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The Effects of Foreign Direct Investment on
Regional Innovation Capacity in China

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June 2018

Summary:
Foreign direct investment (FDI) has been widely considered as an essential channel contributing to a host countries' innovation development through knowledge and skill spillover effects. In recent years, China has become the second biggest FDI recipient in the world and continues to promote its domestic innovation ability. Here, the question of how FDI affect the growth of regional innovation in China is posed. By applying an alternative knowledge production function (KPF), we investigate the effects of FDI on the development of self-innovation capacities in 31 Chinese provinces using a fixed-effects specification panel data analysis covering the period from 2000 to 2015. Our findings on the contribution of FDI to the growth of different kinds of patent applications in different regions are mixed. Significant results were mainly found for invention patents in the eastern region. Concluding, we suggest potential policy implementations.

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The Effects of Foreign Direct Investment on Regional Innovation Capacity in China

EIIW Diskussionsbeitrag 247
EIIW Discussion Paper 247

Table of Contents

List of Figures

List of Tables

1. Introduction

China's growth dynamics in the decades after the opening up since 1978 has been impressive as trade, FDI, rising research and development (R&D) expenditure-gross domestic product (GDP) ratios, better human capital formation, and other elements have contributed to a considerable increase in productivity and real per capita income, respectively. Since more recently, i.e., from circa 2015, China's economic growth has slowed, and with the increased pressure of rising labour costs, the next stage of China's international economic catching-up process will have to put more emphasis on innovation dynamics than before. While physical capital accumulation, as well as human capital formation dynamics, can certainly play a role for many decades in supporting a continuous increase of China's per capita income, sustained economic growth can only be achieved if firms in China can improve in the fields of product innovation as well as process innovation.

China's process of economic development has mostly been characterised by an early opening up of China's coastal regions which over many years have also obtained the most R&D support from the central government; as regards the big state-owned enterprises (SOE), these firms also benefited from easy access to the state-dominated banking system in China while private investors often had to pay much higher interest rates (Shao, Zilibotti, and Alder, 2013). Given the geographical location of these coastal provinces, several special economic zones (SEZs) have been organised along the coast to provide a more flexible environment for foreign and domestic enterprises to do business and stimulate investment. Sharma, Wang, and Wong (2014) point out that in addition to enjoying a series of preferential policies and treatments, more importantly, these SEZs also have tariff-free imports of intermediate products and supplies. All of the aforementioned advantages helped the eastern region become very appealing to foreign enterprises looking to set up subsidiaries in China. In comparison, the more central and western regions of China have recorded higher foreign direct investment inflows only since the beginning of the 21st century. Although over the last two decades a rapid increase of economic and technological development zones (ETDZs) established in China to stimulate the economy and technology development, the regional disparities that China has been experiencing remain substantial. As regards the task of central government and of regional governments facing challenges concerning stimulating regional economic growth and productivity growth, respectively, one of the major tasks requires investing sufficiently in public infrastructure and higher education/universities plus specific research activities. In the 12th Five-Year Plan (FYP) of China, the Chinese government has emphasised the importance of attracting more inward FDI (IFDI) to technology-intensive industries and has encouraged foreign firms to invest more in Mid- and West-China (China's 12th Five-Year Plan, p.112). Subsequently, the 13th FYP has highlighted the leading role for innovation in terms of development over the coming five years (2016-2020) (China's 13th Five-Year Plan, p.17). However, it is not yet entirely clear whether sufficient innovation and growth momentum can be achieved in different sub-regions in China so that the potential problem of the middle-income trap (Glawe and Wagner, 2017) can be avoided.

The presence of foreign firms in a region could be of double economic significance in China: Firstly, foreign subsidiaries often hire skilled Chinese workers and engineers and over many years have continuously invested in their staff so that training and skill-upgrading are emphasised in a way that is quite crucial for knowledge-intensive production. Not only do firms invest in the skill formation of newly hired skilled labour, the tenure of part of the staff in multinationals' subsidiaries in China typically is fairly long and thus could help to set industry standards or regional standards in relevant employment fields. Since most Chinese and foreign firms co-exist in industrial parks in China, one may argue that foreign firms often stand for the smaller part of total sales or output in such an industrial park. At the same time, one may argue that outward-oriented Chinese firms in such parks indeed are strongly interested in the standards applied by leading western competitors. However, there are considerable differences across China's regions, and there could be critical interregional spillovers both with respect to R&D effects and with respect to regional FDI intensities as has been emphasised by Wang, Meijers, and Szirmai (2017) who find interregional R&D spillovers and also significant benefits from international FDI spillover effects. The authors also point out that FDI in a region has a negative impact on the growth of industrial output in neighbouring regions – a fact that could be explained by regional specialisation and clustering effects which could stimulate inflows of the mobile worker from adjacent regions.

Meanwhile, to the extent that export intensity (exports relative to GDP) has to be considered as an essential element in generating new knowledge for Chinese regions, Xie (2006) argued the necessity of excluding the spillover effects of trade from FDI due to the fact that export-oriented enterprises have to compete in the global market which leads to an increase in the product innovation and efficiency of those companies. In the study of Melitz (2003), where the author modeled the productivity gains within a group of heterogeneous firms, he found that most export-related companies have better chances to expand while the firms doing least in the export sector will face crowding out from the market in an economy which is opening up. Moreover, one may emphasise that the medium term export dynamics will be shaped mainly by the GDP development of China's trading partners on the one hand, on the other hand, one cannot ignore sizeable international trade policy developments. There could emerge new protectionism against China – with the Trump Administration in the US pushing for more trade liberalisation in China, as well as more capital flow liberalisation. From the above perspectives, it is quite important to understand the relative importance of export intensity and FDI inflows.

The present paper is organised as follows: Section 2 presents a descriptive overview of the development of China's innovation ability and IFDI. Section 3 takes a close look at the theoretical framework and relevant aspects of the existing literature, followed by the development of hypotheses. In section 4, the methodology and data are explained. Section 5 presents the results of the empirical analysis and a discussion of the empirical evidence. Section 6 incorporates the conclusions, a series of policy recommendations, and suggested improvements for future research.

