the companies in the PRD worked in the Chinese state-owned enterprises or in other private companies before they started to work as CEOs in the current companies. We expect that such work experiences of CEOs affect companies' willingness for R&D also in positive way. CEOs may bring in their well-established personal networks especially with public bureaus into current companies, which may make it easier for current companies to gain access to financial capital and to information about changing policies.

We apply the STATA module "ivprobit" to respectively estimate the four instrumental-variable probit models by using Newey's efficient two-step estimator (Newey, 1987).[32] Each of the iv-probit models consists of the corresponding baseline KPF model and a linear function which regresses R&D expenditure on the two abovementioned instruments and on the other exogenous variables specified in the baseline KPF model. We obtain from the first-stage estimations a relatively high F statistics (around 7) and a p-value smaller than 0.01, irrespective of innovation outcomes considered. This implies a relatively high relevance of the instrumental variables used here for instrumenting R&D expenditure.[33] Based on the estimation results of the full models, we apply overidentification tests using Amemiya-Lee-Newey minimum chi-sq statistics to test the validity of instrumental variables (Baum et al., 2003; Baum et al., 2006). Irrespective of innovation outcomes considered, the test results can not reject the null hypothesis that all instruments are valid. Given the relevance and validity of the instruments used, we apply Wald tests on the correlation parameter between the error term of the baseline probit model considered and the error term of the linear function of R&D expenditure to test whether R&D expenditure is indeed an endogenous variable and instrumental-variable estimation is indeed needed (Wooldridge, 2002). Again, irrespective of innovation outcomes considered, results of Wald tests can not reject the null hypothesis that the correlation parameter is not significantly different from 0, suggesting that the potential endogeneity problem of R&D expenditure does not seem to be significant in our cases and our estimation results of the baseline models above stay valid. Table 2 summarises the three test results for each iv-probit model estimated.

Table 2 Summary of test results based on estimations of iv-probit models

Innovation outcome considered	Prodf_dm	Proc_dm	Isales1_2k	patent
Number of observations	115	118	114	120
1. F Statistics (Test of joint significance of instruments)	6.91 (0.000)	7.06 (0.000)	6.90 (0.000)	6.75 (0.000)
2. Amemiya-Lee-Newey minimum chi-sq statistics (Test of validity of instruments)	0.787 (0.375)	0.379 (0.538)	0.395 (0.530)	2.531 (0.112)
3. Wald test of exogeneity	0.07 (0.797)	2.46 (0.117)	1.14 (0.286)	0.97 (0.325)
Instrumented: lnexprdweu1tr				
Instruments: predict, careerceo and all other exogenous variables in the baseline models				

Note: p-values in parentheses.

[32] See Stata Press (2005a) p517-530 for more information.

[33] F Statistics equal to 10 is often used as rule of thumb (e.g. Staiger and Stock, 1997; Kilic et al., 2007) to suggest joint significance of instruments. In our case, F Statistics equal to 7 is relatively high but is still smaller than 10. However, limited data availability restricts the search for more relevant instrument variables.

In the second extended models, importance measures of knowledge sources are used to proxy the usage intensity of knowledge sources used by the innovative companies in the PRD. Based on the second extended models, in addition to check the result robustness we aim to test whether the usage of knowledge sources alone matters for innovation or the usage intensity also plays an important role in this regard. Results suggest that the core findings from the estimated baseline models are hardly affected (Table A3 in the Appendix).[34] Knowledge sources which were found to matter based on the baseline models stay significantly relevant. In addition, based on the findings of the extended models we apply z-test statistics[35] to test whether usage intensity also matters. Table 3 show the test results. The usage intensity of most of the knowledge sources which were found to be significantly and positively relevant based on the baseline models does not seem to matter. Technical markets and fairs are the only one exception. The more intensive companies may source from markets, the higher the probability that they may successfully develop innovative products or may successfully create new knowledge qualified for patenting.[36] Such findings suggest that most of the knowledge sources which were found to be significantly and positively relevant based on the baseline models are crucial sources from which companies may obtain key information for innovation. In these cases, the usage of these knowledge sources alone already matters.

