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How Do Chinese Industries Benefit from FDI Spillovers?

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Abstract

Recently, Foreign Invested Enterprises (FIEs) in China have increased their investment in not only production activity but also R&D activity. This paper examines the impact of spillovers from such activities on two types of innovations by Chinese domestic firms: Total Factor Productivity (TFP) and invention patent application, using comprehensive industry and province-level data. We evaluate such spillovers according to FIEs' ownership structure, the origin of foreign funds, and the type of their activity: R&D, and production. We find an interesting asymmetry between spillovers to TFP and patent application : while we do not find significant intra-industry spillovers from FIEs, which is in line with previous studies, we find robust inter-industries spillover on TFP. On the other hand, we find substantial intra-industry spillovers promoting invention patent application but no evidence of inter-industries spillovers. Furthermore, whereas spillovers from FIEs to Chinese firms' TFP stem from their production activities, the source of spillovers to invention patent application is mostly through their R&D activity. Our findings indicate a need for multi-dimensional evaluation on the role of FDI in developing countries.

Keywords: China, FDI spillovers, R&D, Innovation
JEL classifications: O12;O3;F23;O53

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1. Introduction

Chinese economy has attained most impressive growth in the past few decades among the emerging economies, drawing the world's attention to the mechanism of its success. Most agree that the reform carried out in vast area of its economic system since the late 1970s, is central to China's grand transformation. Among the components of such reform, the internationalization of its industries allowed Chinese economy to capture globalization as the fuel for its growth. While increased presence of multinational enterprises is perhaps one of the most apparent features of globalization, nowhere has it been more relevant than in China, the world's largest recipient of foreign direct investment (henceforth FDI). The spillover of technology and knowledge from foreign invested enterprises (henceforth FIEs) has often been considered as an essential factor contributing to the rapid development of Chinese Economy.

Another important factor that is likely to be driving China's sustained economic growth and further development of its industry is the buoying research and development (henceforth R&D) activity. The R&D by Chinese firms has been growing with average annual rate of more than 18% between 1995 and 2005. The driving force of such drastic increase has been the business sector comprising 71.1% of China's R&D investment (OECD, 2009). Although the major part of such business based R&D investment have been born by domestic firms, the presence of FIEs in China's R&D activity is expanding rapidly. As FIEs regard China not as a mere factory but also a R&D site, the recent trend is likely to accelerate.[1] This paper provides one of the first empirical evidences of spillover from the R&D activity by FIEs in China using unique industry-province level dataset covering a comprehensive range of manufacturing industries over all provinces and designated cities.

1 Jefferson et al. (2003) suggested that while the number of FIEs practicing R&D is still small, those that do are highly R&D intensive. Puga and Trefler (2010) reported increasing "incremental innovation" such as product improvement carried out possibly by multinational plants in China.

We contribute to the debates regarding the spillover from FIEs to the development of domestic firms by providing new insights on the nature of such spillovers. As it is well known, the studies on the effect of increased presence of FIEs have hardly reached consensus: while Kokko (1994), Blomström and Sjöholm (1999), Keller and Yeaple (2003) reported positive impact of FDI on the productivity of domestic firms within the same industry, Haddad and Harrison (1993) claimed there is no such effect and Aitken and Harrison (1999) found negative impact for Venezuelan firms. More recently, Jarvorcik (2004), Blalock and Gertler (2008) emphasized the inter–industrial or "vertical" spillovers as the relevant spillovers from FDI. The extent of such spillovers is also shown to be shaped by the ownership structure (Jarvoick and Spartareanu, 2008), or the origin of FIEs (Huang, 2004). Meanwhile, Todo and Miyamoto (2006) found significant spillovers only from FIEs that perform R&D activities in the host country, suggesting that spillovers can be fairly different depending on the type of activity engaged by FIEs and their R&D activity rather their production may be the important source of spillover.

In this paper, we attempt to provide interpretations to those diverse empirical findings by following way. First, we infer *the nature* of knowledge spillovers by observing to which types of innovations by China's domestic firms are spillovers more relevant: total factor productivity (TFP) that can be regarded as process innovation or invention patent application that is often referred as product innovation. Second, we segregate FIEs with respect to both the type of ownership structure, ie. joint-venture or wholly-owned, and the origin of their fund, ie. Hong Kong, Macau and Taiwan (HMT) or Other countries, mostly OECD countries. Although those two factors have been often considered separately in previous studies, they have not been incorporated simultaneously. However, depending on the industry, FIEs with different ownership structure and origin tend to have large presence in R&D activity. Further, the somewhat inconsistent previous empirical results on the spillovers in Chinese industries may be due to the insufficient disaggregation according to those important characteristics. Thirdly, we consider two different activities by FIEs as sources of spillovers: their knowledge creation that is R&D, and production. The spillover from FIEs' R&D activity and that from production indeed turns out to be quite different, suggesting a potential problem with previous approach that captures the presence of FIEs with their share in industry sales. Lastly, we take into account inter-industries (vertical) spillovers as well as the intra-industry (horizontal) spillovers.

We unravel series of new facts on spillovers in Chinese industries. Firstly, we find that the spillovers from the R&D activities by FIEs are mostly directed to product innovation rather than process innovation of domestic firms. Whereas like many previous studies we do not observe robust evidence of spillovers to the TFP level of domestic firms in the same industry, we find strong knowledge spillovers promoting their patent application. Secondly, we find significantly positive spillover through forward-linkages to TFP but no convincing evidence of inter-industrial spillovers to patent application. Thus, when we consider the productivity of domestic firms, effect of FDI is most likely the intensified competition against FIEs in the same industry but also possibly the availability of high quality input from upstream industries. However for inventive product innovation, fruits of FDI come mostly from FIEs in the same industry where technological distance is small and inter-industrial spillovers are of not much use. These findings suggest that nature of spillovers within a same industry is closely related to technology or knowledge of FIEs but that of inter-industries spillovers is to production network. Consistent to such inference, we find that the source of vertical spillovers to TFP is FIEs' production activity whereas horizontal spillovers to patent application stem from FIEs' knowledge creation activity. Our results thus detangle the complex role of FIEs in the development of Chinese industries, and provide rich implication on the investment and innovation policy of developing countries.

The remainder of this paper is organized as follows. The next section provides a brief overview of recent development of the research related to the spillovers from FIEs that we incorporate in our analysis. Section 3 presents some statistical facts on the recent R&D activity in China. Section 4 introduces empirical framework as well as description of the dataset employed, and Section 5 presents the empirical results. Section 6 concludes.

2. Recent Findings on the Spillovers from FDI

At the macroeconomic level, there are seldom doubts about the contribution of inward FDI to the development of emerging economies, especially when it is about Chinese Economy.[2] Views are much more mixed when it comes to the contribution of FDI to the development of domestic enterprises. Mounting studies-some of them cited earlier- so far have not reached a clear conclusion whether an increased presence of FIEs benefits the domestic enterprises. Somehow, analysis of spillover from FIEs has seen some innovations in recent years.

2.1. Horizontal or Vertical Spillover?

One of the most important innovations in recent studies on spillover is the incorporation of inter-industries or "vertical" spillovers. While the existence of FIEs possessing advanced technology within the same industry is expected to stimulate productivity improvement of domestic firms through knowledge spillovers and competition pressure,[3] in developing countries where the

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[2] Whalley and Xin (2006) for example claim that foreign invested firms may have realized over 40% of China's economic growth in 2003 and 2004, and the GDP growth rate might have been 3.4% points lower without FDI. Studies such as Berthelemy and Demurger (2000),Yao (2006), Kuo and Yang (2008) confirm significant contribution of FDI to China's provincial economic growth. Lai et al. (2006) claim that FDI acted as a channel through which China absorbed International technology spillover. i.e., the spillover from the R&D carried out in OECD countries.

