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In-house R&D and External Knowledge Acquisition – What Makes Chinese Firms Productive?

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Abstract: This paper analyses the influence of in-house R&D and external knowledge acquisition on the total factor productivity (TFP) of listed Chinese firms for the time period 2001-2010. We find a quantitatively important positive effect of in-house R&D. The achieved level of technological sophistication of Chinese firms is sufficient to benefit from R&D collaboration with domestic partners. We do not find a significant effect for employing inventors with access to international knowledge or for collaborating with international partners. International knowledge acquisition is only effective if conducted via joint ventures, i.e. if it is supported by a deep organizational relationship.

JEL Classification: O32, O33

Keywords: in-house R&D, knowledge acquisition, productivity, patents, China

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1 Introduction

After initiating economic reforms in 1978, China's real per capita GDP has grown at an average rate above 8% per year until today. This impressive economic performance has transformed China into a middle income country. In the past growth has relied on rising total factor productivity (TFP) and on an increase in the input factors labor and capital (Zhu, 2012). Because China is approaching its limits of factor accumulation, TFP growth will be even more important to sustain economic development in the future. A potential source of TFP growth lies in the reduction of input factor misallocation (Brandt, van Biesebroeck, & Zhang, 2012; Hsieh & Klenow, 2009). However, efficient allocation requires far reaching reforms which are difficult to realize in China's economic and political context.

A further source of TFP growth, which has rarely been investigated for China's economy, is shifting the productivity frontier outwards by investment in R&D. Throughout the decade after China's WTO accession, from 2001 to 2010, investment in R&D has increased from 0.95% to 1.83% of GDP (World Bank, 2012). The resulting number of invention patent applications has risen from around 63,000 to over 526,000. In 2011, almost 80% of these applications have been filed by domestic applicants (SIPO, 2012). However, so far it remains unclear whether this investment will translate into higher TFP. Critics claim that the enormously rising number of patent applications will have only a small impact on TFP growth unless the quality and commercial relevance of the underlying research is substantially improved (World Bank, 2012).

For Western firms there is general evidence for a positive influence of in-house R&D on firm-level TFP (Griliches & Mairesse, 1999). There is also evidence for a positive effect on TFP through the active use of external knowledge acquisition via technology purchasing (Cassiman & Veugelers, 2006), employing researchers in different countries (Griffith, Harrison, & Van Reenen, 2006), R&D collaboration (Belderbos, Carree, & Lokshin, 2004),

and research joint ventures (Benfratello & Sembenelli, 2002). The exposure to knowledge spillovers generated by companies in foreign ownership (i.e. through Foreign Direct Investment, FDI) has also a positive influence on TFP (Haskel, Pereira, & Slaughter, 2007). However, there is a lack of evidence of whether the mechanisms successfully used by Western firms also work for firms in an emerging country context. For Chinese firms there is mixed evidence on the influence of FDI (Fu & Gong, 2011) and positive evidence that purchasing of technology is increasing productivity (Hou & Mohnen, 2011). However, the effectiveness of different types of own R&D activity have not been analyzed so far. We contribute to the literature by analyzing in the emerging country context of China the influence of in-house R&D and a comprehensive set of knowledge acquisition mechanisms on TFP. We investigate the mechanisms of employing inventors with access to international knowledge, engaging in R&D collaborations and conducting joint ventures. Furthermore, we differentiate between knowledge acquisition from domestic and international sources because a higher level of absorptive capacity is necessary to benefit from the latter.

For our empirical analysis we assembled a unique dataset which includes information on 1,903 Chinese firms listed at the stock exchanges of mainland China over the time period 2001 through 2010. We combine accounting data with patent data which allows us to derive rich information about in-house R&D, the human capital of inventors, and domestic as well as international R&D collaborations. We further include information on domestic and international joint ventures and complement the dataset with detailed information on the operational environment of the firms. To analyze the TFP of Chinese firms, we employ the approach developed by Olley and Pakes (1996) with firms' value added as our output measure.

Our analysis establishes that TFP is positively influenced by in-house R&D based on domestic knowledge. TFP is calculated after the input factors labor and capital as well as the operational environment are controlled for in a production function. Of the thus calculated

TFP levels we find that in-house R&D accounts for 13.8%. This evaluation identifies R&D which results in patenting activities as a highly relevant source of TFP growth for the Chinese economy. For domestic knowledge acquisition we identify a positive influence of R&D collaborations but no effect of domestic joint ventures. The latter may not contribute to TFP because they are not necessarily conducted with the main aim of knowledge acquisition driven by business motives but can also be induced by government-led restructuring of less competitive industries.

With respect to international knowledge acquisition Chinese firms still face limitations. We find that Chinese firms are not yet able to profit from working with international inventors or from R&D collaborations with international partners. Only the longer-term, deep organizational relationship with an international partner via a joint venture ensures that learning from international knowledge can take place. Overall, Chinese firms profit from knowledge acquisition. The combined influence of in-house R&D and knowledge acquisition on TFP increases to 15.9%.

We conduct further investigations to understand how the effects of in-house R&D and knowledge acquisition change over time and find an increase in the ability of Chinese firms to benefit from international knowledge. Whereas international joint ventures do not show a significant influence on TFP during the first half of the time period covered in our sample, we can identify a positive effect in the second half. Furthermore, the R&D investments of firms owned by the central or a local government may be less efficient because we cannot identify a positive influence of in-house R&D on TFP for these ownership types. The positive effect of in-house R&D is restricted to private firms.

The remainder of this paper is structured as follows. Section 2 provides prior evidence on knowledge acquisition by Chinese firms, Section 3 derives our hypotheses, Section 4 explains our empirical method, Section 5 describes the data sources and the sample, Section 6 presents the results, and Section 7 concludes.

2 Prior Evidence on Knowledge Acquisition by Chinese Firms

Throughout the period of China's planned and early transition economy, R&D was mainly performed by research institutes while firms functioned as manufacturing units (Liu, 2009). Top-down allocation of inputs and centrally specified production quotas prevented both firm-internal R&D activities and incentives for knowledge transfer between firms and research institutes, and thus resulted in an generally insufficient industrial applicability of domestic R&D (Liu & White, 2001). Consequently, the Chinese economy was dependent on the acquisition of foreign technologies, but, without conducting in-house R&D, Chinese firms were unable to develop those further.