In contrast, results show that usage intensity of some knowledge sources, which were found to be insignificant for certain innovation outcomes, matters. These knowledge sources are suppliers and non-OEM customers for developing innovative products, companies from the same industry and hiring qualified workers for implementing innovative processes, and markets for realising above-average innovation sales. Alone the usage of these knowledge sources would not matter for carrying out the corresponding innovative outcomes. However, with intensive usage of these sources companies are expected to be more capable of carrying out the corresponding innovation outcomes. Taking suppliers and non-OEM customers as knowledge sources for developing innovative products as an example, with intensive sourcing activities, companies may not just focus on short-term revenue and source only non-technical skills from their suppliers or non-OEM customers to enhance their innovation sales. They also source technical skills to carry out innovative products to sustain their long-term development.

[34] Table A3 in the Appendix presents the estimated coefficients of the extended models and Table A4 the marginal effects at a selected reference point. See footnote 30 for more information.

[35] We used the Stata build-in function "lincom" to test the difference between the estimated coefficients of knowledge sources with different importance measures. See Stata Press (2005b) p39-45 for more information.

[36] It is worth noting that, as mentioned in Section 4.2.1, the positive relevance of markets as knowledge sources for patenting may be partially attributable to companies' preference for making use of formal institutions.

In addition, results show that the usage intensity of OEM customers and companies from the same industry, which were found to be significantly but negatively relevant for realising above-average innovation sales, also matters. This suggests that using these knowledge sources turns to be less restrictive against realising high innovation sales when they are used more intensively. However, such results may be, to some extent, externally determined through the positive effects of using such knowledge sources intensively on implementing innovative processes and on developing innovative products, respectively.

Table 3 Summary of test results on the role of usage intensity of knowledge sources by innovation outcome (based on estimated exteneded models with importance measures of knowledge sources)

Hypothese (1-tailed)	prodf_dm	proc_dm	isales1_2k	patent
	(1)	(2)	(3)	(4)
_b[oem_st]-_b[oem_md]>0	-0.338	0.352	1.053**	-0.287
	(0.748)	(0.521)	(0.627)	(0.555)
_b[supnoem_st]-_b[supnoem_md]>0	1.826**	-0.258	-1.686	-0.489
	(0.806)	(0.756)	(0.734)	(0.627)
_b[compet_st]-_b[compet_md]>0	-1.092	1.761***	-0.310	-0.359
	(0.744)	(0.632)	(0.585)	(0.600)
_b[uni_st]-_b[uni_md]>0	-[a]	0.647	0.112	-0.570
	-[a]	(0.623)	(0.541)	(0.816)
_b[mkt_st]-_b[mkt_md]>0	1.168*	-0.398	1.079**	1.395**
	(0.807)	(0.607)	(0.519)	(0.676)
_b[group_st]-_b[group_md]>0	-[b]	-1.135	1.472**	-[c]
	-[a]	(0.695)	(0.736)	-[c]
_b[pers_st]-_b[pers_md]>0	0.608	1.002**	-0.098	-1.073
	(0.500)	(0.593)	(0.432)	(0.530)

Notes: [a]Not available because Uni_st is dropped due to perfect success prediction. [b]Not available because Group_md is dropped due to its perfect success prediction. [c]Not available because Group_md is dropped due to its perfect success prediction.***, **, * significant at 1%, 5% and 10% level, respectively; standard error in parentheses.

The third way to test the robustness of the estimation results of the baseline models is also an attempt to generalise the results shown above. As mentioned in Section 4.1, estimation results till now may only be valid for clarifying the knowledge production processes among companies which indeed successfully carry out innovative outcomes. In order to take companies which made efforts to innovate but do not yet carry out innovation outcomes into account, a probit selection model is estimated simultaneously in addition to the baseline KPF model and it regresses companies' success of carrying out innovation outcomes to some innovation determinants suggested by the literature. Table 4 presents the estimation results of the corresponding extended models. It shows that the correlation between the error term in the baseline KPF model and the error term in the probit selection model are not significantly different from zero in cases of having innovative processes, innovation sales and patenting as innovation outcomes.[37] This finding seems to suggest that the potential problem of companies which made innovation efforts but do not yet come out with innovation outcomes is not

[37] The parameter "rho" is bounded in value. Thus, it is not suitable for being used as base for testing the null hypothesis that correlation between error terms is equal to zero. Instead, the parameter "rho" is transformed into an unbounded scale by using its arc-hyperbolic tangents "atanhrho" (Roodman, 2009).

significant at least for the cases with these three innovation outcomes. Companies which made innovation efforts for carrying out these three types of innovation outcomes seem to be able to accomplish their innovation activities and come out with some results. In other words, the findings of the baseline models with these three innovation outcomes are robust and can be used to describe the corresponding knowledge production processes in general.