[3] This is analogous to the effect of trade liberalization enhancing domestic firms' productivity reported for Chilean firms by Pavcnik (2002).

technology gap between foreign and domestic firms is large, such positive effect can be offset by the effect of FIEs reducing domestic firms' sales thus forcing them to operate with reduced production scale. The empirical evidences on horizontal spillovers are indeed fairly mixed. It is often found to be negative or non-existent in developing countries (e.g. Aitken and Harrison, 1999 for Venezuelan firms, or Haddad and Harrison, 1993 for Moroccan firms), but it can be positive for developed countries (e.g. Keller and Yeaple, 2003 for the U.S. firms, Haskel et al., 2007 for U.K. firms). Empirical findings are no more clear cut for Chinese industries as well: while Hu and Jefferson (2002) report negative effect on the domestic firms in Electronics industry, Lin et al. (2009) report no significant spillover, whereas Abraham et al. (2010) report positive spillover.

On the other hand, domestic firms can benefit from the spillovers through backward or forward linkages. For example, FIEs in downstream industries may provide local suppliers technology transfer (Blomstrom and Kokko, 1998). In such case, spillovers through backward linkage occur. On the other hand, domestic firms may benefit from the supply of higher quality inputs provided by the FIEs in upstream industries, thus experiencing spillovers through forward linkages. Javorcik (2004), Blalock and Gertler (2008) and Girma et al. (2008) reported positive spillovers through backward linkage for Lithuanian, Indonesian and U.K. firms respectively. They however do not find spillovers through forward linkages. On the other hand, Lin et al. (2009) reported for Chinese firms, evidence of strong spillovers through forward linkages while the significance of backward spillover is sensitive to the origin of FIEs.

2.2. Ownership Structure of FIEs

Another notable feature of recent studies on spillover is the incorporation of the various characteristics of FIEs. The ownership structure of FIEs is especially considered important for it is expected that greater leakage of technology and intangible assets occurs under the participation of domestic investor (Blomstrom and Sjoholm, 1999). Joint-venture firms are thus more likely to be a source of spillovers than wholly-owned firms. Jarvoick and Spartareanu (2008) indeed found for Romanian firms the evidence of stronger spillover through backward linkages from joint-venture projects. On the other hand, foreign firms may have more incentive to transfer advanced technology to the wholly-owned affiliates which they have higher controlling power. For example, Ramachandran (1993) found that wholly foreign-owned subsidiaries in India receive more resource for technology transfer than domestic Indian firms or joint-venture. Therefore, while possible spillovers are less easy to intercept compared to those from joint-ventures, the presence of wholly-owned firms with more advanced technology provides domestic firm chance of larger catch-up. Abraham et al. (2010) recently reported that Chinese firms benefit from positive horizontal spillover from joint-venture FIEs but face negative effect from wholly-owned foreign firms.

2.3. The Origin of FIEs

The difference in spillovers due to origin of FIEs' fund has been explored in some studies such as Javorcik, and Spartareanu (2007) which consider the origin of FIEs as the factor shaping the extent of local sourcing due to geographic factors. It is however a more essential issue in case of China, for one of the most striking features of FDI to China is the large presence of Hong Kong, Macao and Taiwanese (HMT) investment. Beside the difference in degree of technological sophistication, FIEs with HMT and non-HMT origin can be different in their objectives and thus degree of competition between domestic firms. Zhang (2005) claimed that while HMT origin FDI is mostly motivated by China's cheap labor cost and are highly export-oriented, FDI from OECD is often intended to capture China's large domestic market.[4] However, empirical results by studies

[4] Branstetter and Foley (2007) reported that in 2004, whereas about 39.7 billion dollars sales of U.S. affiliates in China were directed to local market, only 3.7 billion dollars sales were directed to the U.S. market. Chen and Roger (2006) also claimed from their own corporate survey that German investment in China is deeply market oriented, while becoming larger in size and higher in quality.

exploring such difference of origin are mixed. Using provincial data, Huang (2004) found that the presence of HMT firms has positive effect on TFP at the province-level but found no such effect for non-HMT firms. Lin et al. (2009) more recently reported negative horizontal spillover from HMT firms to domestic firms but positive spillover from non-HMT firms. On the other hand, Abraham et al. (2010) reported positive significant spillovers from FIEs of both origins that are statistically indifferent. These somewhat inconsistent results may partly be due to the different behavior between joint-venture and wholly-owned FIEs with same origin.

2.4. The Type of Activity Engaged by FIEs

Less explored avenue on the analysis of spillovers from FIEs so far is the distinction on the type of their activities. So far the majority of existing studies have described the presence of FIEs with their share in industry level sales. Such approach however provides little hint about the actual channel of spillovers. Although the “knowledge spillovers” from R&D activity have been widely recognized since Griliches (1979), few authors have incorporated it into the analysis of spillovers from FIEs. Todo and Miyamoto (2006) examined the horizontal spillover to Indonesian firms by segregating FIEs between those performing R&D and those that do not. They only found positive spillover from the FIEs performing R&D. Similarly, Todo (2006) found that Japanese firms enjoyed significant horizontal spillover from FIEs’ R&D activity but not from their production activity. For Chinese firms, Cai, Todo and Zhou (2007) reported the effect of FIE’s R&D stimulating the entry of domestic high-tech firms at the Zhongguancun Science Park. Motohashi and Yuan (2007) found evidence of horizontal and vertical spillovers from FIEs’ R&D stock in Auto and Electronics industry.

2.5. Where Do Spillovers Manifest?

Spillovers are often observed on various factors other than sales or productivity. As surveyed by Griliches (1990), patent application is one of the most popular yet debated indices of innovation output that is often used to infer the knowledge spillover. Hu and Jefferson (2009) reported that increased presence of FIEs seems to have contributed to the recent surge of patent application in China, but interpret such effect mostly as the opportunistic behavior by domestic firms to hold patent to preempt competition, rather than knowledge spillover. Another measure of innovation is the new product development. For example, Girma, Gong and Görg (2007) assessed the horizontal effect of FDI in the new product sales by China's domestic firms. They find that only domestic firms with sufficiently high R&D intensity and good financial access measured as the ratio of bank loan to asset enjoy significant spillovers.

3. A Glance on the Domestic and Foreign R&D in China

We start by observing recent trend of R&D efforts in Chinese industries using the data from "*Statistics on Science and Technology Activities of Industrial Enterprises*" compiled by the National Bureau of Statistics of China. Figure 1 provides a picture of an impressive growth of business based R&D investment in China and quickly rising presence of FIEs' R&D investment. R&D investment in Chinese industry grew at the annual average rate exceeding 22% between 2000 and 2006. Of the total R&D investment in 2006 which amounted to near 180 billion yuan, 72.3% was by domestic firms, and 27.7% was by FIEs. The rapid expansion of FIEs' R&D investment has been realized mostly by firms with non-HMT origins. Especially, the past few years saw a marked increase in R&D by wholly-owned non-HMT firms.[5]

[5] The increase of wholly-owned firms itself after the deregulation on foreign capital share following China's accession to WTO in the late 2001, may partly explain phenomenon.

We next turn to the industrial aspect of recent leap of China's R&D investment. Table1 shows that R&D activity is distributed fairly unevenly across industries. About 50% of industrial R&D is concentrated in three machinery manufacturing: General purpose machinery, Transport Equipment Communication Equipment, Computers and other Electronic Equipment. The increasing weight of those industries with relatively high R&D intensity is most likely a driving force of China's buoying industrial R&D.[6] We also note that the weight of foreign R&D is far from negligible in those industries. Actually, in industries with largest amount of R&D such as Communication Equipment, Computer and other Electronic Equipment Production, foreign R&D comprises half of R&D investment.