In line with deepening economic reforms, the Chinese government sought to facilitate access to foreign knowledge and to reposition Chinese firms into the center of an increasingly market-oriented innovation system (OECD, 2007). By encouraging FDI in the 1990s and 2000s, the manufacturing and R&D operations established by foreign firms in China were intended to provide technology transfer and spillovers (World Bank, 2012). Further, hundreds of research institutes were transformed into more commercially-oriented entities or directly restructured into firms (Jakobson, 2007) while universities started to conduct more applied R&D and founded numerous firms as spin-offs (Hu & Mathews, 2008). Earlier reforms followed the maybe naïve concept to grant market access to foreign firms in exchange for foreign knowledge, with little concern about possible absorption of knowledge by Chinese firms. In contrast, more recent innovation policies take a much more nuanced approach and seek to stimulate in-house R&D and domestic and international knowledge acquisition mechanisms of Chinese firms (Liu, Simon, Sun, & Cao, 2011).

Because access to international knowledge has been historically more important for the Chinese economy than diffusion of domestic knowledge, most studies have investigated the international dimension. However, the prior evidence on the capabilities of Chinese firms to

benefit from externally available knowledge is ambiguous. Whereas Abraham, Konings, and Slootmaekers (2010) find positive spillover effects from the presence of international firms – and especially from the presence of international joint ventures, Fu and Gong (2011) find mixed evidence for spillovers through foreign R&D. Several studies investigate the possibility to learn from the purchase of foreign technology. A complementarity of in-house R&D and purchasing of technology has been found for patenting (Li, 2011), product innovations (Hou & Mohnen, 2011), and TFP (Hu, Jefferson, & Jinchang, 2005).

3 Development of Hypotheses

The majority of Chinese firms increased the intensity of their R&D endeavors only recently. Specifically in emerging countries, R&D investments may not immediately generate profits due to high fixed costs implying that the contributions of R&D to TFP only become observable after some time. Consequently, despite rising R&D investments and patent applications the contributions to TFP in China remain uncertain. The World Bank (2012, p. 164) notes that "Increased publishing of scientific papers and patenting is likely to have only a small impact on productivity growth […] unless the quality of this research and its commercial relevance and uptake is substantially increased.". Although previous firm-level studies find a positive influence of R&D on TFP (Hu & Jefferson, 2004; Fu & Gong, 2011; Hu, Jefferson, & Jinchang, 2005), the quantitative importance of the influence of R&D on TFP remains unclear. Given the evidence from the available studies we hypothesize:

Hypothesis 1: In-house R&D has a positive effect on the TFP of Chinese firms.

Depending on its level of absorptive capacity, a firm may apply different acquisition mechanisms for complementing internal knowledge with more advanced external knowledge (Cohen & Levinthal, 1990; Laursen & Salter, 2006). Because Chinese firms find it less challenging to benefit from domestic than international sources of knowledge (Li, 2011), we

differentiate between domestic and international mechanisms of knowledge acquisition. We need to note that empirically we can only observe a net effect which depends on the balance of returns and costs associated with the use of a particular mechanism. This means that even if we cannot identify a positive influence on TFP, it is possible that the firm incorporated new knowledge in the production process.

Firstly, a firm could initiate R&D collaboration with domestic actors in which the knowledge transfer between the parties involved is increased. With respect to TFP, several studies have confirmed the positive impact of knowledge spillovers arising from interaction among Western firms (see, for example, Adams & Jaffe, 1996; Belderbos, Carree, & Lokshin, 2004). Especially in the case that firms see cost as a critical obstacle to start or increase R&D, R&D collaboration might provide a strategy for cost sharing (Cassiman & Veugelers, 2002). Secondly, a firm could seek to acquire knowledge by joining forces with other firms in the form of a joint venture. Firms involved could benefit through the diffusion of know-how, increasing R&D activities, and the integration of new technologies (Gugler & Siebert, 2007).

Prior studies have shown that the absorptive capacity of Chinese firms is low (Li, 2011) and that firms fall short in utilizing domestic knowledge available at universities and research institutes (Huang & Wu, 2012). Also, firms in emerging countries often still need to establish mechanisms of knowledge acquisition and therefore have to initially bear the higher costs of this process (Lee, forthcoming). However, since the available studies are based on earlier time periods and the Chinese economy develops at a high pace, we expect to find positive net effects for domestic knowledge acquisition as they are typically found for Western firms.

Hypothesis 2: Domestic knowledge acquisition has a positive effect on the TFP of Chinese firms.

International knowledge acquisition provides access to different forms of knowledge since knowledge is typically localized (Audretsch & Feldman, 1996). Generally, the higher

complexity of foreign knowledge makes it more difficult for Chinese firms to utilize international acquisition mechanisms (Fu & Gong, 2011). Further, the acquisition of foreign knowledge may be accompanied by barriers imposed by language, culture, and labor immobility (Li, 2011) and often requires additional investments by the firm to overcome those. Therefore, successful international knowledge acquisition not only requires a higher absorptive capacity than necessary for domestic acquisitions, but also implies higher costs.

Chinese firms can broaden their knowledge base by hiring non-Chinese inventors or by employing inventors abroad. For Western firms it has been shown that they can tap into the knowledge stock of other countries by placing inventors there (Griffith, Harrison, & Van Reenen, 2006; Harhoff, Mueller, & Van Reenen, 2012). Firms can also increase their knowledge base by hiring inventors from firms of other countries, a mechanism which has been shown to work for US-based firms (Rosenkopf & Almeida, 2003). The constraints discussed above may be especially relevant if the Chinese firm opts to hire inventors with access to international knowledge in order to improve its human capital base.

There are also implications for international R&D collaboration with overseas actors. While domestic R&D collaborations might support cost sharing, additional overseas R&D investments and transaction costs involved with international R&D collaboration are likely to increase costs substantially. Further, foreign firms might be cautious when dealing with Chinese partners and have incentives to maximize incoming spillovers while at the same time minimizing outgoing spillovers through investments in knowledge protection (Cassiman & Veugelers, 2002). It has been shown that foreign firms are reluctant to share the most advanced technology with Chinese partners if they do not have control via an ownership stake (Long, Zhang, Feng, & Pan, 2003).

Regarding knowledge acquisition mechanisms based on organizational integration, international joint ventures have widely been used as a platform of obligatory knowledge transfer from the international to the Chinese joint venture partner. In the 1980s Chinese firms

were not able to close the gap to the technological frontier by working together with foreign partners (Naughton, 2007, p. 357). International joint ventures provide a number of benefits for Chinese firms compared to other international acquisition mechanisms. The investment made by both parties provides a mutual commitment to the commercial success of the joint venture. Conventionally, the foreign partner contributes the technology while the Chinese partner adds market knowledge and local expertise. Based on this framework, during the life cycle of a joint venture the Chinese partner has the opportunity to learn about foreign technology and might further benefit from diffusion of knowledge occurring by the fluctuation of employees between the joint venture partners and training provided. Therefore, Chinese firms are more likely to benefit from international joint ventures compared to the other international acquisition mechanisms. With respect to international knowledge acquisition it is less clear whether there is a net benefit due to the aforementioned higher costs. Nevertheless, we expect that the benefits outweigh the costs:

Hypothesis 3: International knowledge acquisition has a positive effect on the TFP of Chinese firms.