Table 4 Estimation results (estimated coefficients of extended models considering selection bias problem)

	prodf_dm (1)	proc_dm (2)	isales1_2k (3)	patent (4)
lnexprdweu1tr	0.762*	-0.040	1.889***	0.193
	(0.395)	(0.091)	(0.416)	(0.130)
oem_dm	-1.185**	0.465*	-0.977**	-0.137
	(0.505)	(0.270)	(0.394)	(0.350)
supnoem_dm	0.598	0.029	0.865**	-0.813**
	(0.378)	(0.262)	(0.436)	(0.361)
compet_dm	-0.359	-0.303	0.872*	-0.280
	(0.317)	(0.207)	(0.448)	(0.308)
uni_dm	0.509	-0.025	0.849**	0.489
	(0.375)	(0.161)	(0.335)	(0.395)
mkt_dm	0.822**	0.236	-0.527	0.765**
	(0.327)	(0.204)	(0.417)	(0.385)
group_dm	0.541*	0.193	-1.073***	0.420
	(0.322)	(0.153)	(0.360)	(0.276)
pers_dm	-0.635	-0.142	-0.620	0.134
	(0.399)	(0.270)	(0.413)	(0.278)
lnsize	-0.059	0.195**	0.062	0.027
	(0.217)	(0.093)	(0.174)	(0.162)
age	0.021	0.025	0.034	0.027
	(0.030)	(0.023)	(0.040)	(0.027)
exporter	-0.405	-0.049	0.756*	-0.118
	(0.507)	(0.202)	(0.418)	(0.305)
foreignown~o	0.354	0.374	-0.305	0.039
	(0.466)	(0.279)	(0.409)	(0.308)
foreignown~i	-0.786	0.074	0.172	-1.370***
	(0.713)	(0.269)	(0.513)	(0.500)
_cons	1.023	-1.047**	-4.371***	-0.295
	(1.220)	(0.454)	(0.955)	(0.683)
inno				
lnsize	0.186***	0.179***	0.186***	0.182***
	(0.032)	(0.000)	(0.032)	(0.033)
mktcompet_md	0.566*	0.102	0.409	0.607*
	(0.303)	(0.219)	(0.299)	(0.318)
mktcompet_st	0.429	-0.241	0.244	0.422
	(0.301)	(0.202)	(0.292)	(0.314)
manuf	0.056	0.100***	0.051	0.056
	(0.166)	(0.000)	(0.162)	(0.151)
_cons	-0.861**	-0.325	-0.688**	-0.847***
	(0.341)	(0.202)	(0.338)	(0.326)
/atanhrho_12	-2.839**	15.229	0.375	0.788
	(1.233)	(14.402)	(0.427)	(0.816)
rho_12	-0.993	1.000	0.358	0.657
	(0.017)	(0.000)	(0.373)	(0.464)
Obs.	197	198	197	199
Wald Chi2	29.16***	9.595e+5***	50.15***	25.02**

Note: ***, **, * significant at 1%, 5% and 10% level, respectively; robust standard error in parentheses.

In contrast, the correlation between the error term in the baseline KPF model with innovative products as innovation outcome and the error term in the probit selection model is found to be significantly different from zero. The negative sign of the correlation suggests that the findings of the baseline KPF model may be overestimated, if the findings are to be used to interpret all companies' product innovation activities in general. Although results suggest that innovative companies seem to more productively use innovation inputs to come out with innovative products, innovation inputs which are found to be significant in the extended model are the same as the innovation inputs which were found to be significant in the corresponding baseline KPF model above.

5 Conclusion

This paper analysed an original firm-level dataset collected in the PRD in China. It estimated firm-level KPF models, based on the KPF concept proposed by Criscuolo et al. (2005) and Wagner (2006) to investigate knowledge production processes of the electronics companies in the PRD in China. It aimed to clarify whether companies in China as the second-tier follower in the FG model may innovate in a similar way as companies in the Asian NIEs did in the past and whether they use different knowledge sources to support them to carry out different innovation outcomes.