Table 1 also reveals that the weight of foreign R&D across Chinese industries is substantially diverse with respect to the origin and ownership structure of FIE. While non-HMT R&D often display higher share than R&D with HMT origins, this is not the case for industries such as Smelting and Processing of Ferrous Metal, or Chemical Fiber. While the presence of non-HMT joint-venture is especially pronounced in industries such as Furniture, Rubber, Transportation machinery, HMT joint-ventures are more active R&D maker in Papermaking, Printing, or Plastic Product. On the other hand, the presence of wholly-owned foreign firms, especially with non-HMT origin, is concentrated to some industries such as Communication Equipment, Metal, Plastic and Textile. Such uneven presence of foreign R&D with different ownership structure and origins implies that the nature of spillover from foreign R&D can also be very different. It seems therefore sensible to incorporate difference in ownership structure and origin simultaneously in order to grasp the role of FIEs' R&D correctly.

Finally, we observe the geographical aspect of foreign R&D. Figure 3 shows that foreign

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[6] For example, Hu and Jefferson (2008) argue that recent leap of R&D investment can be explained at least partly, by the 250% rise in R&D intensity of electronics and telecommunication industry (from 2.97% of value added in 1995 to 7.34% in 2000), and the doubling weight of this industry on total industry sale.

R&D is significantly concentrated in provinces mostly in coastal area. Although FIEs' R&D with HMT origin and those with non-HMT are distributed similarly, the size of non-HMT R&D in Shanghai, Jiangsu province, and Tianjin stands up against those of HMT origin. Conversely, FIEs' R&D with HMT origin is somewhat more active in Beijing and Fujian province. Those provinces enjoy large presence of FIEs' R&D even compared to the size of domestic R&D. Such uneven geographical distribution of FIEs' R&D suggests that agglomeration may be an important factor shaping the spillover from the FIEs' R&D. It is however likely to be reflecting at least partly, the industrial structure of each province: i.e. whether the province has industry which host large weight of FIEs' R&D.

4. Empirical Strategy and Data

4.1 Empirical Strategy

We address the spillovers from FIEs to two types of innovation by domestic firms; their TFP as proxy for process innovation and their invention patent applications as proxy for product innovation. We incorporate in our analysis various factors found in recent studies that may influence the extent of spillovers. In order to estimate the contribution of the R&D efforts by domestic firms and spillover from FIEs' R&D stock to TFP of domestic industry, we start by the following Cobb Douglas framework:

$$Y_{irt} = A_{irt} L_{irt}^{\beta_L} K_{irt}^{\beta_K} e^{\varepsilon_{irt}} \tag{1}$$

where Y is value added of domestic firms in industry i and region r at time t, L is the labor input, K is the physical capital stock, β_L and β_K are elasticities of output with respect to labor and physical capital input. Assuming that R&D activities and knowledge spillovers positively affect the technology parameter *A*, we decompose the sources of TFP into the following factors; own R&D efforts, technology transfer from abroad and domestic, technological change attributed to the knowledge spillover from FIEs' R&D activities and spillovers from FIE's production activities. We defined the log of TFP level of domestic firms in industry *i* and province *r* at year *t* as the residuals of real value-added unexplained by the contribution of labor and capital input by estimating equation (1); $\ln tfp^{D}_{irt} = \ln Y^{D}_{irt} - \hat{\beta}_L \ln L^{D}_{irt} - \hat{\beta}_K \ln K^{D}_{irt}$.

We model the TFP of domestic industries as a function of own R&D effort, spillovers from FIEs and technology transfer. Assuming log-linear functional form, we estimate the effects of these factors on TFP level by the following equation.[7]

$$\ln tfp^{D}_{irt} = \alpha_0 + \alpha_1 \ln R^{D}_{irt} + \alpha_2 \ln R^{F}_{irt-1} + \alpha_3 \ln K^{F}_{irt-1} + \alpha_4 \ln TP^{Df}_{irt} + \alpha_5 \ln TP^{Dd}_{irt} + u_{ir} + u_t + v_{irt} \qquad (2)$$

where *i* denotes the industry, *r* the province or city, and *t* the year. α_0 is a constant, u_t represents the time trend, u_{ir} represents the individual effect of pair of industry and province and v_{irt} is the idiosyncratic error term distributed as iid. The dependent variable, $\ln tfp^{D}$ is log of TFP of domestic firms at the industry-province level. R^{D} is the stock of own R&D investment of domestic firms in industry *i* and province *r* constructed by the method explained later on. Similarly, R^{F} is the stock of FIEs' R&D in the same industry and province which coefficient indicates knowledge spillover from the knowledge creation activity by FIEs. The source of spillover is of course not limited to R&D activity. To capture the spillovers from FIEs' activity other than R&D, which we

7 We adopt the two-step procedure that estimating the effects of R&D and spillover on TFP after TFP level is first obtained rather than directly estimating them on value added. This procedure has the advantage that labor and capital input need not be used as regressors.

regard as production activity, we add FIEs' capital stock, K^F intended to represent their production activities. Taking into account that spillovers take time to manifest on the innovation by domestic firms as opposed to their own R&D activity, we take one period lag for the explanatory variables expressing spillovers from FIEs' activities. Furthermore, we disaggregate the two variables expressing the activities of FIEs according to the ownership structure and the origin of fund of FIEs. That is, we divide FIEs' R&D and capital stock into; that of joint ventures with HMT origin, wholly-owned FIEs with HMT origin, joint ventures with non-HMT origin and wholly-owned FIEs with non-HMT origin. Lastly, TP^{Df} is the stock of technology purchase from foreign country while TP^{Dd} is that of technology purchase from domestic market, both intended as measurement of technology transfer.

Spillovers from FIEs may be relevant not only with in a same industry but also across industries through forward or backward vertical linkages. In our full specification model, the terms corresponding to such inter-industries spillover is also added into the estimated equation as follow.

$$\begin{aligned}\ln tfp_{irt}^{D} = \alpha_0 + \alpha_1 \ln R_{irt}^{D} + \alpha_2 \ln R_{it-1}^{FH} + \alpha_3 \ln R_{it-1}^{FF} + \alpha_4 \ln R_{it-1}^{FB} + \alpha_5 \ln K_{it-1}^{FH} \\ + \alpha_6 \ln K_{it-1}^{FF} + \alpha_7 \ln K_{it-1}^{FB} + \alpha_8 \ln TP_{irt}^{Df} + \alpha_9 \ln TP_{irt}^{Dd} + + u_{ir} + u_t + \nu_{irt}\end{aligned} \quad (3)$$

where upper subscript *FH* indicates FIEs locating in same industry thus corresponds to "horizontal" or intra-industry spillovers, whereas *FF* denotes the FIEs locating in upstream industries thus expressing spillovers through forward vertical linkages, and *FH* indicating FIEs in downstream industries corresponding to spillovers through backward vertical linkages.

With respect to the type of innovation, TFP is often considered as process innovations rather than product innovations. We observe number of invention patent application, P^D as a proxy for the product innovations by domestic firms. We regress it on the same set of explanatory variables as in the specification for TFP, assuming the patent production function where own R&D effort, technology transfer and spillover from FIEs' R&D and production activities are its inputs.

In case of TFP, we estimate equation (2) and (3) by applying OLS based on the pooling data, fixed effects model and random effects model based on the panel data. However, there is a concern that the specifications suffer from the endogeneity problem caused by the correlation between the error term and the regressors. In this case, the estimators will be biased if the R&D investment or technology purchase is altered by unobserved productivity differences across the pair of industry and region. We therefore use the system generalized method of moments (GMM) estimation developed by Blundell and Bond (1998) in order to deal with the endogeneity problem of explanatory variables and to eliminate time-invariant individual effects. In this specification, we treat the own R&D stock and technology purchase stock as endogenous and FIEs' R&D stock and capital stock as predetermined variables. As instruments, we used the second and deeper lags of these variables for the first-differenced equation and their first-differenced lags for the level equation. We implement one-step GMM estimation with robust standard errors including year dummy variables as strictly exogenous variables. In case of patent production function, the estimated the coefficients on regressors can be biased downward due to the substantial number of observations at zero values. We therefore employ Tobit model with random effects to mitigate such concern.