4 Method

To analyze how in-house R&D and knowledge acquisition from domestic and international sources influence TFP of Chinese firms, we employ the approach developed by Olley and Pakes (1996). We estimate a standard Cobb-Douglas production function with value added as output variable and labor and capital as main input variables. In the standard form the Olley-Pakes approach uses a three-stage algorithm with one stage used to model the exit of firms. We find exit of firms – measured as exit from the stock market – to be very rare in our data as only 18 firms do exit. We therefore adjust the Olley-Pakes algorithm to only include the control for simultaneity but not the control for selection.

For our main specification we estimate the following equation:

$$ln(value\ added)_{it} = \beta_0 + \beta_1\, ln(labor)_{it} + \beta_2\, ln(capital)_{it} + \sum_{j=1}^{J} \beta_j\, in\text{–}house\ R\,\&\,D\ and\ external\ knowledge\ acquisition_{it-1} + \sum_{k=1}^{K} \beta_k\, operational\ environment_{it-1} + \sum_{l=1}^{L} \beta_l\, control\ variables_{it} + \varepsilon_{it} \quad (1)$$

The coefficients of in-house R&D and external knowledge acquisition are of main interest for the paper. In our specification we also control for the firms' operational environment with a focus on the influence of several innovation policies. As general control variables we include ownership type and regional GDP levels. Thus, we include a broad set of factors which might influence the firms' productivity and R&D strategies at the same time.

For the quantification of our results we are interested to know how a given change in the R&D activities influences TFP. We evaluate this change in the original production function as the error term of the log-linearized form used for estimation corresponds to the logarithm of TFP. We use the following formula to calculate the percentage increase in TFP for an increase of one standard deviation in the activity of interest:

$$\frac{\Delta\ TFP}{mean\ TFP} = \frac{(\text{mean}\, x_j + \text{std}\, x_j)^{\beta_j} - (\text{mean}\, x_j)^{\beta_j}}{mean\ TFP} \quad (2)$$

The calculation of the size of the effects for dummy variables is more straight forward and is achieved by just exponentiating the coefficient. All standard errors are clustered at the firm-level and are calculated by bootstrapping with 50 replications.

We are not able to use other control function approaches such as the one by Levinsohn and Petrin (2003) which require explicit information on material costs. One potential

disadvantage of Olley and Pakes (1996) compared to Levinsohn and Petrin (2003) is the need to restrict the sample to observations with positive values for investment. The resulting loss of efficiency is of limited importance in our dataset as only 0.4% of observations have zero investment. We would have liked to include the R&D stock of the firm as additional determinant of output, but comprehensive data on R&D expenditures is not available for listed Chinese firms.

The Olley-Pakes procedure only controls for the potential endogeneity of the input factors labor and capital but our measurements of in-house R&D and external knowledge acquisition are also potentially endogenous inputs. For example, the employment of inventors with access to foreign knowledge is a costly exercise that only firms with sufficient financial capacity can master. Since high TFP is positively related to profitability, there may be an effect of reverse causality. Furthermore, foreign firms may select the most productive Chinese firms as their local partners for R&D collaboration or joint ventures. As we are not able to control for the potential endogeneity of the R&D activities, our results should accordingly be interpreted as correlations. We try to reduce the influence of endogeneity by lagging all variables related to in-house R&D, knowledge acquisition, and the operational environment of the firm by one period but acknowledge that this is not a full solution. The lag furthermore allows for the fact that it takes time before research influences productivity.

5 Data

5.1 Data Sources and Sample

Our dataset includes 1,903 Chinese firms listed in the A-share segment of the two stock exchanges in mainland China, Shanghai and Shenzhen. We obtained accounting data from Compustat via Wharton Research Data Services (WRDS) for the time period 2001-2010 and complemented the data with employment information from Datastream, patent information

from PATSTAT and joint venture information from Zephyr. This sample includes many of China's largest firms and firms with political or economic importance (Du & Xu, 2009). Only "national" firms can be listed on the stock exchanges of Shanghai and Shenzhen. According to the definition of the China Securities Regulatory Commission (2006; 2002) a firm is considered "national" if the percentage of total shares held by foreign parties does not exceed 20%. Thus, our study describes the learning experience of "true" Chinese firms. We start our analysis in the early 2000s because R&D and patenting activities by Chinese firms were not widespread before.

Initially, our data includes 2,105 firms for which we have 13,649 observations with non-missing accounting information. We exclude 53 observations which have zero investment and disregard 133 firms from the financial and the retail sector because patents are of limited importance in these sectors. In order to eliminate outliers, we delete firm-year observations that exhibit values above the 99th or below the 1st percentile of the value added-to-employees-ratio, the value added-to-capital-ratio, and the employees-to-capital ratio. Our full estimation sample, including patenting as well as non-patenting firms, is based on information for 1,903 firms for which we have 11,740 observations. The sample for our main results is restricted to patenting firms and includes information on 1,143 firms for which we have 4,814 observations.

Patent data is obtained from the October 2011 version of the EPO Worldwide Patent Statistical Database PATSTAT. As the patent information is used with a time lag of one year it covers the time period 2000-2009. The matching of accounting information to patent portfolios is based on the company name. The matching is performed in a semi-manual approach to take care of the following complications: Firstly, spelling errors or systematical abbreviations might occur in the names of the patent owners. Secondly, the patent law allows Chinese patent applicants to use their Chinese name in Chinese characters, their Chinese name in Pinyin format, their English company name, or any combination thereof. PATSTAT

converts the name into Pinyin format if the firm has originally filed in Chinese characters. We therefore had to construct several name patterns for the matching process in order to obtain complete patent portfolios.[1]

In the following we want to give an indication for the amount of inventive activity covered in our sample. According to PATSTAT, the Chinese patent office SIPO received approximately 855,000 invention patent filings with earliest priority at the SIPO in the time period 2000-2009. Of those, about 406,000 filings originated from firms (domestic and international) as opposed to universities, research institutes or individuals. Here the international firm filings pertain to subsidiaries of international firms which developed inventions inside China. In our sample we cover approximately 46,000 patents. Given the broad definition of firm filings, we can conclude that the publicly listed firms in our sample cover with 11.4% a quite substantial share of those filings.

5.2 Definition of Main Variables

This sub-section presents a definition of the main variables. Detailed definitions for all variables and references to data sources can be found in the data appendix, Table A1. As output measure of our production function we use an approximation of the value added of the firm. Value added is calculated as revenue minus the difference of costs of goods sold and the product of average wage costs and number of employees. The difference between costs of goods sold and total wage costs mainly represents material costs.