2. Descriptive Overview of China's Innovation Ability and Inward Foreign Direct Investment

Generally speaking, China's patent applications grew rather slowly after China established its patent law in 1985 until the beginning of 2000, since then it has been increasing dramatically, as highlighted in Figure 1. The number of total patent applications in China soared over 1.3 million in 2016, almost 25 times more than the number in 2000. By comparing the number of patent applications from Chinese residents and non-residents, since 2005, the number of patent applications from domestic applicants overtook those from foreign applicants, and have also been proliferating to reach 1.2 million in 2016. In comparison, the growth rate of patent applications from non-residents is considered low during the same period.

Figure 1:   **The number of China's total patent applications by filing office, 1985–2016**
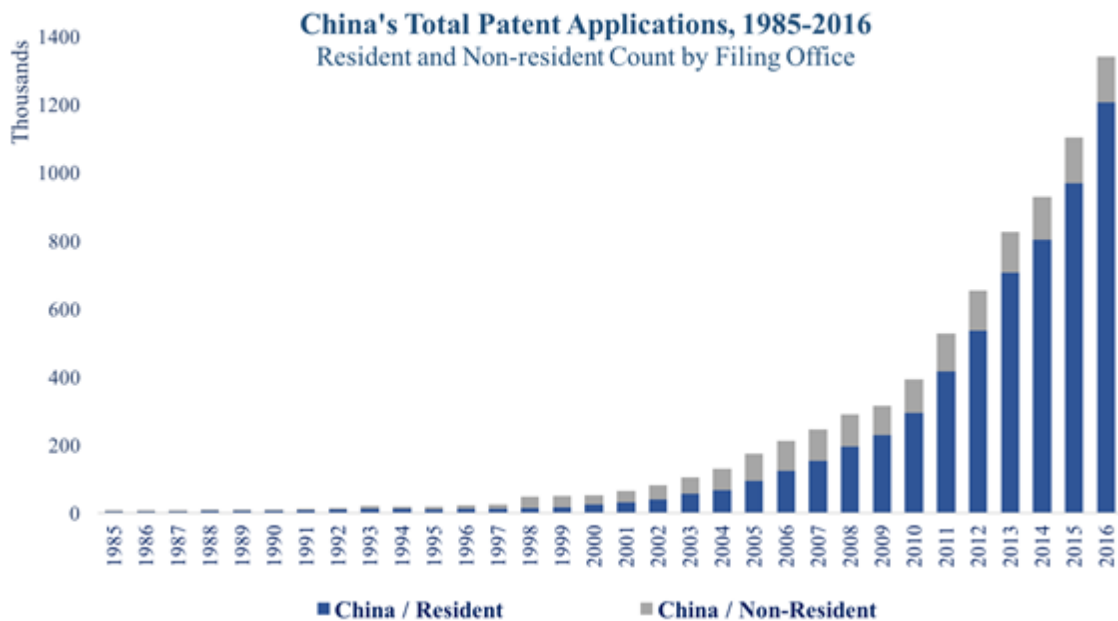
Source: World Intellectual Property Organisation

In comparison to China's innovation capacity, which suffered from slow growth initially, FDI in China increased quickly and substantially after the Chinese government started to open its market. As is clear from Figure 2, China has continually received growing levels of FDI. A closer look at the FDI intensity (the ratio of IFDI and GDP) measurement, clearly shows that both China's IFDI flows and stocks increased significantly, especially after 1992, afterward, reaching a peak in 1994 and 1998, respectively. The primary reason for this has been broadly discussed in many contributions to the literature, for example, Cheng and Kwan (2000); Liu (2002); Sigurdson (2004) and Fu (2008). Following this research, the rapid growth of FDI inflows and stocks can be explained by the actions of the

Chinese government which enacted several open policies after Deng Xiaoping's trip to China's south-eastern region and SEZs in order to further promote economic reforms and the opening of the domestic market. Following a continued decline of IFDI, mainly related to the Asian financial crisis, the FDI stock intensity of China started to recover after 2011. Additionally, the significant difference between FDI flows and stocks, as well as the growing trend especially after 2008 need to be carefully considered. These may lead to different results for China's IFDI study.

Figure 2: China's Inward Foreign Direct Investment Flows and Stocks, 1980-2016

China's Inward Foreign Direct Investment Flows and Stocks, 1980-2016

- ■ FDI flow US$ at current price in billions (left axis)
- ■ FDI stock US$ at current price in billions (left axis)
- — The ratio of FDI to GDP (right axis)
- — The ratio of FDI stock to GDP (right axis)
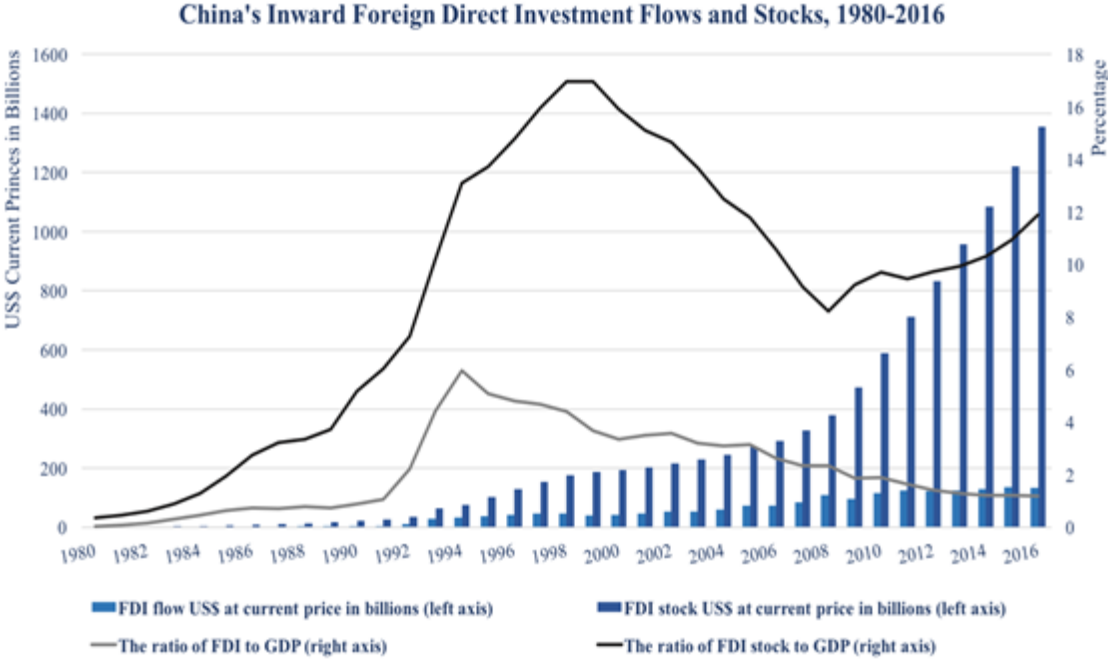
Source: UNCTAD