4.2 Data

We construct an unique industry-province level data by combining two statistical surveys conducted by the National Bureau of Statistics of China (NBS); "*the Survey of R&D Activity for Large and Medium Size Enterprises* (henceforth RDA survey)" as the source of R&D, technology purchase and patent applications, and "*the Industry Statics data for State-owned and Non-state-owned Industrial Enterprises above Designated Size* (henceforth IND survey)" as the source of the basic industrial-province level data for calculating TFP. Both datasets are yearly data covering large and medium size Chinese firms[8]. The two datasets can be divided into the data on domestic firms and that on FIEs for each variable by using ownership structure and origin of fund. Although studies like Liu and Wang (2003) and Cheung and Lin (2004) used industry or province level data to find positive contribution of FDI on TFP or patent application, their data include foreign firms within its figure. They are thus subject to endogeneity problem argued by Aitken and Harrigan (1999): if foreign firms invest in industries or regions with initially high performance, the positive relation between industry level performance and FDI can be observed even in lack of any spillover. In our dataset, this issue can be overcome by splitting the data into domestic part and FIEs part. This separation of data enables us to directly examine the effect of spillover FIEs on the performance of domestic part. As a result, we obtain an unbalanced panel data composed of 39 industries and 31 provinces with period between 2000 and 2007. The number of observations is roughly 1,000 every year, for domestic part and foreign sample each.

For the first dependent variable, ln*tfp* which is calculated as the residuals of real value-added unexplained by the contribution of labor and capital input by estimating Cobb Douglas function. We retrieved data on value-added, labor input measured as the number of regular workers and capital stock measured as net value of fixed assets of domestic firms from IND survey.[9] As for the second dependent variable, we used the number of invention patent applications at the industry-province level retrieved from RDA survey. The reason we focus on invention patent application instead of whole application including utility model and trademark is the possible large existence of defensive application motivated by strategic intent rather than innovation, and the fact

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[8] The large and medium-size enterprises must attain the following three criteria simultaneously, that is (1) the total employees large that 300, (2) total sales revenue larger than 30 million Yuan, (3) total assets larger than 40 million Yuan.

[9] The estimated labor share and capital share are 0.64 and 0.25, respectively, when estimating production function by fixed effect model including time dummies.

that economic meaning associated with the three categories of China's domestic patent (invention, utility and trademark) are very different. It is therefore adequate to refine our evaluation of product innovation in order to capture meaningful spillovers from FIEs. Of course, there are a number of observations reporting zero and the value of one is added to each observation before taking logarithm.

From RDA survey, we construct R&D stock of domestic and foreign firms from R&D expenditure using perpetual inventory method where we set the depreciation rate to 15%.

$$R_t = E_t + (1-\delta)R_{t-1}, \tag{4}$$

where *R* is R&D stock, *E* is R&D investment and δ is depreciation rate. We construct initial stock value, R_{tb} from R&D investment in 2001 by assuming constant average growth rate for the period, *g* as following:

$$\begin{aligned} R_{tb} &= E_t + (1-\delta)E_{t-1} + (1-\delta)^2 E_{t-2} + \cdots \\ &= \frac{E_t}{1-\left(\frac{1-\delta}{1+g}\right)} \\ &= \frac{E_t(1+g)}{g+\delta} = \frac{E_{t+1}}{g+\delta} \end{aligned} \tag{5}$$

As proxy for technology transfer, stocks of foreign and domestic technology purchase are also constructed in the same way. The capital stock of FIEs used as a proxy for spillovers from production activity by FIEs is measured as the net value of fixed assets reported in the IND survey. The variables presenting inter-industry spillover are calculated as input-output coefficient multiplied by the FIEs' R&D stock in upstream or downstream industries as Javorcik (2004). The proxy for spillover from FIEs' R&D activity through forward linkages is defined as follow:

$$R_{it}^{FF} = \sum_{k \neq i} \alpha_{ki} R_{kt} \tag{6}$$

where α_{ki} is the share of output provided from industry *k* to *i*. Similarly, the backward effect is defined as follow:

$$R_{it}^{FB} = \sum_{k \neq i} \alpha_{ik} R_{kt} \qquad (7)$$

where α_{ik} is the share of output provided from industry i to k. We collected the data on input-output coefficient from the input-output table compiled by the NBS. The proxy for intra-industry spillover from FIEs in equation (3), R^{FH} is defined as summation of FIEs' R&D stock in the same industry. The all data on nominal value is transformed to real value by using producer price index at the industry-level published by NBS. Table 2 describes the summary statistics of main variables of interest.

5. Estimation Results

5.1. Intra-industry Spillover from FIEs on TFP

We start by observing the possible spillover from the R&D and production activity by the FIEs to the TFP of domestic firms in the same industry. The equation (2) is estimated by OLS, fixed effects model, random effects model and system-GMM estimation. The estimation results are shown in Table 3. The FIEs' R&D and capital stock in the same industry and region are divided into four variables, respectively; that of joint ventures with HMT origin, wholly-owned FIEs with HMT origin, joint ventures with non-HMT origin and wholly-owned FIEs with non-HMT origin. Before we begin, we note the model selection. Regarding the panel analysis, the result of the F test leads to the rejection of the null hypothesis that individual effects equal zero; thus, the fixed effects model is more appropriate than OLS. Moreover, the result of the Breusch-Pagan test rejects the pooling estimation and supports the random effects model. In the Hausman test, the random effect model is rejected at 1 percent of statistical significance, and thus the fixed effects model is favorable in comparison with the random effects model. In order to cope with the endogeneity of regressors, the results of system-GMM estimations are also presented in column (4) and (8). The results of the Hansen test for overidentifying restrictions and the Arrellano-Bond test for second-order autocorrelation suggest that the instruments are orthogonal and there is no serial correlation in the error term. We consider the result of system-GMM estimations as the most robust result for our estimation and use the results as benchmark.

First, it is found across various models that the domestic firms' own R&D stock contributes substantially to their productivity. A 10% increases in own R&D stock is likely to result in 0.9% higher TFP. The significant contribution of own R&D is robust across all specification. On the other hand, we cannot find consistent evidences of significant knowledge spillovers from FIEs' R&D stock within the same industry. When we add FIEs' production activity as another possible source of spillovers, we still do not find positive effects that are stable across different models. We therefore do not have robust evidence supporting positive or negative intra-industry (or "horizontal") spillovers from FIEs regardless of the type of activities.[10] Our results seems to contrast with Lin et al (2009) reporting positive spillover from non-HMT FIEs, or Abraham et al. (2010) reporting negative spillovers from wholly-owned FIEs. Our different result from those works may be partly due to the difference in specification though it is difficult to compare their results directly with our result because their studies use firm-level data. For instance, those works employ the share of FIE in industry output to infer the spillovers. Further, Lin et al. (2009) do not control time effect in their fixed effect model, while Abraham et al. (2010) employ OLS estimation. However, we are convinced that controlling both time effects and fixed effects is indispensable for precise estimation, especially the time effects considering the upward trend of the performance and R&D activity by China's domestic firms and FIEs in recent years.[11] In addition to this matter, our results are more robust than the earlier studies in the point of controlling for endogeneity of

[10] Even if we employ the aggregate of R&D or capital stock by four types of FIEs as a regressor, the coefficient is not significant at all.

[11] The results are not changed when we estimate the first-differenced model of equation (2) which enable to eliminate the fixed effects,

regressors by system-GMM estimations.[12]

5.2. Intra-industry Spillover from FIEs on Invention Patent Application

We observe next the contribution of horizontal spillovers to the invention patent applications by domestic firms. The estimation results are presented in Table 4. In addition to the standard panel model, we add the result of Tobit model with random effects for reason mentioned above. The results of Log likelihood test indicate that the use of Tobit model with random effects is more appropriate than just Tobit model on pooling data. As for the Tobit model, the marginal effects for the probability of being uncensored are also presented in column (4) and (8).