Concerning the patent variables, two important methodological aspects need to be noted. Firstly, we base our measures on patent families instead of patent applications since the

[1] For example, the firm “China International Marine Containers” files patents under its full English name but also under the abbreviations “CIMC” or “China Int Marine Containers” and under the Pinyin formats “Zhongguo Guoji Haiyun Jizhuangxiang” and “Zhong Ji Jituan”.

number of families more closely corresponds to the number of inventions. When compiling patent families, we rely on the INPADOC family definition available in PATSTAT. Secondly, we apply the usual 15% annual depreciation rate (Hall, Jaffe, & Trajtenberg, 2005) to account for the fact that technology becomes obsolete over time. Precisely, the patent stock in year *t* is the patent filings of that year plus the patent stock in year *t*-1 depreciated by 15%.

In order to analyze knowledge acquisition mechanisms in detail we break up the patent stock into several components. In-house R&D is measured as the stock of patent families with inventors exposed to domestic knowledge only and excluding patent families with coapplicants. For the identification of the international background of inventors we rely on information about their family name and their country of residence given in the patent application. We use the inventor's family name and match it against a comprehensive list of Chinese family names which informs us whether or not the inventor is of ethnic Chinese origin. An analysis of the country of residence allows us to determine whether the inventor resides in China or abroad. If a patent family includes at least one inventor of non-Chinese origin or with residence outside China, we count it towards our measure of international human capital. We identify R&D collaborations by the stock of patent families with either a domestic or an international co-applicant and observe the number of joint ventures with domestic or international partners via a match with the database Zephyr. For the regression analysis we use the logarithm of the knowledge acquisition variables whose count has been increased by one to avoid missing values.

5.3 Descriptive Statistics

Table 1 presents the descriptive statistics of our sample. Our main sample of patenting firms consists of 4,814 observations for 1,143 firms. On average, these firms achieve a value added of 1,226 million RMB. The mean of employees is 5,243 and the mean of capital is 2,538 million RMB. We estimate a mean TFP of 1.81. Concerning the patent stock, we find that

firms hold on average a depreciated stock of 22.97 patent families with a broad spread from 0.07 to 14,201. As is typical for firm-level data, we find a very skew distribution with less than 50% of the firms having filed more than three patent families.

Almost all firms conduct in-house R&D. We identify 232 firms involved in domestic R&D collaborations and 153 firms with domestic joint ventures. With 20.3% of our firms using domestic R&D collaborations, this is the most frequently used domestic mechanism. On average 2.2 patent families indicate the use of a domestic R&D collaboration. 122 firms filed patents with international human capital involved, 49 firms are engaged in international R&D collaborations, and knowledge acquisition by international joint ventures is used by 76 firms. Thus, for international mechanisms, employing international human capital is most frequently used, namely by 10.7% of firms. On average 1.0 patent families show the use of this mechanism.

As the Chinese economy develops at a high pace, it is of interest to investigate the use of knowledge acquisition mechanisms across time. Figure 1 depicts the number of firms which have used the corresponding mechanism at least once up to the respective year. The most intensely used mechanism throughout the sample period is domestic R&D collaboration. In 2009, more than 200 firms in our sample have collaborated domestically, whereas there were just 17 firms doing so in 2000. A similar rise but at a lower level can be observed for domestic joint ventures. The use of international mechanisms is also increasing over time but the level of use is typically below the domestic mechanisms. It should be pointed out that the *share* of firms using a mechanism is not increasing over time. The number of firms listed on stock markets is increasing during our sample period and firms seem less sophisticated in the first years of their listing.

6 Empirical Analysis

6.1 Main Results

Throughout the models (1) to (8) in Table 2 the net effect of R&D activities on the TFP of Chinese firms is analyzed. Model (1) investigates the effect of accumulated R&D as measured by the patent stock on the TFP of patenting and non-patenting firms. The model accommodates labor, capital and the patent stock as main regressors. The coefficients on labor and capital indicate decreasing returns to scale. We find a positive and significant influence of the patent stock on the TFP of Chinese firms. Firms without patent applications appear to be significantly more productive than firms with patents which could be due to high fixed costs of initiating R&D. However, this effect is small because even firms with only one patent family show a higher productivity than firms without any patents. In model (2) we restrict the analysis to patenting firms and find a comparable influence of the patent stock on TFP. Throughout the remaining models we investigate the effect of R&D activities in more detail and exclude non-patenting firms for this purpose.

In the following model (3), we analyze the effects of in-house R&D and mechanisms of knowledge acquisition on TFP. We split the overall patent stock of the firm into in-house R&D, R&D collaborations and use of inventors with access to international knowledge. In addition, we include joint ventures as a mechanism for knowledge acquisition. Firstly, domestic in-house R&D has a positive and significant effect. Increasing the amount of in-house R&D by one standard deviation starting from the mean corresponds to a gain of 16.6% in TFP. Hence, *Hypothesis 1* is confirmed by our results.

Secondly, we investigate whether domestic knowledge acquisition contributes to TFP. Domestic R&D collaborations have a positive and significant effect on TFP. The quantification reveals that increasing our variable of domestic R&D collaborations by one standard deviation increases TFP by 41%. This effect is relatively large and supports the

positive implications of knowledge sharing and cost reduction arising from domestic R&D collaboration. If we further divide the domestic collaborations into collaborations with firms, universities, research institutes, and individual inventors, we find that only collaborations with firms exhibit a significant effect (results not reported). Therefore firms seem to be the most important knowledge source for other firms. Yet, concerning the effect of organizational integration of knowledge by joint ventures, we do not find a significant effect.[2] Domestic joint ventures may not contribute to TFP because they are not necessarily conducted with the main aim of knowledge acquisition but can also be induced by government-led restructuring of less competitive industries. Overall, the Chinese government still has considerable influence over Chinese firms (Naughton, 2007, p. 324). Thus, concerning the effect of domestic knowledge acquisition mechanisms, we actually can confirm *Hypothesis 2* but only for the mode of Chinese firms collaborating with domestic firms.

Thirdly, we turn to the effect of international knowledge acquisition. The employment of inventors with access to foreign knowledge does not significantly improve TFP. Although the firm's knowledge base potentially is enriched with foreign tacit knowledge there is no measurable net benefit from the use of this mechanism. The literature discussed in Section 2 suggests low absorptive capacity of Chinese firms, additional R&D related investments, and high transaction costs as possible reasons for the insignificance of the international human capital variable. If we include the constituent parts of the international human capital variable separately – namely foreign inventors living abroad, foreign inventors living in China, and Chinese inventors living abroad – we find them to be individually insignificant as well. Here it should be acknowledged that we cannot identify Chinese inventors with an overseas education who returned to work in China. This group has also exposure to international

[2] We also tested the acquisition of domestic and international firms as potential mechanism for knowledge acquisition but found both variables to be insignificant.

knowledge and could contribute to rising productivity levels in China. The effect of international R&D collaborations is also not significant. Foreign firms have incentives to maximize incoming spillovers while minimizing outgoing spillovers through knowledge protection.[3] Turning to international joint ventures we find a positive and significant effect on TFP. Raising our variable of international joint ventures by one standard deviation corresponds to an increase of 17.1% of TFP. It is the first time throughout our investigation that an international acquisition mechanism yields a positive and significant net effect. As discussed in Section 3, international joint ventures provide a number of benefits compared to other international mechanism of knowledge acquisition. It seems that the long-lasting and deep relationship with an international partner facilitates the successful acquisition of foreign knowledge. To conclude, we can only partly confirm *Hypothesis 3*, namely for international joint ventures.