Figure 3 (patent applications) and Figure 4 (FDI stock intensity, namely, FDI stock relative to GDP) allow comparing empirical data between 2000 and 2015 at a sub-regional level in China, namely the eastern region, the middle region, and the western region. The names of the Chinese provinces in each of the regions mentioned above are listed in Appendix 1. The figures show a discernible concentration in the eastern region for both patent applications and FDI stock intensity, even despite the 16-year period of rapid economic growth in China, the gap remains significant. On the left side (Figure 3), it is clear that the most innovative provinces are situated around the Pearl River Delta[1] in 2000, followed by the Yangtze River Delta[2] and the Bohai Rim[3]. However, in 2015, the innovative centre shifted to the Yangtze River, although the Guangdong area is still very innovative.

In comparison with other inland provinces, the Sichuan and Chongqing areas stand out since 2000 with relatively high patents. Meanwhile, there is a slow trend of innovation expansion towards the south-western region during the term from 2000 to 2015. On the

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[1] Guangdong; Hong Kong, China; Macao, China
[2] Shanghai; Jiangsu; Zhejiang
[3] Beijing; Tianjin; Hebei; Liaoning; Shandong

right- hand side in Figure 4, the FDI stock intensity of China in 2015 illustrates an increasing trend among eastern provinces, especially in the Yangtze River Delta, and a slow increase towards to the middle provinces. However, the growth trend of the FDI stock intensity in the western region is not significant.

Figure 3: **The number of China's accepted domestic patent applications 2000 vs. 2015**

The Number of Chinese domestic patents application (accepted) in 2000

The Number of Chinese domestic patents application (accepted) in 2015

Source: MOST, CSY, NBSC

Figure 4: **FDI stock intensity of Chinese provinces 2000 vs. 2015**

FDI stock intensity of China's provinces in 2000

FDI stock intensity of China's provinces in 2015

Source: MOST, CSY, NBSC

Based on the explanation from the Patent Law of China on the classifications of invention-creations, there are three kinds of patents which have been defined by their outcomes: inventions, utility models, and designs. Generally, "inventions mean new technical solutions proposed for a product, a process or the improvement thereof, utility models mean new technical solutions proposed for the shape and structure of a product, or the combination thereof, which are fit for practical use, and designs mean, with respect to a product, new designs of the shape, pattern, or the combination thereof, which are rich in an aesthetic appeal and are fit for industrial application." (Patent Law of the People's Republic of China, Article 2). Upon a closer look at the proportion of the three different kinds of accepted domestic patent applications per 10,000 inhabitants in 2000 and 2015 (Figure 5), it is clear that the eastern region has an absolute advantage in terms of all three kinds of patents when compared with mid- and west-regions. Interestingly, a catching-up process of advanced technology and industrial products design innovation can be seen in western provinces by looking at the development of the invention and design patents, and the figures had doubled by 2015 compared to 2000. Besides, the number of invention and design patent applications from western provinces even overtook the same kinds of patents from central provinces, which are closer to eastern China and thus considered to benefit more from the technology spill-over effects.

Figure 5: The comparison of the three kinds of domestic accepted patent applications per 10,000 inhabitants in three regions of China in 2000 and 2015
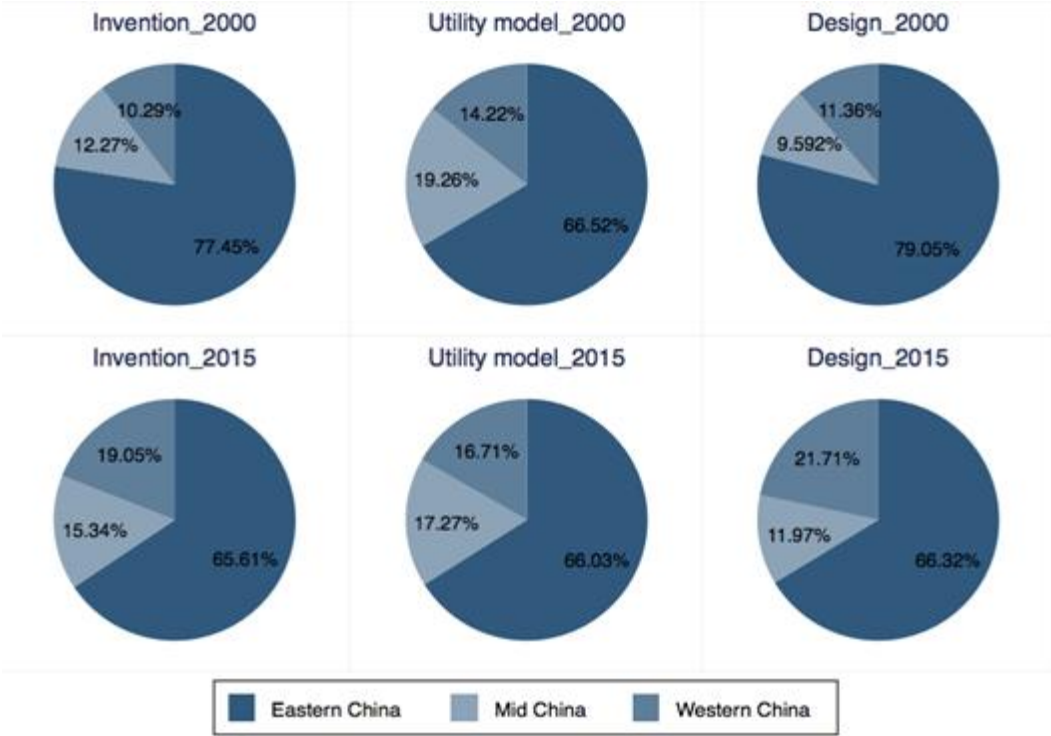
Source: Own representation

3. Literature Review

3.1 Theoretical Framework and Modelling

Long run national and international output dynamics are often analysed on the basis of a production function where the Cobb–Douglas function or the CES function plays a crucial role – with the standard question being how to explain in growth accounting analysis the growth rate of total factor productivity. The innovation analysis has suggested for many regions that the KPF is a useful concept, typically the approach of Griliches (1990) and Machlup (1962) which suggests that the increase in knowledge, e.g., approximated by patent applications, is a function of the number of researchers and the ratio of cumulated FDI inflows relative to GDP. A 2016 study presents empirical evidence for 20 EU countries where besides the two variables mentioned so far per capita income also plays a role (Jungmittag & Welfens). The analysis by those authors also suggests a compact and rather direct new method of growth decomposition, namely to consider a KPF for the stock of knowledge – which would correspond to the number of total patents and not just to current patent applications, then to insert the KPF into the macroeconomic production function which then can be used for growth decomposition analysis in a more informative way than the traditional approaches.