From Table 4, we again observe robust contribution of own R&D that is most pronounced within the Tobit model with random effects, where 10% increase in domestic R&D stock is associated with 0.9% increase in invention patent application. Contrary to the case with TFP, we observe significant horizontal spillovers from the R&D activity by FIEs with various ownership structure and ownership. Intra-industry spillovers from FIEs in Chinese industries are thus rewarding *product innovation* rather than *process innovation* of Chinese firms. The rank of magnitude of knowledge spillovers among different ownership structure and origin of FIEs is not very clear. Overall, non-HMT FIEs seem to contribute more than HMT origin FIEs, although the contribution of the wholly-owned firms with HMT origin dominates if we rely on the results of Tobit model with random effects. The spillovers from joint-venture firms with HMT origin is apparently the smallest and is not significant under the Tobit model with random effects.

The significance of spillovers from FIEs' R&D activity is not altered when we include foreign capital stock in regressors. Production activities by FIEs on the other hand do not seem to contribute except that of wholly-owned FIEs with non-HMT origin from which we find a

[12] The result of system-GMM is not changed even if we treat the spillover regressors as strictly exogenous. Although we also estimated the specification with the lagged logarithm of TFP level as a regressor, the result of Hansen test shows that the instruments are not orthogonal to the error term.

significantly positive spillovers although smaller in magnitude than that of R&D activity. Intra-industry spillovers therefore stem mostly from the knowledge creation activity by FIEs rather than from their production.

5.3 Vertical Spillovers

We next observe the spillovers from the FIEs operating in the upstream or downstream industries by estimating equation (3). Regarding the selection of fixed and random effects models, the results of Hausman test support fixed effects model. As for system-GMM estimations, the results of tests for overidentifying restrictions and second-order autocorrelation show that the instruments are orthogonal and there is no serial correlation in the error term.[13] From the first four columns of Table 5, we observe significantly positive spillover from FIEs' R&D activity through forward linkage, and negative spillover through backward linkage. However, significant spillovers from foreign R&D disappear once spillovers from foreign productions proxied by the capital stock of FIEs in upstream and downstream industries are included in column (5) to (8). The source of positive spillover through forward linkage and negative spillover through backward linkage is therefore not the knowledge creation activity of FIEs but rather their productions. One way to interpret the positive spillover through forward linkage is that FIEs in upstream sectors provide inputs of higher quality which may allows domestic firms to up-grade product quality. The negative spillover from the R&D through backward linkage on the other hand, suggests the possibility that expansion of FIEs' production shifts input demand from domestic firms to other FIEs or imported goods.[14] We conclude that inter-industries spillovers through input-output linkage rather than

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[13] As in the case of intra-industry spillovers, we confirmed that the first-differenced model generates the similar results with fixed effects model. Further, the result of system-GMM is not changed even if we treat the spillover regressors as strictly exogenous. The result of specification with the lagged logarithm of TFP level as a regressor leads to the rejection of Hansen test.

[14] Such displacement of backward linkages was discussed by Rodriguez-Clare (1996) who theoretically predicted the case where increasing presence of FIEs that procure less locally than domestic firms can be detrimental to a country's welfare.

intra-industrial spillovers are more essential for productivity of China's domestic firms, and such spillovers stems from production of FIEs but not from their knowledge creation activity.

Let us now look at the vertical spillovers to the invention patent application by domestic firms. To our knowledge this is the first study that assesses vertical spillovers of FIEs to invention patent application. Looking at Table 6, we cannot find consistent evidence supporting significant inter-industries spillovers from neither knowledge creation activity nor production of FIEs. On the other hand, the result shows that the effect of horizontal knowledge spillovers is positive and significant even after controlled for the spillovers from FIEs' productions. These results indicate that knowledge spillovers from FIEs reward domestic firms operating in same industry where technological distance between FIEs and domestic firms are relatively small, but seem to be not relevant for those operating in different industries.

6. Concluding Remarks

In recent years, China has accomplished remarkable economic growth According to the authors' calculation based on the aggregated of industrial data for the period of 2000-2007 used in this analysis, TFP growth accounted approximately 70% of annual growth rate of industrial value added and the average annual growth rate of TFP was 10%. The internationalization of China's industries through large inflow of FDI and increased presence of FIEs is expected to have played a significant role in the evolution of productivity. In this paper we examined the effect of spillovers from FIEs' activities on two types of innovation by domestic firms: their TFP and invention patent application, using China's comprehensive industry-province level data.

We incorporated in our empirical analysis various elements recently found to be important with regard to spillovers from FIEs. First, we consider two different sources of spillovers from FIEs' activity: their R&D and production instead of previous approach that captures the presence of FIEs with FIEs' share in industry sales. Second, we applied a finer segregation of FIEs with respect to both the type of ownership structure, ie. whether FIEs are joint-venture or wholly-owned, and the origin of their fund, ie. Hong Kong, Macau and Taiwan, or other countries mostly OECD countries. Finally, we examined both inter-industries (vertical) spillover and intra-industry (horizontal) spillover. Our main findings are summarized as follows:

(1) The buoying R&D investments by domestic firms are contributing significantly to both their productivity and patent application. Our results indicate that the buoying R&D investment of domestic firms would increase domestic TFP by about 2.2% and invention patent application by 2% under the fact that the average annual growth rate of domestic R&D investment is 22%.

(2) Spillovers from FIEs within a same industry stem mostly from their R&D activity, and contribute to product innovation (proxied by invention patent application) of domestic firms rather than their process innovation (proxied by TFP). Intra-industry spillover from FIEs' R&D activity is expected to increase invention patent application of domestic firms by about 1% under the fact that the average annual growth rate of FIEs' R&D investment is 33%.

(3) While the relative size of such knowledge spillovers on patent application across different ownership structure and origins of fund is not well established, spillovers from joint-venture FIEs with HMT origin seems to be smaller than ones from other types of FIEs.

(4) Spillovers from FIEs operating in upstream or downstream industries originate from their production activity rather than their R&D activity, and reward the process innovation of domestic firms through forward linkage. Spillovers from FIEs' production activity thorough forward linkages would increase TFP by 1.4% and accounts about 14% of industrial TFP growth given the fact that the annual growth rate of FIEs' capital stock is 18%. Since TFP growth is caused by various factors including the high capacity utilization due to robust demand growth during this period or the effect of structural changes due to institutional reform, we consider this

magnitude to be economically significant. However FIEs affect negatively the TFP of domestic firms through backward linkage, suggesting displacement of procurement. “Vertical” spillovers on the other hand, do not seem to have significant effect on the product innovation.

Our analysis revealed some new findings on spillovers from FIEs in China, the World’s largest recipient of FDI. It provides explanations to an important puzzle found in most studies of spillovers, which is the lack of positive spillovers to the domestic firms within a same industry referred as “demonstration effect”. We show that such effect actually exists but previous studies have not been looking at the right subject. Spillovers from FIEs are present both within a same industry and across different industries, but the types of innovation by domestic firms they contribute and the kind of activities they stem from are in fact different. Our results therefore point out the importance of assessing spillovers with diverse criteria than TFP alone. They also allow rich inference on the nature of spillovers that have not been discussed in dept by previous studies: knowledge spillovers are only effective on domestic firms sharing close technological distance with FIEs, whereas spillovers from FIEs’ production is enjoyed by domestic firms that are not directly competing against FIEs. Such observation is clearly not possible with previous approach that often captures spillovers merely as an output share of FIEs.