Next we briefly discuss the influence of the operational environment of the firm, which is mainly characterized by innovation policy measures. The effect of a firm's location in a policy zone is positive and significant and corresponds to a 13.1% increase of TFP. For firms belonging to the high-tech oriented strategic emerging industries, the Chinese government provides several incentives (subsidies, tax reductions, and other preferential treatments). However, we do not find a significant effect that firms operating in these industries have a higher TFP. Although there is an indication that the patent subsidies offered by provincial governments increased the number of patent applications (Li, 2012), we do not find evidence that the subsidies would increase TFP beyond the effect we measure through the R&D activities.

[3] One could expect that Chinese firms are better in absorbing knowledge from partners in other emerging countries. Since 94% of international co-applications are with partners in developed countries, we do not have enough observations to test this conjecture.

Geographic proximity to a top university reveals a positive and significant effect on TFP. Precisely, being close to these universities increases TFP by 14.4%. Interestingly, no significant effect can be identified for top research institutes. The success of universities as knowledge sources may be due to their graduates which find employment in our firms and constitute a direct knowledge transfer. Chinese FDI guidelines define in which industries FDI is encouraged, restricted, or prohibited. Consequently, the level of foreign competition but also the availability of horizontal spillovers varies. If a firm is doing business in an industry in which FDI is encouraged, we find TFP lower by 17.7% compared to firms in industries in which FDI is not explicitly regulated. The categories of restricted and prohibited FDI do not show a significant influence.

As general control variables we include dummies for ownership type but we do not observe productivity differences between privately owned and state owned firms. In order to control for agglomeration effects, we include GDP per capita on the regional level. This variable also controls for the educational level of the labor force and thus for the quality of the labor input. We find a positive coefficient but not a significant influence on TFP.[4]

What is the overall contribution of in-house R&D and knowledge acquisition to the level of TFP of Chinese firms? We start with the average TFP level of 1.81 from our main model (3) and add back in the explanatory power of knowledge acquisition by multiplying the

[4] As a methodological robustness check we calculate a System-GMM model for our main specification model (3). We include the lagged values of value added, labor and capital in the production function. We assume that labor and capital is predetermined and instrument accordingly. Instruments starting in t-3 are used. There is no autocorrelation of third order and the Hansen test of overidentifying restrictions as well as the difference in Hansen test is passed. Our results are qualitatively confirmed. We find positive and significant influences of in-house R&D and domestic R&D collaborations and a positive but insignificant effect of international joint ventures.

coefficients of the knowledge acquisition mechanisms by the mean of their variables. We thus arrive at a TFP level of 1.85. If we add back in the contribution of in-house R&D, we obtain a level of 2.15. Taking this latter value of TFP as a reference level of 100%, we can conclude that in-house R&D alone contributes 13.8% to TFP and that together with knowledge acquisition mechanisms the contribution increases to 15.9%. Thus we find a quantitatively important contribution of the different R&D activities to the level of TFP.

6.2 Further Investigation

We conduct further investigations to understand how the effects of in-house R&D and knowledge acquisition on TFP change over time and by ownership type. Firstly, we split the sample at the median of observations into an early period (2001-2007) and a later period (2008-2010). Most results of models (4) and (5) are consistent with the results obtained in our main model (3). Nevertheless, we observe important changes over time regarding the influence of international joint ventures as their influence is insignificant in the earlier period but turns positive and significant in the later period. This finding suggests that Chinese firms were able to increase their net benefit from international knowledge acquisition by joint ventures over time.

Concerning the operational environment, we find that the positive influence of being geographically close to a top university is measured more precisely over time. The second important change over time can be observed in FDI. In the early period the coefficient for encouraging FDI is negatively significant. Thus, Chinese firms operating in industries where FDI is encouraged suffer from foreign competition. This effect cannot be found any more in the later period. Further, industries with restricted entry of foreign firms provide supportive conditions for Chinese firms in the later period: by limiting the level of foreign competition the net benefits from horizontal spillovers become observable. Thus, over time Chinese firms

became either more competitive, increased their absorptive capacity to benefit from horizontal spillovers, or both.

Secondly, we split the sample according to China's specific ownership types. Throughout the models (6) to (8) we separately investigate centrally state owned firms, locally state owned firms, and privately owned firms. A first striking finding is that in-house R&D only has a positive and significant effect on the TFP of private firms. While all three ownership types pursue in-house R&D, it does not enhance TFP of state owned firms. This may be related to the fact that China's state-owned firms are often obliged to fulfill the guidelines and statistical planning targets of innovation policy (Dong & Gou, 2010). They are thus pressured by the state to invest in R&D but this R&D fails to be transformed into output. For example, it has been shown that state owned firms have a lower ratio of patents in force to R&D expenses than privately owned firms (World Bank, 2012).

Another difference is revealed with regard to R&D collaboration. While domestic R&D collaboration has a positive and significant effect on the TFP of locally state owned firms and of private firms, the effect is not significant for centrally state owned firms. Often, the latter are monopolistic conglomerates with lesser incentives to cooperate with actors outside the group. Locally state owned firms have less internal resources compared to centrally state owned conglomerates but operate in more competitive industries, which increases their incentives for R&D collaboration. Further, collaboration with other locally state owned firms from the same province may result in especially high net benefits of collaboration due to mutual ownership by the same provincial government which can decrease transaction costs. Private firms in China are, in general, exposed to higher levels of competition compared to state owned firms which might provide incentives for cost sharing by domestic R&D collaboration.

The positively significant effect of international joint ventures on TFP, as observed in model (3) is only confirmed for centrally state owned firms. Many international activities are

realized with the initial guidance and support of the central government, which in turn favors centrally state owned firms. For example, private firms argued that state owned firms get preferential treatment and subsidies for outward investment into Europe (European Chamber, 2013). The combination of regulatory authority and ownership control within the central government may provide incentives to bureaucrats to grant preferential treatment to its own firms and in turn makes it easier for centrally state owned firms to benefit from international joint ventures in China. In contrast, firms with other ownership types might be confronted with higher administrative costs and, consequently, a positive net effect of international joint ventures is more difficult to reach for these firms.