Following the theoretical approach of Jungmittag and Welfens (2016), and their panel data analysis, the subsequent analysis takes a closer look at Chinese regions. From a simple

theoretical perspective, the knowledge production function is – with A denoting the stock of knowledge – a function $dA/dt = f(R', K^{**}/Y, x, y\ldots)$, where R' is the number of researchers, K^{**} refers to the stock of inward FDI, x represents the export intensity (exports X relative to real output Y), y is per capita income, t is the time index, so that $A_{t-1} + dA/dt = A(t)$; the depreciation of knowledge is ignored here for simplicity. In the macroeconomic production function $Y = F(K, L, A)$, knowledge A is input as are the capital stock K and labour L. The detailed calculations can be found in Appendix 2.

3.2   Empirical Literature

A certain amount of research has already been done on this topic; however, different findings regarding the effects of FDI on China's regional innovation capacity have been derived by different researchers. A structured review of selected literature, including the output, is presented in Appendix 3.

Cheung and Lin (2004) researched the spillover effects of FDI on innovation in China based on the provincial data from 1995 to 2000. They found a positive effect of FDI on the number of domestic patent applications and emphasise the demonstration effects on local R&D activities. A study carried out by Chen and Chen (2006) also supports the spillover effects of FDI on Chinese domestic innovation ability by analysing cross sectional industry-level data. They further emphasised the positive and significant competition effects from FDI, when the technology gap is small between the domestic and foreign industries. Hou and Guan (2006) separated provinces into three groups according to their different innovation abilities. They found that FDI spillover has significant positive effects on the increase of domestic patent applications. However, the degree of FDI spillover effects is related to the regions' absorptive abilities.

Bo (2007) examined the relationship between FDI and regional innovation ability from two perspectives. Firstly, the author investigated the various impacts of FDI on three kinds of patent applications. The positive and robust contribution of FDI is the highest on patents for design, and declines with regard to patents for utility model and patents for invention. Secondly, the influence of FDI on different regions is analysed, the author found the effects of FDI are most influential in the east cluster, decreasing progressively in the mid and west clusters. The main reason presented is the difference in relation to the innovation absorptive capacities of each region, human capital in particular affected the investment quality. A study of the spillover effects of FDI on regional innovation ability in China between 1998 and 2004 (Fu, 2008) found a positive and significant contribution of FDI to regional innovation capacity overall. However, it is different between the coastal region and the inland region. FDI is not an active driver of innovation capability in inland provinces. Based on the results, the author further controlled the provincial absorptive capacity to test the degree of FDI effects on the regions; the outcomes remain the same.

By studying how FDI affects the self-innovation ability of Chinese high-technology industries in the period 1999-2008, Zhao and Li (2010) illustrated that FDI has a positive effect on high-technology self-innovation abilities, but the estimated coefficients are not different from zero at the usual significance levels. Again, FDI affects different regions differently. The authors found adverse effects of FDI on the high-technology innovation

abilities of eastern China, but significant positive contributions in middle and western China. In a contribution to the literature from Wang and Meijers and Szirmai (2017) on technological spillovers and industrial growth in China's regions from 1990 until 2005, the authors analyse the different outputs derived from different types of FDI. They believe that despite the direct impact from international FDI on innovation, there is an indirect impact from interregional FDI due to the mobility or re-investment of FDI across regions. In their results, the authors find that regions profit more from international (direct) FDI spillovers when their local R&D stocks are high. However, interregional (indirect) FDI has a negative contribution to neighbouring regions no matter the degree of R&D stock.

The existing research adapts different methods to understand the effects of FDI on the regional innovation ability from the macro level to the micro level, as well as the influence of different types of FDI. However, the empirical analysis results are diverse. Meanwhile, most of the existing empirical research depend on relative small examples by using pooled regression analysis. Therefore, the first contribution to the existing research from this study is that the authors conduct an alternative KPF for a better understanding of the contribution of FDI on innovation development. The second contribution of this paper is to provide a more comprehensive and contemporary study to investigate the effects of FDI on different kinds of regional domestic innovation abilities by analysing provincial macro-level data with fixed effects panel analysis.

3.3   Hypotheses

According to the review of current research and the alternative KPF framework, and in accordance with the descriptive analysis of the development of China's patent applications and received FDI, the following hypotheses were developed:

Hypothesis 1: FDI has positive and substantial effects on the overall self-innovation ability in China.

According to the results of existing literature, many researchers find a positive and statistically significant impact of FDI on regional innovation ability in China. However, there are also some researchers who hold an opposite perspective. Therefore, it is important to understand the effect of FDI on innovation ability on the national level firstly. With a combination of the results from Figure 1 to Figure 4, there is a similar growth trend between accepted domestic patent applications and the FDI stock intensity. Thus, our first hypothesis is that FDI has a positive and significant effect on domestic innovation ability in China.

Hypothesis 2: FDI is a significant contributor to the growth of the domestic patents for invention in eastern China, but not in middle and western China.

It is not surprising that during the time the major FDI stocks are concentrated on the eastern region of China due to the opening up policy. Later on, benefit from its superior geographical location, rapid economic development, and rich labour resource, the eastern area became the most innovative region in China, especially in the Pearl River Delta and

Yangtze River Delta. By considering the FDI dynamics in the eastern provinces, it might be the case that a growing amount of FDI stocked and further benefit to the growth of high skill and technology industry in eastern China. Therefore, more patents for invention, which are considered the more highly valued, have been generated. However, for middle region, both the percentage and growth rate of invention patent applications is minimal in Figure 5 considering the increased volume of FDI stock during the same period, an adverse spatial inter-region effect might impact on the generate of invention patents in the mid-region from the east. For western China, the FDI stock is low, the effect of FDI on innovation may difficult to be captured. Therefore, the second hypothesis is that FDI will have the most significant contribution to the growth of domestic patents for invention in the eastern region.