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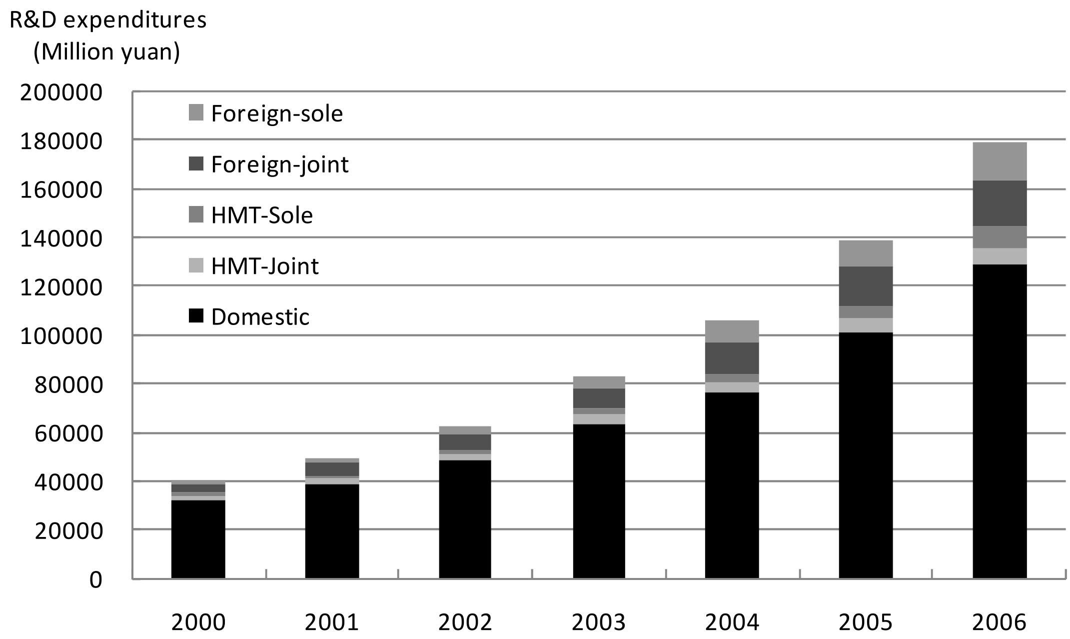

Figure1: Transition of China's business based R&D expenditure

Source: Calculated by Authors based on the Statistics on the Survey of R&D Activity for Large and Medium Size Enterprises by the National Bureau of Statistics of China.

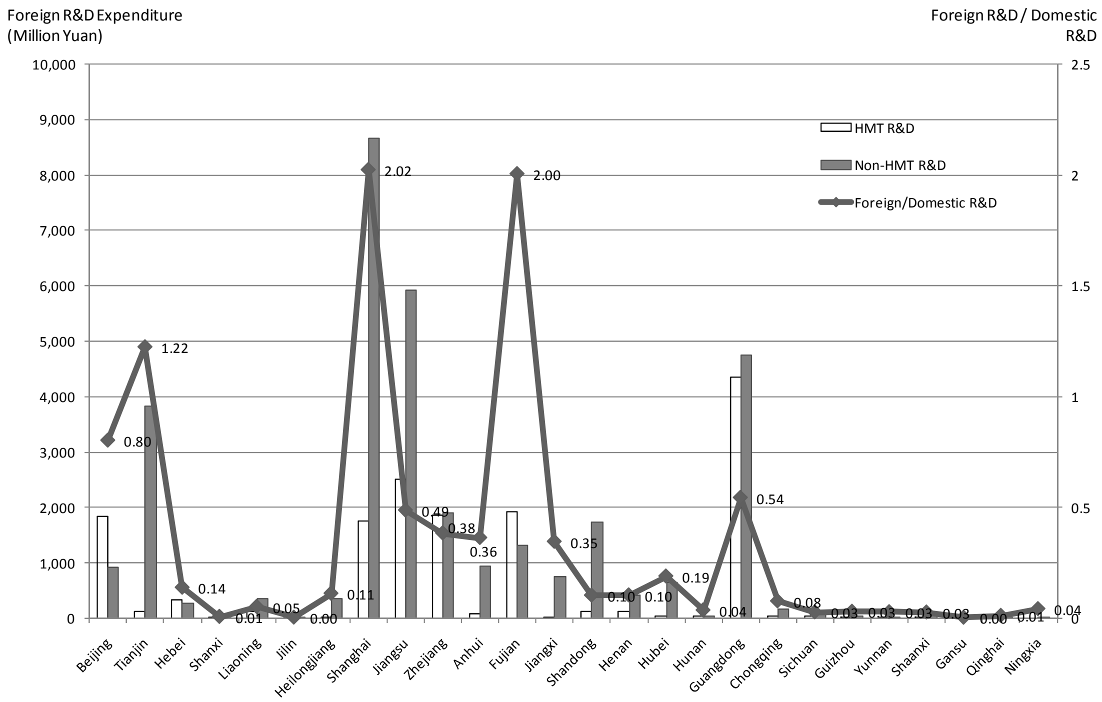

Figure2. The Regional Distribution of Foreign invested firms' R&D expenditure

Source: Calculated by Authors based on the Statistics on the Survey of R&D Activity for Large and Medium Size Enterprises by the National Bureau of Statistics of China.

Table1. The weight of Domestic and Foreign firms in R&D expenditure

2-digit Industry	Total R&D (1,000yuan)	Domestic R&D	HMT-Joint R&D	HMT-Sole R&D	Foreign-joint R&D	Foreign-sole R&D
Textile Industry	3,048,254	78.8%	2.3%	4.8%	3.2%	10.9%
Textile, Clothing and Footwear Production	828,430	94.1%	2.2%	1.0%	1.9%	0.8%
Timber Processing & Wood, Bamboo, Cane, Palm Fiber and Straw Products	414,481	92.4%	0.3%	4.8%	2.2%	0.3%
Furniture Manufacturing	192,143	30.7%	0.0%	0.6%	68.2%	0.5%
Papermaking and Paper Products	1,224,427	86.2%	8.7%	0.3%	2.6%	2.2%
Printing and Record Medium Reproduction	232,471	78.9%	14.0%	0.0%	6.3%	0.7%
Raw Chemical Materials and Chemical Products	9,503,863	90.4%	2.4%	0.9%	3.1%	3.3%
Medical and Pharmaceutical Products	5,047,515	78.6%	2.9%	1.6%	11.4%	5.4%
Chemical Fiber	1,308,653	90.3%	6.2%	1.2%	2.4%	0.0%
Rubber Products	1,314,176	67.3%	0.9%	1.5%	28.2%	2.1%
Plastic Products	1,103,137	58.3%	12.9%	5.5%	4.3%	19.1%
Smelting and Pressing of Ferrous Metals	13,357,837	95.5%	3.0%	0.2%	0.8%	0.5%
Smelting and Pressing of Nonferrous Metals	4,092,525	92.9%	3.2%	0.2%	3.6%	0.0%
Metal Products	1,688,780	67.2%	5.1%	8.3%	8.5%	10.9%
General-purpose Equipment Manufacturing	7,728,854	74.4%	2.6%	1.3%	16.0%	5.7%
Special-purpose Equipment Manufacturing	5,832,481	85.2%	1.8%	4.4%	6.0%	2.6%
Transport Equipment Manufacturing	19,617,841	62.8%	2.5%	0.9%	27.6%	6.2%
Electric Equipment and Machinery	12,860,704	74.7%	5.2%	2.0%	14.0%	4.1%
Communication Equipment, Computers and Other Electronic Equipment Production	31,448,066	47.0%	8.1%	8.0%	17.6%	19.3%
Total	*138,999,268*	*73.0%*	*4.1%*	*3.2%*	*12.2%*	*7.5%*

Source: Calculated by Authors based on the Statistics on the Survey of R&D Activity for Large and Medium Size Enterprises by the National Bureau of Statistics of China.