Finally, we discuss two differing effects of the operational environment by ownership type. Firstly, only private firms benefit from proximity to top universities. This finding implies a higher potential of private firms to utilize the human capital provided by universities. While university graduates might be employed by state owned and private firms alike, actually more than half of the graduates from elite engineering programs in China prefer a job with the state sector (Boswell & Rozelle, 2012), state owned firms fail to generate TFP gains from hiring these. Secondly, only state owned firms are suffering from foreign competition in industries in which FDI is encouraged. In contrast to private firms, throughout China's transition period most state owned firms operated in monopolistic or oligopolistic industries. After encouraging FDI in an increasing number of industries, incumbent state owned firms are less prepared than private firms to respond to foreign competition.[5]

[5] As a further robustness check we investigated whether firms with high and low absorptive capacity would benefit differently from in-house R&D and knowledge acquisition. We divided the sample according to the median value of the patent stock. We did not find that firms with high absorptive capacity would benefit more from their R&D activities.

7 Conclusion

This study investigates the influence of in-house R&D and external knowledge acquisition on the TFP of Chinese firms for the time period 2001-2010. Regarding the period we study, our findings suggest a direct effect of in-house R&D on firm level TFP in China. Further, the absorptive capacity of Chinese firms has sufficiently been developed to benefit from domestic R&D collaboration. For domestic joint ventures we cannot identify a positive net effect. Nonetheless, the absorptive capacity of Chinese firms is still too low to benefit from employing inventors with access to foreign knowledge or international R&D collaboration. These mechanisms of international knowledge acquisition either demand higher levels of absorptive capacity, which has not been reached yet, or involve additional R&D investments and transaction cost which diminish the net effect of these mechanisms. At the current stage, Chinese firms are only able to benefit from international knowledge acquisition in the form of an international joint venture because it entails a long-lasting and deep relationship with the international partner. Overall, we identify investments in in-house R&D and knowledge acquisition as an important contribution to the TFP development of Chinese firms and therefore of China's economy.

Our study has several limitations. With the current data availability we are not able to investigate on which prior inventions the R&D of Chinese firms exactly builds because our patent data source does not contain information on references for patent families which are restricted to the Chinese patent office. By listing earlier patent applications and scientific articles, references give an indication for the technological basis of inventions. If references are available in the future, it will be possible to investigate, for example, whether prior domestic or international inventions become more important over time. Furthermore, when evaluating how Chinese firms benefit from international knowledge sources, we are dependent on publicly available information. Many Western firms are concerned that Chinese

firms increase their productivity through unauthorized use of knowledge. This is a mechanism that could not be investigated in this study.

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Tables and Figures

Table 1: Descriptive Statistics

Variable	Mean	Std. dev.	Median	Min.	Max.	No. firms[#]
Production function						
Value added (mio. RMB)	1,226	9,892	342.4	0.470	496,724	
Labor (number of employees)	5,243	18,637	2,159	12.00	552,698	
Capital (mio. RMB)	2,538	27,196	492.4	0.395	1,066,850	
Investment (mio. RMB)	523.0	6,120	82.71	0.003	229,856	
TFP[##]	1.808	1.157	1.533	0.127	14.58	
Patent stock	22.97	295.8	3.000	0.074	14201	1,143
In-house R&D						
In-house R&D	20.07	236.5	2.850	0	10,139	1,127
Domestic knowledge acquisition						
Domestic R&D collaboration	2.174	63.72	0	0	4,011	232
Domestic joint venture	0.178	0.629	0	0	11	153
International knowledge acquisition						
International human capital	1.009	12.16	0	0	292.8	122
International R&D collaboration	0.218	2.878	0	0	86.81	49
International joint venture	0.096	0.442	0	0	8	76
Operational environment						
Policy zone	0.173		0	0	1	224
Strategic emerging industry	0.281		0	0	1	487
Provincial patent subsidy	0.921		1	0	1	1099
Top university nearby	0.409		0	0	1	445
Top research institute nearby	0.446		0	0	1	535
FDI not regulated	0.132		0	0	1	192
FDI encouraged	0.631		1	0	1	895
FDI restricted	0.180		0	0	1	282
FDI prohibited	0.058		0	0	1	94
Control variables						
Owned by central state	0.178		0	0	1	168
Owned by local state	0.347		0	0	1	301
Privately owned	0.475		0	0	1	674
Regional GDP/capita	0.457	0.198	0.457	0.033	1.951	

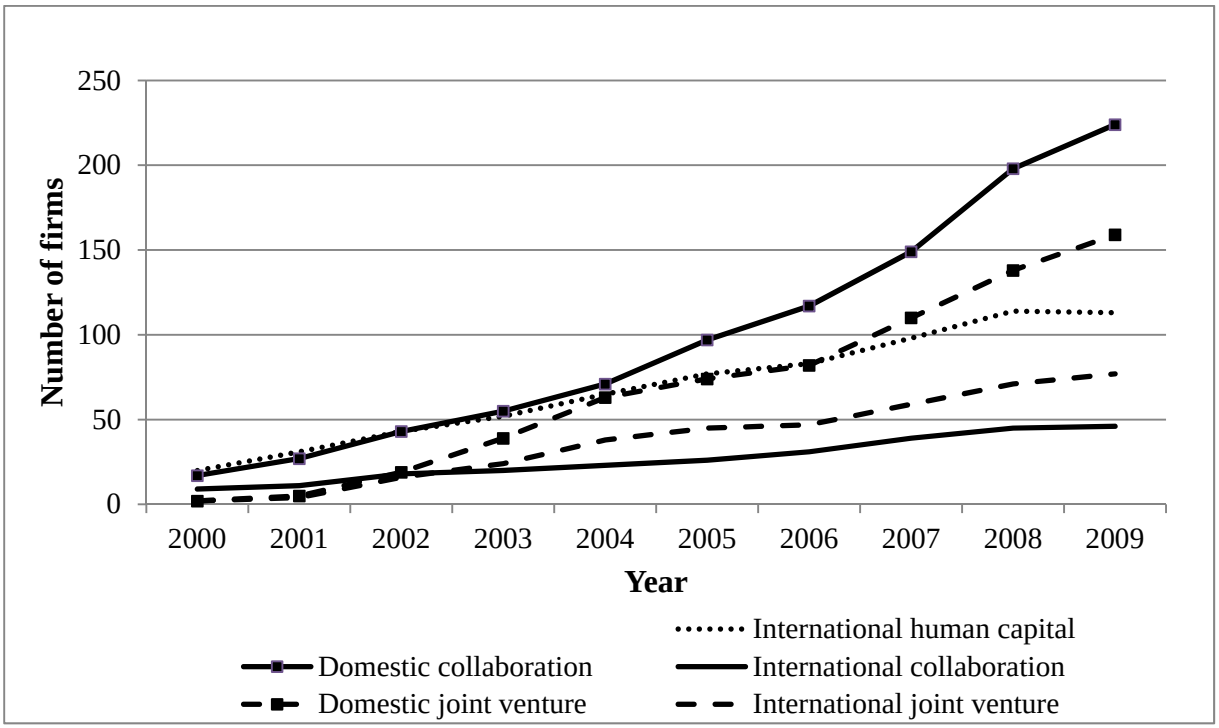
Notes: The statistics are calculated for the 4,814 observations of the 1,143 firms with at least one patent application. [#] Number of firms gives an impression of how many firms engage in a specific activity. [##] TFP as calculated by the method of Olley and Pakes (1996) from model (3) of Table 2.