Hypothesis 3: FDI contributed positively and significantly to the increase of domestic patents for utility models in the eastern region, but the similar influence cannot be found in inland China.

Although the east area remains the dominant role of attracting FDI stock in China, there is still a noticeable change, i.e., the shift of the FDI centre from the Guangdong area to the Yangtze River Delta and Bohai Rim, within the east-region between 2000 and 2015 (Figure 4). Meanwhile, the Yangtze River Delta and Bohai Rim became one of the most innovative areas in 2015 (Figure 3). Guangdong province is active in the information and communication technology (ICT) sector. In comparison, the development of the Yangtze River Delta is more comprehensive regarding sectors, which with a focus on automobiles, chemicals, machinery and so on. Based on a more detailed definition from the National Bureau of Statistics of China (NBSC): "the utility model patents indicate the practical and new technical proposals on the shape and structure of the product, it covers machines, processes, methods and any manufactured that has a useful and specific function." Utility models patents are considered an important engine for manufacturing production utility and process. Therefore, we believe that FDI also contributed significantly to the increase of domestic patents for utility models in the eastern region.

Hypothesis 4: FDI is an essential factor for the development of domestic patent applications for design in the mid-region, but not in the eastern and western region.

By looking at the results from Figures 3-5, there is a small increase in the number of invention and design patent applications in the mid-region up to 2015. Meanwhile, the FDI stock intensity is also rising in these provinces. Considering the location closer to the coastal regions, it may have benefited from inter-regional technology spill-overs effects on the comparatively low skill manufacturing over the years. Furthermore, the mid-region benefits from a series of national economic development plans, for example, "the Rise of Central China Plan" (中部崛起计划), and 11th Five-Year Plan of China, which also encourage FDI flows to inland China by systematically suggesting advanced comparative sectors, and providing preferential policies and treatments. However, the middle region is still the main agricultural production base and heavy industrial district of China. It faces many develop restrictions, for example, unbalanced industrial structure, relative weak transport infrastructure, backward education, and environmental pollution. Therefore, we

estimate that FDI will have a positive and significant influence on raising the number of patent applications relating to design in the middle provinces.

Hypothesis 5: FDI is not an important driver for the development of domestic patent applications in the western region.

From the descriptive analysis results (Figures 3-5), the increase of invention and design patents are clearly visible for western provinces. Sichuan and Chongqing exhibit an advanced innovation ability already since 2000. However, high FDI intensities do not appear in these areas. Also, other western provinces show neither a considerable increase with regard to total patent applications nor the FDI intensity during the same period. Therefore, we see that FDI has no significant impact on regional innovation ability in the western provinces. The western part of China is generally seen as being a less developed area. Many studies find adverse effects of FDI on the underdeveloped regions due to the lack of necessary production inputs and weak absorptive capacities. For most of the western provinces, the relatively poor economic and scientific development may not be attractive for efficiency- and knowledge-seeking FDI. Therefore, the development of the self-innovation ability in West-China may be mostly unaffected by FDI, compared to the strategic support from provincial and national governments.

4. Methodology and Data

4.1 Methodology

This study focuses on the effects of FDI on the self-innovation ability of 31 selected Chinese provinces[4] from 2000 to 2015. A panel data analysis is thus considered as an appropriate method as it provides more informative data, increases the degrees of freedom, and reduces multicollinearity amongst explanatory variables (Kennedy, 2003; Baltagi, 2008). Since the risk of an omitted variables bias is large in terms of the unobserved individual effect or individual specific characteristics of the provinces in China, therefore, fixed-effects and/or random-effects panel data models are usually chosen to deal with the problem of heterogeneity and individual effects that may or may not be observed (Park, 2011). In our study, we are more interested in comparing the difference between the individual groups, considering the size of the sample, therefore, in general, a fixed-effects specification is preferred.

In the next step, we conduct several tests to examine the selection of the model specification. We first test whether the fixed effects estimation is superior to the pooled panel regression using an F–test. As the test results show, the null hypothesis which there is no province fixed effects was rejected. Thus we can conclude that there is a significant increase in goodness-of-fit in the fixed effects model. The authors implement several diagnostic tests to ascertain the time-specific effects, region-specific time trend effects,

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[4] Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang

homoscedasticity, serial correlation, and autocorrelation. Ultimately, time fixed-effects are included, and we produced robust standard errors estimates by clustering the 31 provinces due to disturbances being heteroscedastic and autocorrelated.

4.2   The Empirical Model

The following model is based on the framework and hypotheses explained above. Therefore, as highlighted in the equation below, the following panel analysis models were conducted:

$$lnPAT_{it} = \beta_0 + \beta_1 ln(FDI\_i)_{it-1} + \beta_2\, ln(RGDPpc)_{it-1} + \beta_3 ln(RDpt)_{it-1} + \beta_4 ln(X\_i)_{it-1} + \mu_i + \delta_t + v_{\ it} \tag{1}$$

$$lnPAT_{it} = \beta_0 + \beta_1 ln(FDI\_i)_{it-1} + \beta_2\, ln(RGDPpc)_{it-1} + \beta_3 ln(RDpt)_{it-1} + \beta_4 ln(X\_i)_{it-1} + \beta_5 \ln(FDI_i)_{it-1} * Region_1 + \beta_6 \ln(FDI_i)_{it-1} * Region_2 + \mu_i + \delta_t + v_{\ it} \tag{2}$$

$$lnPAT_{it} = \beta_0 + \beta_1 ln(FDI\_i)_{it-1} + \beta_2\, ln(RGDPpc)_{it-1} + \beta_3 ln(RDpt)_{it-1} + \beta_4 ln(X\_i)_{it-1} + \beta_5 \ln(FDI\_i)_{it-1} * Region_3 + \mu_i + \delta_t + v_{\ it} \tag{3}$$

where

PAT	stands for the total and three kinds of patent application intensity in China; it is a proxy for regional innovation capacity;
FDI_i	refers to a proxy for the foreign direct investment stock intensity;
RGDPpc	refers to the real gross regional product per capita;
RDpt	is the full–time equivalent of research and development personnel;
X_i	represents export intensity;
$\boldsymbol{Region_j}$	indicates three categories for China's three regions, $j = 1$ if it is the eastern region, $j = 2$ if it is the mid-region, $j = 3$ if it is the western region;
$\boldsymbol{\mu_i}$	denotes the unobservable, time-invariant individual specific effect;
$\boldsymbol{\delta_t}$	is the time-specific effect;
$\boldsymbol{v_{it}}$	are the idiosyncratic disturbances;
i	refers to the provinces of China (i =1, ... N) and t denotes time (t =1, ... T).