Descriptive analysis in this paper showed that companies in the PRD in China do not seem to innovate completely in the same way as their counterparts in the Asian NIEs did decades ago. We found that, on the one hand, innovative companies in the PRD tend to rely on the same sources such as parent company, joint ventures and OEM customers as their counterparts in the Asian NIEs to extend their innovation capabilities. And they also carried out innovative processes over time. On the other hand, we found that some of the innovative companies in the PRD already started to invest a lot in their own R&D activities. And even more companies introduced innovative products into markets than implementing innovative processes. The last two points seemed to suggest that companies in the PRD in 2007 may be better equipped with technological capabilities and resources than their counterparts in the Asian NIEs when they started to innovate.

In order to clarify the roles of different innovation inputs for different innovation outcomes in more detail, we estimated firm-level KPF models, considering four different innovation outcomes to proxy new knowledge created: innovative products, innovative processes, innovation sales and patenting. Estimation results of the baseline models, which consider companies' R&D expenditure in log and companies' usage of different knowledge sources to obtain innovation-related technologies and knowledge as innovation inputs and control for some firm-specific characteristics, are robust. We found that companies in the PRD tend to utilise different kinds of innovation inputs to carry out different innovation outcomes.

More concretely, we found firstly that innovative companies in the PRD rely strongly on their OEM customers as their knowledge sources to carry out innovative processes to increase their production efficiency. In contrast, they rely more on own R&D activities to develop innovative products, to realise higher innovation sales or to create new knowledge qualified enough for patenting, for which they hardly obtain technological supports from their OEM customers. These findings are consistent with the findings in the case-study literature in the Asian NIEs. Moreover, we found that innovative companies in the PRD rely on sourcing innovation-related information such as up-to-date information on customer needs and on technologies currently supplied from fairs and technical markets to carry out innovative products and to create new knowledge for patenting. Companies in the Asian NIEs seemed to hardly apply such sources decades ago, when the telecommunication techniques and transportation technologies were still quite undeveloped. Underdeveloped technologies of these sorts may act as impediments against efficient information exchanges and against frequent visits of economic agents to technical markets worldwide. Last, but not least, we found that innovative companies in the PRD rely on utilising expertise of universities and research institutes to realise higher innovation sales or to create new knowledge qualified for patenting. Because the research capacity of local universities and research institutes is still limited, the high relevance of this knowledge source for carrying out certain innovation outcomes suggests that companies in the PRD seem to be capable of utilising expertise of universities and research institutes located somewhere else. The geographical and cultural proximity between the PRD in China and the Asian NIEs especially Hong Kong and Taiwan makes it probably easier for them to gain access to and profit from the academic knowledge there which has developed rapidly since 1980s. In contrast, companies in the Asian NIEs may profit less from academic knowledge, when they started to innovate decades ago due to, on the one hand, low research capacity in local universities and research institutes at that time. On the other hand, the long distance to Japan, the cultural difference and the underdeveloped telecommunication techniques made it probably more difficult for them to gain access to more advanced academic research in the Japanese universities at that time.

In summary, based on the estimation results we found some similarities but also differences of the knowledge production processes between companies in the PRD in China as the second-tier follower in the FG Model and companies in the Asian NIEs as the first-tier followers decades ago. The development especially in telecommunication techniques and transportation technologies over the last decades may contribute to building up a better environment for companies in the PRD to innovate. Compared to their counterparts in the Asian NIEs, companies in the PRD have a larger pool of knowledge sources which become available for them to acquire innovation-related knowledge and technologies, which were however not available decades ago. Although the similarities found seem to still suggest that companies in the PRD innovate in a similar way as their counterparts in the Asian NIEs at least to some extent, the easier access to different knowledge sources for companies in the PRD to carry out different innovation outcomes may make it easier for them to climb up the industrial upgrading ladder at a much higher speed.

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Appendix

Table A1 Company distribution by importance of different knowledge sources

	oem	supnoem	compet	uni	mkt	group	pers
N	152	152	153	152	153	153	152
n_use	77	75	76	62	81	85	102
of n_use							
1	18 (23%)	15 (20%)	16 (21%)	16 (26%)	23 (28%)	37 (44%)	52 (50%)
2	32 (42%)	21 (28%)	19 (25%)	11 (18%)	24 (30%)	19 (22%)	30 (29%)
3	14 (18%)	27 (36%)	20 (26%)	10 (16%)	18 (22%)	14 (16%)	15 (14%)
4	6 (8%)	4 (5%)	10 (13%)	10 (16%)	8 (10%)	4 (5%)	6 (6%)
5	7 (9%)	8 (11%)	11 (15%)	15 (24%)	8 (10%)	11 (13%)	2 (2%)

Notes: N refers to the number of innovative companies with valid responses to the survey question regarding knowledge sources. n_use refers to the number of innovative companies using knowledge sources considered. A 5-scale importance level was used for assessing the importance of knowledge sources considered, when companies use them: 1-very important; 2-important; 3-of normal importance; 4-a little important; 5-not important.
Source: Own PRD Company Survey 2007.