Table 2. Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
TFP level of domestic firms	5663	3.91	0.91	-5.67	7.78
Invention patent application	5692	0.88	1.23	0	8.99
Own R&D stock	5692	10.01	4.13	0	17.88
Technology purchase stock from abroad	5692	7.87	5.02	0	16.47
Technology purchase stock from domestic	5692	5.52	4.64	0	14.90
HMT R&D stock joint	5692	2.19	4.10	0	15.45
HMT R&D stock 100%	5692	1.12	3.16	0	16.24
non-HMT R&D stock joint	5692	2.74	4.58	0	16.56
non-HMT R&D stock 100%	5692	1.39	3.45	0	16.13
HMT Capital stock joint	5692	4.55	5.89	0	17.69
HMT Capital stock 100%	5692	2.96	5.30	0	17.62
non-HMT Capital stock joint	5692	5.64	6.27	0	17.03
non-HMT Capital stock 100%	5692	3.76	5.83	0	18.46
FIEs' R&D stock Forward	5661	8.33	3.12	0	14.73
FIEs' R&D stock Backward	5661	7.78	3.59	0	15.05
FIEs' R&D stock Horizontal	5661	3.95	5.17	0	16.86
FIEs' Capital stock Forward	5661	11.49	2.19	0	16.66
FIEs' Capital stock Backward	5661	11.10	3.13	0	16.88
FIEs' Capital stock Horizontal	5661	7.63	6.55	0	18.78

Table 3. Intra-Industry Spillovers to TFP of Domestic Firms

Dependent Variable: TFP of domestic firms	(1) OLS	(2) Fixed	(3) Random	(4) GMM	(5) OLS	(6) Fixed	(7) Random	(8) GMM
Own R&D	0.044	0.018	0.041	0.09	0.044	0.018	0.041	0.09
	[0.005]**	[0.005]**	[0.004]**	[0.025]**	[0.005]**	[0.005]**	[0.004]**	[0.025]**
HMT R&D joint	0.011	0.002	0.007	0.006	0.012	0.004	0.007	0.009
	[0.002]**	[0.004]	[0.003]*	[0.006]	[0.003]**	[0.004]	[0.004]**	[0.006]
HMT R&D 100%	-0.003	-0.004	-0.003	-0.002	-0.002	-0.001	-0.001	-0.002
	[0.003]	[0.004]	[0.004]	[0.004]	[0.003]	[0.004]	[0.004]	[0.005]
non-HMT R&D joint	0.001	-0.003	0.001	-0.003	-0.003	-0.003	0.000	-0.005
	[0.002]	[0.003]	[0.003]	[0.007]	[0.003]	[0.003]	[0.003]	[0.006]
non-HMT R&D 100%	0.002	-0.004	-0.002	-0.001	0.004	0.000	0.002	0.002
	[0.003]	[0.004]	[0.003]	[0.005]	[0.003]	[0.004]	[0.004]	[0.005]
HMT Capital joint					-0.001	-0.001	0.001	-0.003
					[0.003]	[0.002]	[0.002]	[0.004]
HMT Capital 100%					0.000	-0.003	-0.002	0.000
					[0.002]	[0.002]	[0.002]	[0.004]
non-HMT Capital joint					0.006	0.000	0.002	0.004
					[0.002]**	[0.002]	[0.002]	[0.005]
non-HMT Capital 100%					-0.003	-0.007	-0.006	-0.004
					[0.002]	[0.002]**	[0.002]	[0.003]
Technology purchase from abroad	0.027	0.001	0.02	0.025	0.027	0.001	0.020	0.024
	[0.004]**	[0.005]	[0.004]**	[0.019]	[0.004]**	[0.005]	[0.004]**	[0.020]
Technology purchase from domestic	0.016	-0.01	0.001	-0.002	0.015	-0.009	0.002	-0.002
	[0.004]**	[0.004]*	[0.004]	[0.019]	[0.004]**	[0.004]*	[0.004]	[0.019]
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	2.73	3.333	2.882	2.405	2.726	3.344	2.880	2.415
	[0.047]**	[0.059]**	[0.045]**	[0.195]**	[0.047]**	[0.060]**	[0.045]**	[0.195]**
N of observations	5663	5663	5663	5663	5663	5663	5663	5663
N of groups		1026	1026	1026		1026	1026	1026
R-squared	0.28	0.39			0.28	0.39		
F test that all $u_{il} = 0$ (pooling vs fixed effects)		F = 15.35 Pr>F = 0.000				F = 15.37 Pr>F = 0.000		
Breusch-Pagan Lagrangian multiplier test (pooling vs random effects)		chi-sq = 5667.12 Pr>chi-sq = 0.000				chi2(1) = 5665.78 Prob > chi2 = 0.000		
Hausman test (random effects vs fixed effects)		chi-sq = 89.10 Pr>chi-sq = 0.000				chi-sq = 100.20 Pr>chi-sq = 0.000		
P-value of Hansen test for overid. Restrictions				0.518				0.523
Arellano-Bond test for AR(2)				0.525				0.535

Note: Standard errors in brackets. * and ** indicate the statistical significance at 5 percent and 1 percent, respectively.

Table 4. Intra-Industry Spillovers to Invention Patent Application of Domestic Firms

Dependent variable: Invention patent applications of domestic firms	(1) OLS	(2) Fixed	(3) Random	(4) Tobit with random effects		(5) OLS	(6) Fixed	(7) Random	(8) Tobit with random effects	
Own R&D	0.056	0.014	0.047	0.274	0.091	0.056	0.014	0.047	0.273	0.091
	[0.003]**	[0.008]	[0.006]**	[0.018]**		[0.003]**	[0.008]	[0.006]**	[0.018]**	
HMT R&D joint	0.02	0.012	0.020	0.013	0.004	0.03	0.013	0.021	0.013	0.004
	[0.005]**	[0.005]*	[0.004]**	[0.008]		[0.006]**	[0.006]*	[0.005]**	[0.009]	
HMT R&D 100%	0.017	0.032	0.028	0.031	0.011	0.027	0.029	0.027	0.032	0.011
	[0.007]*	[0.006]**	[0.005]**	[0.010]**		[0.008]**	[0.007]**	[0.006]**	[0.010]**	
non-HMT R&D joint	0.045	0.007	0.027	0.031	0.010	0.048	0.006	0.026	0.027	0.009
	[0.004]**	[0.005]	[0.004]**	[0.007]**		[0.005]**	[0.005]	[0.004]**	[0.008]**	
non-HMT R&D 100%	0.032	0.035	0.038	0.027	0.009	0.027	0.029	0.032	0.02	0.007
	[0.007]**	[0.005]**	[0.005]**	[0.009]**		[0.007]**	[0.006]**	[0.005]**	[0.009]*	
HMT Capital joint						-0.01	-0.002	-0.002	-0.002	-0.001
						[0.003]**	[0.003]	[0.003]	[0.006]	
HMT Capital 100%						-0.014	0.002	-0.002	-0.004	-0.001
						[0.004]**	[0.003]	[0.003]	[0.006]	
non-HMT Capital joint						-0.003	0.000	0.000	0.005	0.002
						[0.003]	[0.003]	[0.003]	[0.005]	
non-HMT Capital 100%						0.011	0.009	0.009	0.011	0.004
						[0.004]**	[0.003]**	[0.003]**	[0.006]*	
Technology purchase from abroad	0.027	0.013	0.032	0.08	0.027	0.029	0.012	0.032	0.079	0.026
	[0.003]**	[0.007]	[0.005]**	[0.011]**		[0.003]**	[0.007]	[0.005]**	[0.011]**	
Technology purchase from domestic	0.06	0.015	0.043	0.056	0.019	0.059	0.014	0.043	0.056	0.019
	[0.003]**	[0.006]*	[0.005]**	[0.010]**		[0.003]**	[0.006]*	[0.005]**	[0.010]**	
Year dummies	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	
Constant	-0.574	0.204	-0.42	-4.394		-0.555	0.203	-0.418	-4.393	
	[0.031]**	[0.090]*	[0.050]**	[0.179]**		[0.032]**	[0.091]*	[0.050]**	[0.179]**	
N of observations	5692	5692	5692	5692		5692	5692	5692	5692	
N of groups		1032	1032	1032			1032	1032	1032	
R-squared	0.44	0.17				0.44	0.17			
F test that all u_{it} = 0 (pooling vs fixed effects)		F = 7.56 Pr>F = 0.000					F = 7.51 Pr>F = 0.000			
Breusch-Pagan Lagrangian multiplier test (pooling vs random effects)		chi-sq = 4078.44 Pr>chi-sq = 0.000					chi-sq = 3990.47 Pr>chi-sq = 0.000			
Hausman test (random effects vs fixed effects)		chi-sq = 117.67 Pr>chi-sq = 0.000					chi-sq = 141.15 Pr>chi-sq = 0.000			
P-value of Likelihood-ratio test of sigma_u=0				0.000					0.000	

Note: Standard errors in brackets. * and ** indicate the statistical significance at 5 percent and 1 percent, respectively. As for the Tobit with random effects estimation, there were 3,144 left-censored observations. The marginal effects for the probability of being uncensored are also presented at the right of the column (4) and (8).