Table 2: Determinants of Firm-Level Total Factor Productivity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Model	All firms	Firms with patents	Knowledge sources	Years 2001-2007	Years 2008-2010	Owned by central state	Owned by local state	Privately owned
ln(Labor)	0.411***	0.435***	0.431***	0.366***	0.494***	0.472***	0.418***	0.439***
	(0.0114)	(0.0241)	(0.0229)	(0.0260)	(0.0218)	(0.0545)	(0.0359)	(0.0235)
ln(Capital)	0.365***	0.334***	0.328***	0.468***	0.219***	0.526***	0.470***	0.438***
	(0.0373)	(0.0691)	(0.0713)	(0.0806)	(0.0731)	(0.0918)	(0.0735)	(0.0939)
ln(Patent stock)	0.0987***	0.102***						
	(0.0153)	(0.0160)						
No patent application	0.0490**							
	(0.0217)							
In-house R&D								
ln(In-house R&D)			0.0824***	0.0849***	0.0798***	0.0552	0.0517	0.117***
			(0.0169)	(0.0251)	(0.0159)	(0.0382)	(0.0351)	(0.0247)
Domestic knowledge acquisition								
ln(Domestic R&D collaboration)			0.149***	0.193***	0.123***	0.110	0.251***	0.121***
			(0.0280)	(0.0576)	(0.0317)	(0.0783)	(0.0829)	(0.0461)
ln(Domestic joint venture)			-0.145	-0.112	-0.131	-0.362**	-0.156	0.0100
			(0.103)	(0.109)	(0.109)	(0.158)	(0.125)	(0.158)
International knowledge acquisition								
ln(International human capital)			-0.0682	-0.0786	-0.0403	0.000398	-0.186	-0.109
			(0.0631)	(0.0739)	(0.0876)	(0.118)	(0.142)	(0.103)
ln(International R&D collaboration)			-0.0561	0.00442	-0.0858	-0.0471	0.0812	-0.0161
			(0.0733)	(0.120)	(0.134)	(0.279)	(0.223)	(0.151)
ln(International joint venture)			0.263**	0.0930	0.301**	0.494**	0.202	0.242
			(0.118)	(0.139)	(0.136)	(0.216)	(0.161)	(0.190)
Operational environment								
Policy zone	0.0376	0.114**	0.123**	0.167***	0.113**	0.188	0.166*	0.104
	(0.0356)	(0.0520)	(0.0522)	(0.0579)	(0.0569)	(0.165)	(0.0991)	(0.0713)
Strategic emerging industry	-0.0403	-0.0267	-0.0182	0.00503	-0.0325	-0.0759	0.00873	-0.0355
	(0.0284)	(0.0368)	(0.0345)	(0.0506)	(0.0339)	(0.0785)	(0.0687)	(0.0414)
Provincial patent subsidy	0.000693	-0.0247	-0.0192	-0.0244	0.130	-0.0302	0.0326	-0.106
	(0.0305)	(0.0708)	(0.0711)	(0.0526)	(0.328)	(0.111)	(0.0741)	(0.0966)
Top university nearby	0.0949***	0.126***	0.135***	0.133*	0.127**	0.0636	0.150	0.123**
	(0.0314)	(0.0462)	(0.0454)	(0.0731)	(0.0558)	(0.160)	(0.104)	(0.0571)
Top research institute nearby	0.0100	-0.0168	-0.0223	-0.0437	-0.0181	-0.108	-0.0401	0.0501
	(0.0286)	(0.0375)	(0.0379)	(0.0572)	(0.0480)	(0.121)	(0.0920)	(0.0516)
FDI encouraged	-0.220***	-0.194***	-0.195***	-0.207***	-0.0393	-0.345***	-0.273***	-0.0610
	(0.0284)	(0.0451)	(0.0443)	(0.0511)	(0.0563)	(0.108)	(0.0839)	(0.0567)
FDI restricted	-0.106***	-0.00569	-0.00936	-0.0568	0.233***	-0.101	0.0572	0.0167
	(0.0331)	(0.0512)	(0.0509)	(0.0636)	(0.0791)	(0.128)	(0.0869)	(0.0650)
FDI prohibited	-0.0198	-0.0325	-0.0487	-0.0101	0.115	-0.148	-0.0271	-0.0269
	(0.0361)	(0.0558)	(0.0549)	(0.0831)	(0.0909)	(0.177)	(0.122)	(0.107)
Control variables								
Owned by local state	0.00209	0.0407	0.0455	0.0364	0.0840			
	(0.0379)	(0.0525)	(0.0499)	(0.0609)	(0.0681)			
Privately owned	-0.0114	0.0380	0.0289	-0.0221	0.0769			
	(0.0328)	(0.0452)	(0.0447)	(0.0581)	(0.0545)			
Regional GDP/capita	0.0472**	0.0467	0.0396	0.0750	0.0306	0.140	0.0860	-0.0311
	(0.0222)	(0.0365)	(0.0382)	(0.0497)	(0.0456)	(0.142)	(0.0803)	(0.0570)
Observations	11,740	4,814	4,814	2,256	2,558	855	1,672	2,287
Firms	1,903	1,143	1,143	574	1,117	168	301	674

Notes: The dependent variable is ln(value added). Results are calculated with the Olley-Pakes algorithm controlling for simultaneity but not for selection. All regressions contain year, industry, and province dummies. Industries without explicit FDI regulation are the reference category for FDI policy. Centrally state-owned is the reference category for ownership. Standard errors are clustered by firm and calculated by bootstrapping with 50 replications. *, **, *** indicate statistical significance at the 10, 5, and 1 percent levels.

Figure 1: Use of Knowledge Acquisition Mechanisms



Note: The figure shows the number of firms which have used the corresponding mechanism at least once up to the respective year. The number of firms in the sample increases from 136 in the year 2000 to 1072 in the year 2009. Listed firms with at least one patent application are included.