The model (1) is used to understand the effects of FDI on overall innovation ability in China, model (2) is conducted to compare the effects of FDI on different types of patents in three Chinese regions. The model (3) is to understand the impact of FDI on general innovation ability in the western region of China. All continuous variables are in natural logarithm, the explanatory variables which are suspected of being endogenous in the regression are lagged by one year. The endogeneity problem has been widely discussed by many researchers, for instance, Fu, X. (2008), Liu (2008), Usai (2011), Tian (2016) and Wang et al. (2016). In particular, they suggest the use of 1-year lagged values in order to

remove possible endogeneity between FDI and the dependent variable, as regions that have higher innovation capacities may attract more FDI. Furthermore, we use the value of thee lagged FDI stock intensity from one to three years, respectively, as according to the report on the 2015 domestic patent survey from the State Intellectual Property Office (SIPO) of the People's Republic of China, the average period for patent R&D activities is under 3 years (83.1% of the total applicants) based on the survey data in 2014. In another word, it is more robust to see the spillover effects of FDI from the value in following years. The descriptive statistics of the principle regression variables are included in Appendix 3.

4.3   Data Description

In the course of collecting the appropriate and relevant data to analyse the effects of FDI on regional innovation capacity in China, a series of limitations of existing data and sources, especially for regional level research became apparent. Firstly, the lack of data integrity and consistency. For example, in a number of cases, data is not available especially before the year 2000 or for certain underdeveloped provinces, such as Tibet and Qinghai. Secondly, the marked discrepancy between national-level data and the sum of provincial data. The explanation for this problem from the National Bureau of Statistics of China (NBSC) is that it is due to the fact that different collection and calculation systems exist in different provinces, as well as the fact that regional governments overstate their economic growth – an issue which is discussed in more detail by Koch-Weser (2013). Lastly, detailed definitions or calculation methods for some topics are either confusing or missing. Due to the above limitations, this study chooses panel data with 31 provinces in China; the time dimensions are that for each province the annual data covering 16 years ranging from 2000 to 2015. The panel data in this study is characterised as a balanced panel. It has primarily been collected from the secondary resources of the Ministry of Science and Technology of the People's Republic of China (MOST), Ministry of Commerce of China (MOFCOM), National Bureau of Statistics of China (NBSC), China Industry Economy Statistical Yearbook (CIESY), Chinese Statistics Yearbook (CSY, 2000-2015), and the Database of China's Main S&T Index (DECMSTI).

The number of three kinds of accepted domestic patent applications (i.e., invention, utility models and design) per 10,000 inhabitants at a regional level was selected as the indicator of regional innovation capacity. In accordance to the traditional discussion on the strengths by using patents as the measurement of innovation, for example, the study by Smith in 2005, we also follow the study of Dang and Motohashi (2015), who found the patent is an informative and meaningful indicator of innovation in China. After comparison with other alternative measurements, we believe that the number of accepted domestic patent applications has several advantages allowing it to best estimate the outcomes of regional innovation. Firstly, the number of accepted domestic patent applications was deemed to be a more complete indicator which takes the diffusion of technology processes into account a factor which has been neglected with regard to many other indicators, such as the new product sales revenue used by Zhao and Li (2010), or the proportion of new products in sales (Lundvall, 2010). Secondly, the chance of omitting innovation outcomes or affecting the time lag due to the process of assessment and approval is smaller than the granted domestic patent applications. However, the limitations of using the number of patent

applications cannot be ignored. The principal argument against the idea of using patent applications to approximate knowledge output is that not all innovations are patented. Perret (2018) has summarised several aspects based on the arguments of Griliches (1979) indicating that knowledge is omitted if the number of patents is considered. For example, tacit knowledge; knowledge that can be codified, but is not yet patented, or that is not even supposed to be codified. Beyond above familiar critics, in the case of China, Dang and Motohashi also mentioned that provincial patent subsidy programs helped the increase of patent numbers more than 30% in their research in 2015. In order to reduce the potential disturbance from the territorial heterogeneity, this research follows the method of Fu (2008), Paci and Usai (1999), Usai (2011), and Huang et al. (2012) by using the number of domestic patents applications per 10,000 inhabitants.

Resulting from a lack of data on provincial-level FDI stocks, the authors of the present paper followed existing research by Xie (2006) by substituting the capital obtained by industrial enterprises with foreign funds for Chinese regional FDI stock. This indicator refers to the total capital invested in industrial enterprises by foreign investors. The data has been compared and adjusted depending on the sources from the NBSC and the CIESY. In our econometric analysis, the FDI stock intensity has been calculated as the ratio of approximated FDI stock to the nominal gross provincial product (GDP).

For the purposes of showing the different development stages of each province, real gross regional product per capita was included in the estimation. It has been derived from the per capita nominal provincial GDP adjusted by the real growth indices of per capita provincial GDP, constant on the price of nominal provincial GDP per capita in 1999. The data were collected and compared from NBSC database and CSY.

The number of full-time equivalent R&D personnel is used to measure the labour capital involved in R&D. It refers to the sum of the full-time persons and the full-time equivalent of part-time persons converted by the workload. The data was collected primarily from the Database of China Main S&T Index (DECMSTI) from MOST, the focus of which is in the fields of science and technology. Many researchers (e.g., Fu, 2008; Huang et al., 2004) claim MOST data to be more precise with regard to the R&D sector, some adjustments have been made based on the sources NBSC and CSY. Usually, R&D expenditures are also considered as an essential input in the generation of new knowledge. However, the correlation of R&D personnel and R&D expenditures is very high in our sample. Perret (2018) explains this finding by arguing that a large proportion of the R&D expenditures is used to pay for the cost of researchers, so, the R&D expenditures has been excluded from the regression to avoid biased results due to the existence of multicollinearity.