Table A2: Descriptions of variables used for estimations and basic descriptive statistics

	Variable description	Mean	Std. Dev.	Min	Max	Obs
Innovation outcomes (Y)						
prodf_dm	Introducing products with new or improved functions into markets (1) or not (0)	0.918	0.276	0	1	134
proc_dm	Carrying out new or improved production methods (1) or not (0)	0.813	0.391	0	1	139
isales1_2k	Realising above-average innovation sales (1) or not (0)	0.450	0.499	0	1	129
lninnosales1	Innovation sales in log	2.048	2.412	-2.436	7.265	129
patent	Applying for patents to react to risks of product piracy (1) or not (0)	0.766	0.425	0	1	145
Innovation inputs (X^{rd} & X^{tt})						
lnexprdweu1tr	R&D expenditure in log	2.270	1.449	1.000	6.687	141
oem_dm	Souring innovation-related knowledge from OEM customers (1) or not (0)	0.507	0.502	0	1	152
oem_md	Assessing OEM customers as a little or normally important knowledge source (1) or not (0)	0.132	0.339	0	1	152
oem_st	Assessing OEM customers as important or very important knowledge source (1) or not (0)	0.329	0.471	0	1	152
supnoem_dm	Souring innovation-related knowledge from suppliers or non-OEM customers (1) or not (0)	0.493	0.502	0	1	152
supnoem_md	Assessing suppliers or non-OEM customers as a little or normally important knowledge source (1) or not (0)	0.204	0.404	0	1	152
supnoem_st	Assessing suppliers or non-OEM customers as important or very important knowledge source (1) or not (0)	0.237	0.427	0	1	152
compet_dm	Souring innovation-related knowledge from companies from the same industry (1) or not (0)	0.497	0.502	0	1	153
compet_md	Assessing companies from the same industry as a little or normally important knowledge source (1) or not (0)	0.196	0.398	0	1	153
compet_st	Assessing companies from the same industry as important or very important knowledge source (1) or not (0)	0.229	0.421	0	1	153
uni_dm	Souring innovation-related knowledge from universities or research institutes (1) or not (0)	0.408	0.493	0	1	152
uni_md	Assessing universities or research institutes as a little or normally important knowledge source (1) or not (0)	0.132	0.339	0	1	152
uni_st	Assessing universities or research institutes as important or very important knowledge source (1) or not (0)	0.178	0.383	0	1	152
mkt_dm	Souring innovation-related knowledge from fairs or technical markets (1) or not (0)	0.529	0.501	0	1	153
mkt_md	Assessing fairs or technical markets as a little or normally important knowledge source (1) or not (0)	0.170	0.377	0	1	153
mkt_st	Assessing fairs or technical markets as important or very important knowledge source (1) or not (0)	0.307	0.463	0	1	153

Table A2 (continued): Descriptions of variables used for estimations and basic descriptive statistics