Data Appendix

Table A1: Variable Definitions and Data Sources

Variable	Definition
Production function	
Value added	Value added of a firm is approximated by revenue minus the difference of costs of goods sold and the product of average wage costs and number of employees. Average wage costs are deflated and available at an industry-year basis. Data sources: Compustat for accounting information, Datastream for number of employees, CEIC for wages, National Bureau of Statistics for deflators.
Labor	Number of employees is used as measurement for the input factor labor. Data source: Datastream.
Capital	Property, plant and equipment in million RMB is used as measurement for the input factor capital. Adjusted for inflation by a fixed assets index deflator. Data sources: Compustat for accounting information, National Bureau of Statistics for deflators.
Investment	Investment of the firm in million RMB is funds used for additions of property, plant, and equipment. Adjusted for inflation by a fixed assets index deflator. Used as proxy variable for unobserved productivity in the Olley-Pakes procedure. Data sources: Compustat for accounting information, National Bureau of Statistics for deflators.
Patent stock	Stock of invention patent families in a firm's portfolio. All patent families are counted by the year of their earliest application (priority). They are accumulated over the time period 1990-2010. We apply an annual depreciation rate of 15%. Data source: PATSTAT October 2011.
In-house R&D	
In-house R&D	Stock of patent families in a firm's portfolio which only includes applications without any foreign inventors living in China or abroad, without Chinese inventors living abroad, and without any co-applicants. Data source: PATSTAT October 2011.

Domestic knowledge acquisition

Domestic R&D collaboration	Stock of patent families in a firm's portfolio which include at least one co-application with a domestic firm, university, research institute or individual but excluding patent families with foreign co-applicants. Data source: PATSTAT October 2011 version.
Domestic joint venture	Number of joint ventures with only domestic partners in which the focal firm participates. Time variant variable counting the joint ventures from their year of inception. Data source: Zephyr database from Bureau van Dyck.

International knowledge acquisition

International human capital	Stock of patent families in a firm's portfolio with at least one foreign inventor living in China or abroad or at least one Chinese inventor living abroad. Data source: PATSTAT October 2011.
International R&D collaboration	Stock of patent families in a firm's portfolio with at least one co-application with a foreign firm, university, research institute or individual. Data source: PATSTAT October 2011.
International joint venture	Number of joint ventures with at least one foreign partner in which the focal firm participates. Time variant variable counting the joint ventures from their year of inception. Data source: Zephyr database from Bureau van Dyck.

Operational environment

Policy zone	Time variant dummy variable which equals 1 if the firm's headquarter is located either in a Science & technology industrial park (STIP), in an Economic & technology development zone (ETDZ) or in a processing zone. The matching is based on a comparison of the 6-digit postcode of the firm's headquarter with the 6-digit postcode of the zone. Data source: Local Governments. – STIP: In the time period 1998-2010 the Central Government recognized 82 STIPs with the aim to generate technology spillovers between indigenous firms, see Liu and Wu (2011) for entry conditions and preferential treatment of firms located in a STIP. – ETDZ: In the time period 1984-2010 the Central Government recognized 113 ETDZs with the aim to foster

	internationalization strategies of firms, see Liu and Wu (2011) for entry conditions and preferential treatment of firms located in an ETDZ. – Processing zone: In the time period 2000-2010 64 processing zones were established for assembly and export activities, see Fu (2011) for details on processing zones.
Strategic emerging industry	A time variant dummy variable equal to 1 in 2006 and later years if the firm's Standard & Poor's business scope profile matches the scope of one or more of the seven strategic emerging industries which were announced in the *Science & Technology Mid Long-Term Plan 2006-2020* in 2006. We follow the *Decision of the State Council on Acceleration and Development of the Strategic Emerging Industries* (No. 32, 2010) that specifies financial support, tax-incentives and subsidies for firms in the following industries: (1) energy efficiency and environmental protection, (2) next generation IT, (3) biotechnology, (4) high-end equipment manufacturing, (5) new energy, (6) new materials and (7) new energy automotive. Data sources: Compustat, State Council.
Provincial patent subsidy	Time variant dummy variable controlling for the years in which provincial patent subsidies have been in place. Matched on the basis of the 6-digit postcode of the firm's headquarter. The provincial level patent subsidy programs have been introduced in the following years: 1999 for Shanghai; 2000 for Beijing, Tianjin, Guangdong, Jiangsu, Chongqing; 2001 for Zhejiang, Heilongjiang, Guangxi, Hainan, Sichuan, Shaanxi; 2002 for Fujian, Jiangxi, Henan, Guizhou, Inner Mongolia, Xinjiang; 2003 for Shanxi, Anhui, Shandong, Yunnan, Tibet; 2004 for Jilin, Hunan; 2005 for Hebei, Qinghai; 2006 for Liaoning; 2007 for Ningxia. Source: Li (2012).
Top university nearby	Time variant dummy variable equal to 1 if universities of the *985* or the *211* programs are located in the same city as the firm's headquarter. The *985* program includes 39 elite universities selected by the Ministry of Education in the time period 1998-2008. The *211* program includes 116 key universities selected by the Ministry of Education in the time period 1996-2009. Source: Ministry of Education.

Top research institute nearby	Time variant dummy variable equal to 1 if institutes of the Chinese Academy of Science (CAS) or the National Engineering Institutes (NEI) are located in the city of the firm's headquarter. CAS includes 150 sub-institutes founded in the time period 1928-2010. NEI includes 148 accredited institutes in the time period 2004-2010. Sources: CAS, Ministry of Science & Technology.
Foreign direct investment (FDI)	Three time variant dummy variables indicating if FDI is encouraged, restricted, or prohibited in the industry of the firm according to the *Catalogue of Industries for Guiding Foreign Investment*. The reference category is industries unspecified in the FDI catalogue The catalogue was amended in the years 1997, 2002, 2005 and 2007. The industry classification of the catalogue is matched manually with Standard & Poor's 120 Global Industry Classification Standard Sub-Industries. Sources: National Development and Reform Commission, Ministry of Commerce.
Control variables	
Ownership type	Time invariant dummy variables controlling for ownership status of the firm in 2010. Ownership by central state, by local state and private ownership is differentiated. Data source: China Securities Index.
Regional GDP per capita	Regional GDP per capita in 100,000 RMB as a proxy to control for city and county-level agglomeration effects. Real values are calculated by using a GDP deflation index. We observe GDP per capita annually for 284 cities and counties over the time period 2001-2010. Based on the 4-digit city-level postcode of the firm's headquarter each firm is matched with the closest city or county for which GDP per capita data is available. Data source: China Economic Information Network.
Province	Dummy variables controlling for each of the 31 provinces in which our firms are located. These variables are based on the 6-digit postcode of the firm's headquarter. Data source: Compustat.
Industry	Dummy variables controlling for the Standard & Poor's Global Industry Classification Group (GICG) a firm is operating in. These variables are specified according to Standard & Poor's Global Industry Classification Group. Data source: Compustat.