In order to measure the trade input effects, the authors choose exports intensity, which is calculated as the ratio of the total value of provincial exports of destinations and catchments (adjusted by the yuan-dollar market exchange rate) to nominal GRP. The data was collected from the NBSC; the yuan-dollar market exchange rate data was taken from the IMF. The description of variables is listed in Table 1:

Table 1:   **The regional ability determinants in China and description of variables**

Variables	Proxy	Original Unit	Expect Impact	Time Period	Source
Innovation Ability (DV)	LN_PAT_i Patent domestic applications accepted per 10,000 inhabitants in logarithm	item		2000–2015	SIPO NBSC
	LN_PAT_i_i Invention patent domestic applications accepted per 10,000 inhabitants in logarithm	item		2000–2015	SIPO NBSC
	LN_PAT_u_i Utility models patent domestic applications accepted per 10,000 inhabitants in logarithm	item		2000–2015	SIPO NBSC
	LN_PAT_d_i Designs patent domestic applications accepted per 10,000 inhabitants in logarithm	item		2000–2015	SIPO NBSC
FDI Stock Intensity	L1_LN_FDI_i Lagged one years FDI stock intensity in logarithm	annual%	+/–	2000–2015	CIESY NBSC
Per capita real provincial GDP	L1_LN_RGDPpc Lagged one year provincial real gross domestic product per capita in logarithm	1000 yuan/man	+	2000–2015	NBSC CSY
R&D Labour Forces	L1_LN_RDpt Lagged one year full–time Equivalent of R&D Personnel in logarithm	man–year	+	2000–2015	MOST CSY DECMSTI NBSC
Export Intensity	L1_LN_X_i Lagged one year export intensity in logarithm	annual%	+/–	2000–2015	NBSC IMF
Region	Eastern Mid Western		+ +/– Ø		NBSC

Notes: SIPO is the State Intellectual Property Office of China; MOST refers to the Ministry of Science and Technology of China; CIESY stands for the China Industry Economic Statistic Yearbook, NBSC is the abbreviation of the National Bureau of Statistics of China; MOFCOM is shorthand for the Ministry of Commerce of China, CSY means the China Statistical Yearbook; DECMSTI refers to the Database of China's Main S&T Index; IMF is the International Monetary Fund, SCPRC is the abbreviation of the State Council of China.

5. Empirical Analysis Results

The estimated results are presented in Table 2. We report the estimations of all patents in column two. The column three to six contain the regression outcomes, which include the interaction effects of FDI intensity and sub-regions, of three different types of patent applications. In column five, the estimation results of total patent applications with the FDI-region interaction term are listed. Due to the estimations are very similar after we lagged FDI stock intensity from 1 to 3 years; therefore, only the 1-year lagged FDI regression results are reported in Table 2.

Table 2:   Analysis of regression results

DV: Accepted Domestic patent applications	LN_PAT_i	LN_PAT_i_i	LN_PAT_u_i	LN_PAT_d_i	LN_PAT_i
	(1)	(2)	(3)	(4)	(5)
L.LN_FDI_i	0.079	0.489**	0.223	0.152	0.062*
	(0.053)	(0.236)	(0.191)	(0.238)	(0.036)
L.LN_RGDPpc	1.301	1.358*	0.814	1.414	1.122
	(0.809)	(0.759)	(0.625)	(1.116)	(0.778)
L.LN_RDpt	0.113	0.159	0.224	-0.139	0.066
	(0.182)	(0.166)	(0.167)	(0.229)	(0.166)
L.LN_X_i	0.095	0.151	0.109	0.067	0.076
	(0.127)	(0.116)	(0.122)	(0.195)	(0.129)
Eastern#L.LN_FDI_i		(base)	(base)	0.775	0.431*
				(0.495)	(0.243)
Mid#L.LN_FDI_i		-0.690**	-0.314	(base)	-0.141
		(0.287)	(0.236)		(0.171)
Western#L.LN_FDI_i		-0.498*	-0.172	0.055	(base)
		(0.251)	(0.188)	(0.258)	
Constant	-3.336	-5.672**	-4.340*	-1.342	-2.459
	(2.734)	(2.633)	(2.282)	(3.368)	(2.594)
Observations	464	464	464	464	464
Adjusted R-squared	0.904	0.927	0.922	0.672	0.909
Number of Province	31	31	31	31	31
Fixed-time effects	Yes	Yes	Yes	Yes	Yes

Note: L1 represents a lag of 1 year. LN means the variable took natural logarithm. Robust standard errors in parentheses, which clustered at the provincial level. *, **, *** mean significant at, 10%, 5%, 1% level, respectively.

As we can see in Table 2, the adjusted R2 is above 0.66 for all the regressions from model 1 to model 5, and the F values are significant at the level of 0.0001. Therefore, all models have a good statistical significance and can explain more than 66% of the variations of domestic patent applications. In model (1), the estimated coefficients of the one-year lagged FDI stock intensity is positive but do not statistically significant even at the .10 level. This estimation result rejects our first hypothesis, which is that FDI has positive and important effects on the innovation ability in China. The result is different from many previous empirical studies on the effects of FDI on China's regional innovation ability, for example, Cheung & Lin (2004), Zhao and Li (2010); and Guang (2007). However, there are also some studies, for instance, Chen (2007), Lai and Bao (2003), which support the result that FDI does not have a significant influence on the regional innovation capacity in China.

As can be seen in the model (2), the one year lagged FDI stock intensity clearly exhibits a significant and positive impact on regional innovation patent applications for invention in the eastern region. The estimated coefficient shows a one-unit increase of one year lagged FDI stock intensity will lead to a 0.489 units increase of regional accepted domestic patent

applications for invention at the .05 significance level in eastern region. At the same time, the effect of FDI on invention patents is predicted to decrease in central region and western region. Compare with the estimated coefficient of FDI in eastern provinces, in this study, for every unit increase of FDI stock intensity, the invention patents are predicted to decrease by 0.690 (p<.05) and 0.498 (p<.10) in mid- and west- provinces. Therefore, our second hypothesis cannot be rejected by the analysis results, which FDI is a significant contributor to the growth of the domestic patents for invention in eastern China, but not in middle and western China.

The analysis results presented in the model (3) show the innovation situations about the domestic patent applications for utility models in the three regions of China. There is no result to identify the positive impact of the FDI stock intensity by lagging one year on domestic patents for utility model at the .10 significance level in the eastern region. The average marginal effect of FDI intensity and regions show an increase of patents for utility models in the east- and west-region, conversely, a drop of patents in the mid region. However, the regression outcomes are statistically insignificant under the level of 10%. Thus, the third hypothesis, which FDI contributed positively and significantly to the increase of domestic patents for utility models in the eastern region, but not in inland China, can be rejected.