Table 5. Inter-Industries Spillovers to TFP of Domestic Firms

Dependent Variable: TFP of domestic firms	(1) OLS	(2) Fixed	(3) Random	(4) GMM	(5) OLS	(6) Fixed	(7) Random	(8) GMM
Own R&D	0.044 [0.005]**	0.018 [0.005]**	0.04 [0.004]**	0.093 [0.025]**	0.044 [0.005]**	0.018 [0.005]**	0.041 [0.004]**	0.099 [0.025]**
R&D Forward	0.102 [0.008]**	0.02 [0.009]*	0.046 [0.007]**	0.085 [0.019]**	0.016 [0.010]	0.017 [0.009]	0.024 [0.009]**	0.003 [0.017]
R&D Backward	-0.107 [0.007]**	-0.012 [0.009]	-0.043 [0.007]**	-0.105 [0.016]**	0.013 [0.009]	-0.008 [0.010]	-0.011 [0.009]	0.016 [0.015]
R&D Horizontal	0.005 [0.002]*	-0.004 [0.003]	0.001 [0.003]	-0.001 [0.007]	0.002 [0.003]	-0.003 [0.003]	0.001 [0.003]	-0.002 [0.006]
Capital Forward					0.088 [0.011]**	0.01 [0.010]	0.042 [0.009]**	0.08 [0.019]**
Capital Backward					-0.131 [0.008]**	-0.011 [0.010]	-0.056 [0.008]**	-0.13 [0.016]**
Capital Horizontal					0.001 [0.002]	-0.003 [0.002]	-0.001 [0.002]	-0.001 [0.004]
Technology purchase from abroad	0.028 [0.003]**	0.001 [0.005]	0.02 [0.004]**	0.032 [0.019]	0.025 [0.003]**	0.001 [0.005]	0.02 [0.004]**	0.027 [0.018]
Technology purchase from domestic	0.014 [0.003]**	-0.01 [0.004]*	0.002 [0.004]	-0.009 [0.017]	0.016 [0.003]**	-0.01 [0.004]*	0.002 [0.004]	-0.006 [0.015]
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	2.728 [0.051]**	3.267 [0.080]**	2.844 [0.055]**	2.47 [0.154]**	2.931 [0.078]**	3.281 [0.108]**	2.916 [0.074]**	2.694 [0.166]**
N of observations	5661	5661	5661	5661	5661	5661	5661	5661
N of groups		1025	1025	1025		1025	1025	1025
R-squared	0.33	0.39			0.37	0.39		
F test that all $u_{il} = 0$ (pooling vs fixed effects)		F= 13.89 Pr>F=0.000				F=12.68 Pr>F=0.000		
Breusch-Pagan Lagrangian multiplier test (pooling vs random effects)		chi-sq= 4944.09 Pr>chi-sq=0.0000				chi-sq=4383.25 Pr>chi-sq=0.000		
Hausman test (random effects vs fixed effects)		chi-sq=128.49 Pr>chi-sq=0.000				chi-sq=149.88 Pr>chi-sq=0.000		
P-value of Hansen test for overid. Restrictions				0.635				0.56
Arellano-Bond test for AR(2)				0.42				0.315

Note: Standard errors in brackets. * and ** indicate the statistical significance at 5 percent and 1 percent, respectively.

Table 6. Inter-Industries Spillovers to the Invention Patent Application of Domestic Firms

Dependent variable: Invention patent applications of domestic firms	(1) OLS	(2) Fixed	(3) Random	(4) Tobit with random effects		(5) OLS	(6) Fixed	(7) Random	(8) Tobit with random effects	
Own R&D	0.058	0.013	0.047	0.282	0.093	0.057	0.013	0.046	0.28	0.093
	[0.003]**	[0.008]	[0.006]**	[0.018]**		[0.003]**	[0.008]	[0.006]**	[0.019]**	
R&D Forward	0.003	0.031	0.026	0.029	0.009	0.003	0.026	0.019	0.014	0.005
	[0.007]	[0.013]*	[0.010]**	[0.020]		[0.010]	[0.014]	[0.012]	[0.025]	
R&D Backward	-0.006	0.008	-0.003	-0.012	-0.004	-0.025	0.015	0.000	-0.016	-0.005
	[0.006]	[0.014]	[0.009]	[0.017]		[0.009]**	[0.015]	[0.012]	[0.025]	
R&D Horizontal	0.055	0.007	0.031	0.032	0.011	0.057	0.006	0.029	0.027	0.009
	[0.003]**	[0.004]	[0.004]**	[0.007]**		[0.004]**	[0.005]	[0.004]**	[0.008]**	
Capital Forward						0.01	0.013	0.011	0.03	0.010
						[0.010]	[0.015]	[0.012]	[0.027]	
Capital Backward						0.021	-0.021	-0.005	0.002	0.001
						[0.007]**	[0.016]	[0.011]	[0.024]	
Capital Horizontal						-0.004	0.001	0.003	0.006	0.002
						[0.003]	[0.003]	[0.003]	[0.006]	
Technology purchase from abroad	0.027	0.011	0.033	0.082	0.027	0.028	0.011	0.033	0.08	0.027
	[0.003]**	[0.007]	[0.005]**	[0.011]**		[0.003]**	[0.007]	[0.005]**	[0.011]**	
Technology purchase from domestic	0.065	0.015	0.047	0.058	0.019	0.064	0.015	0.047	0.058	0.019
	[0.003]**	[0.006]*	[0.005]**	[0.010]**		[0.003]**	[0.006]*	[0.005]**	[0.010]**	
Year dummies	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	
Constant	-0.618	-0.044	-0.608	-4.666		-0.781	0.02	-0.645	-4.853	
	[0.040]**	[0.124]	[0.064]**	[0.195]**		[0.064]**	[0.164]	[0.089]**	[0.250]**	
N of observations	5690	5690	5690	5690		5690	5690	5690	5690	
N of groups		1031	1031	1031			1031	1031	1031	
R-squared	0.41	0.15				0.42	0.15			
F test that all $u_{il} = 0$ (pooling vs fixed effects)		F = 7.84 Pr>F = 0.000					F = 7.81 Pr>F = 0.000			
Breusch-Pagan Lagrangian multiplier test (pooling vs random effects)		chi-sq = 4106.58 Pr>chi-sq = 0.000					chi-sq = 4055.32 Pr>chi-sq = 0.000			
Hausman test (random effects vs fixed effects)		chi-sq = 170.61 Pr>chi-sq = 0.000					chi-sq = 180.33 Pr>chi-sq = 0.000			
P-value of Likelihood-ratio test of sigma_u=0				0.000					0.000	

Note: Standard errors in brackets. * and ** indicate the statistical significance at 5 percent and 1 percent, respectively. As for the Tobit with random effects estimation, there were 3,142 left-censored observations. The marginal effects for the probability of being uncensored are also presented at the right of the column (4) and (8).