group_dm	Souring innovation-related knowledge from parent company, affiliated companies or joint ventures (1) or not (0)	0.556	0.499	0	1	153
group_md	Assessing parent company, affiliated companies or joint ventures as a little or normally important knowledge source (1) or not (0)	0.118	0.323	0	1	153
group_st	Assessing parent company, affiliated companies or joint ventures as important or very important knowledge source (1) or not (0)	0.366	0.483	0	1	153
pers_dm	Souring innovation-related knowledge by hiring highly qualified workers (1) or not (0)	0.691	0.464	0	1	152
pers_md	Assessing recruitment of highly qualified workers as a little or normally important knowledge source (1) or not (0)	0.138	0.346	0	1	152
pers_st	Assessing recruitment of highly qualified workers customers as important or very important knowledge source (1) or not (0)	0.539	0.500	0	1	152
Control variables and others						
lnsize	Number of employees in log	5.117	1.542	0.693	10.309	213
age	Company age	8.685	6.297	0	1	219
exporter	Engaging in export business (1) or not (0)	0.743	0.438	0	1	214
foreignown_to	Totally foreign-owned companies (1) or not (0)	0.341	0.475	0	1	217
foreignown_mi	Owned by Chinese and foreign investors (1) or not	0.088	0.283	0	1	217
inno	Carrying out innovation activities (1) or not (0)	0.715	0.452	0	1	221
mktcompet_md	Facing moderately increasing competition pressure (1) or not (0)	0.356	0.480	0	1	222
mktcompet_st	Facing strongly increasing competition pressure (1) or not (0)	0.590	0.493	0	1	222
manuf	Having production operations (1) or not (0)	0.913	0.283	0	1	195
predict	Being able to at least a little bit predict policy changes (1) or not (0)	0.778	0.417	0	1	216
careerceo	CEO worked in a state-owned enterprise of other private company before working as CEO in the current company (1) or not (0)	0.306	0.462	0	1	219

Source: Own PRD Company Survey 2007.

Table A3 Estimation results (estimated coefficients of extended models with importance measures)

	prodf_dm	proc_dm	isales1_2k	patent
	(1)	(2)	(3)	(4)
lnexprdewu1tr	1.533*	-0.276*	2.389***	0.294*
	(0.831)	(0.166)	(0.539)	(0.161)
oem_md	-2.559***	1.106*	-2.086**	-0.228
	(0.976)	(0.609)	(0.806)	(0.606)
oem_st	-2.897***	1.458***	-1.032**	-0.515
	(1.091)	(0.472)	(0.450)	(0.402)
supnoem_md	0.387	0.978	2.410***	-0.412
	(0.664)	(0.728)	(0.804)	(0.632)
supnoem_st	2.212***	0.720	0.724	-0.901**
	(0.801)	(0.535)	(0.496)	(0.438)
compet_md	0.855	-1.751***	0.842	0.389
	(0.637)	(0.612)	(0.651)	(0.491)
compet_st	-0.237	0.010	0.533	0.030
	(0.566)	(0.466)	(0.432)	(0.465)
uni_md	-2.587***	-0.448	1.014*	1.749***
	(0.674)	(0.553)	(0.537)	(0.633)
uni_st	-[a]	0.199	1.126***	1.178**
	-[a]	(0.510)	(0.424)	(0.525)
mkt_md	1.142	0.894	-1.737**	0.074
	(0.755)	(0.711)	(0.679)	(0.658)
mkt_st	2.310***	0.497	-0.658	1.469***
	(0.569)	(0.532)	(0.520)	(0.466)
group_md	-[b]	1.322**	-2.299***	-[c]
	-[b]	(0.641)	(0.807)	-[c]
group_st	2.481***	0.187	-0.828*	0.684*
	(0.643)	(0.429)	(0.457)	(0.372)
pers_md	-0.936	-1.214**	-0.434	0.861
	(0.702)	(0.592)	(0.530)	(0.533)
pers_st	-0.328	-0.211	-0.532	-0.212
	(0.715)	(0.373)	(0.425)	(0.364)
Obs.	83	120	116	109
Wald Chi2	40.44***	43.03***	40.35***	53.70***
Pseudo R2	0.460	0.280	0.604	0.339

Notes: [a]Uni_st is dropped due to perfect success prediction and, thus, 21 observations are not used. [b]Group_md is dropped due to its perfect success prediction and, thus, 13 observations are not used. [c]Group_md is dropped due to its perfect success prediction and, thus, 13 observations are not used. To save space, estimation results of control variables and constants are not shown here. ***, **, * significant at 1%, 5% and 10% level, respectively; robust standard error in parentheses.

Table A4 Estimation results (estimated marginal effects based on baseline models and the extended models with importance measures)

	prodf_dm Baseline (1)	prodf_dm Extended (2)	proc_dm Baseline (3)	proc_dm Extended (4)	isales1_2k Baseline (5)	isales1_2k Extended (5)	patent Baseline (7)	patent Extended (8)
Pr(Y=1)	0.996	0.999	0.727	0.732	0.797	0.819	0.800	0.728
lnexprdweu1tr	0.010	0.003	-0.025	-0.091	0.551**	0.630*	0.065	0.098
	(0.017)	(0.008)	(0.050)	(0.059)	(0.245)	(0.354)	(0.044)	(0.060)
oem_dm	-0.091		0.199**		-0.363**		-0.046	
	(0.098)		(0.094)		(0.152)		(0.119)	
oem_md		-0.243		0.226**		-0.699***		-0.080
		(0.272)		(0.105)		(0.191)		(0.226)
oem_st		-0.359		0.249**		-0.367**		-0.191
		(0.307)		(0.116)		(0.158)		(0.162)
supnoem_dm	0.004		0.086		0.161		-0.308*	
	(0.007)		(0.113)		(0.117)		(0.161)	
supnoem_md		0.000		0.213*		0.181		-0.151
		(0.001)		(0.124)		(0.197)		(0.241)
supnoem_st		0.001		0.178		0.130		-0.344**
		(0.002)		(0.111)		(0.123)		(0.163)
compet_dm	-0.007		-0.221		0.160		-0.085	
	(0.014)		(0.154)		(0.129)		(0.121)	
compet_md		0.001		-0.603***		0.142		0.112
		(0.002)		(0.144)		(0.142)		(0.127)
compet_st		-0.001		0.003		0.107		0.010
		(0.003)		(0.153)		(0.115)		(0.151)
uni_dm	0.003		-0.001		0.159		0.127	
	(0.007)		(0.124)		(0.126)		(0.078)	
uni_md		-0.251		-0.164		0.154		0.263**
		(0.297)		(0.216)		(0.157)		(0.133)
uni_st		-[a]		0.061		0.161		0.235*
		-[a]		(0.150)		(0.162)		(0.124)
mkt_dm	0.004		0.148*		-0.183		0.156**	
	(0.008)		(0.087)		(0.184)		(0.079)	
mkt_md		0.001		0.203*		-0.614***		0.024
		(0.002)		(0.111)		(0.195)		(0.206)
mkt_st		0.001		0.136		-0.219		0.253**
		(0.002)		(0.114)		(0.233)		(0.123)
group_dm	0.004		0.071		-0.402**		0.105	
	(0.007)		(0.101)		(0.163)		(0.072)	
group_md		-[b]		0.242**		-0.736***		-[c]
		-[b]		(0.121)		(0.177)		-[c]
group_st		0.001		0.058		-0.286		0.173*
		-		(0.129)		(0.188)		(0.100)
pers_dm	-0.020		-0.124		-0.227		0.022	
	(0.039)		(0.129)		(0.140)		(0.088)	
pers_md		-0.010		-0.456**		-0.136		0.201
		(0.022)		(0.197)		(0.177)		(0.127)
pers_st		-0.001		-0.074		-0.171		-0.074
		(0.004)		(0.132)		(0.142)		(0.128)
lnsize	-0.000	-0.000	0.050	0.085	0.010	0.067	-0.013	-0.002
	(0.003)	(0.001)	(0.055)	(0.053)	(0.048)	(0.062)	(0.047)	(0.056)
age	0.000	-0.000	0.011	0.021	0.009	0.007	0.007	0.015
	(0.001)	(0.000)	(0.008)	(0.013)	(0.011)	(0.011)	(0.009)	(0.013)
exporter	-0.012	-0.051	-0.079	-0.182	0.148	0.162	-0.033	-0.024
	(0.021)	(0.102)	(0.144)	(0.184)	(0.133)	(0.172)	(0.106)	(0.142)
foreignown_to	0.003	0.001	0.208**	0.216**	-0.098	-0.124	0.023	0.010
	(0.006)	(0.002)	(0.099)	(0.107)	(0.140)	(0.157)	(0.091)	(0.122)
foreignown_mi	-0.036	-0.006	0.108	0.189	0.049	0.076	-0.553***	-0.634***
	(0.078)	(0.016)	(0.153)	(0.120)	(0.136)	(0.134)	(0.130)	(0.115)

Notes: Reference point for measuring marginal effect: dependent variable is set equal to one, respectively. All metric independent variables are set at their mean levels, and all binary independent variables are set equal to 0 due to the existing exclusiveness between complementary dummy variables. [a]Uni_st is dropped due to perfect success prediction and, thus, 21 observations are not used. [b]Group_md is dropped due to its perfect success prediction and, thus, 13 observations are not used. [c]Group_md is dropped due to its perfect success prediction and, thus, 13 observations are not used. ***, **, * significant at 1%, 5% and 10% level, respectively; standard error in parentheses.