A similar result can also be found for the effects of FDI intensity on the domestic design patents in three regions of China (in column 5). The significant effects of one year lagged FDI stock intensity cannot be identified on the development of local innovation ability for new appearance design in the middle region (p< .10), although the coefficient of FDI shows a positive sign. Instead, positive influence from lagged one year FDI stock intensity can be determined in the region east and west, which are statistically significant at the 0.5 level and 0.1 level, separately. Therefore, we reject the fourth hypothesis that FDI is an important factor for the development of domestic patent applications for design in the mid-region, but not in the eastern and western region.

In model (5), the authors estimated the effect of FDI intensity on the total domestic patent application by including the interaction term of lagged FDI stock intensity and three regions. The results show that in the western region, every one-unit increase of the one-year-lag FDI stock intensity will lead to 0.062 unit domestic patents in the western region at the significance level of .10. At the same time, the total domestic patents in the eastern region will increase 0.431 unit more than the western region due to the impact from the lagged FDI stock intensity at the 0.1 significance level. The outcome remains the same when we more years for FDI stock intensity. Therefore, the regression results reject our fifth hypothesis, which is FDI is not an important driver for the development of domestic patent applications in the western region. This results also further confirmed that the FDI plays a different role in three regions; thus, it is better to analyse the effects of FDI on innovation ability by distinguishing these three regions.

6. Conclusion

This paper investigates the effects of FDI on China's regional innovation capability between 2000 and 2015. We do not find that FDI makes a significant contribution to the

overall innovation capacity in China, but based on the geographic differences, essential spillover effects from FDI can be found in the increase of the total volume of patents, as well as for the different types of patents. Considering the vast amount of inward FDI in China during the last decades, the spillover effects from FDI in technology content development remains limited and various at both a national and regional level, especially in relation to the high technology sector. Although the FDI shows a significant impact on the growth of domestic patents for invention in the eastern region, however, the effect in middle and western regions is negative.

We consider the first explanation for the overall weak effects from FDI on innovation ability in China is the high barriers and requirements to transferring advanced technology across countries, industries or firms, and the characteristics of the high technology itself considering the long learning and development processes involved. Secondly, from the perspective of home country companies, they will protect their core technology more carefully in order to retain their competitiveness, at the same time, many foreign enterprises are not willing to transfer advanced technology into China due to the fear of 'technology leakage'. Crucial for the recipients of FDI in our example, China has a focus on various development areas and stages for different provinces which results in diverse absorptive capacities. Although the central government encourages more FDI inflows to inland China by launching beneficial policies and giving guidance to the industries which have comparative advantages, development is concentrated mainly on the sectors with medium- and low-technology intensities.

When we look at the sub-regional level, the various results are primarily related to the unbalanced investment and the big knowledge gap among various regions. It is especially evident in middle and western regions, the lack of FDI in inland China cannot significantly lead to domestic innovativeness - on the contrary, the closed location, less developed economy, and larger share of unskilled workers compared to coastal regions mean that middle and western Chinese regions are more likely to attract less FDI or low-quality FDI mainly for resource- and market-seeking. Although a slow growth of FDI spillover effects can be found in the western region especially in the low technology required industries, it is not the same case for central provinces. In mid-region, for the increase of the whole and different kinds of patents, FDI has no significant impact, and even an adverse influence from FDI can be found. A potential explanation for this finding can be there is a negative inter-region spatial effect from the eastern region. For example, because of a more appealing working circumstances and opportunity, more skilled labours moved to the eastern provinces, the precise reasons should be further studied.

FDI inflows are heterogeneous and can stand for foreign investment in labour-intensive sectors or capital-intensive and knowledge-intensive sectors (Hu et al., 2018). The question of how to narrow the regional development gap is an urgent and challenging task for policymakers. It seems that the government should provide complementary regional assets, e.g., by investing in the promotion of certain research fields in universities and research labs also more in inland regions. From a foreign investors perspective, regional locational advantages are crucial, and when the focus is more on advanced technology, the role of skilled labour and researchers, as well as high-quality intermediate product suppliers will be crucial. Above all, we suggest firstly that central government and local governments should enhance co-operation concerning FDI policymaking and implement, as well as in

the field of FDI efficiency monitoring; regional clustering analysis could be useful. A continuing effort to encourage FDI flows to inland China should include the following: A step by step opening up in more sectors to foreign investment or more co-operation with foreign high-tech companies should be considered and expanded. Intensifying trade networks with other countries that in turn would encourage China FDI projects could be useful. Different regions should develop their own specifications vis-à-vis attracting more FDI which promises higher technology spill-overs. Adequate clustering approaches could be useful: the regional cluster effects around big cities should be further expanded and promoted in both coastal and inland China. A more active co-operation between universities and enterprises should be organised, and it would not only provide various opportunities to help students and researchers to put their gained knowledge into practice, but also allow firms to enhance their productivity by co-operating on product/process innovation projects and search for well-educated staff. Lastly, the continuing development of intellectual property rights (IPR) protection system and the administrative process of relevant institutions are necessary in order to create a better environment for innovation.

This study also has its limitation. In our study, we do not distinguish the patents according to the category of industry. This limitation might lead to a potential endogeneity problem as is mentioned by Li, Lee, and Ko, (2017) who argue that patent applications might be concentrated in those industries with technology-intensive companies, for instance, IT companies. This drawback can be improved in future research by using industry- or firm-level data.

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Appendix

Appendix 1: The sub-regions of Chinese East-, Mid- and West Provinces

Region	Name	Numbers
East–China	Beijing, Tianjin, Shanghai, Liaoning, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan	10
Mid–China	Inner Mongolia, Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan, Hebei	10
West–China	Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Tibet, Xinjiang, Guangxi	11

Source: NBSC

Appendix 2: An Alternative KPF Specification and Implications for Growth Decomposition

A rather compact knowledge production function (KPF) can be considered subsequently, where f', f'' and f''' are positive parameters and a_0 is the exogenous growth rate of progress (y is per capita GDP, K^{**} cumulated inward FDI, R' is the number of researchers and L is total labour force).

If we use as KPF:

(1) $\qquad \frac{dA}{dt} = f'\frac{AR'}{L} + f''\frac{AK^{**}}{Y} + f'''\frac{dlny}{dt} + a_0 A$

we can write after division by A:

(2) $\qquad \frac{dlnA}{dt} = f'\left(\frac{R'}{L}\right) + f''\frac{AK^{**}}{Y} + f'''\frac{dlny}{dt} + a_0$

We use as a macro production function $y' = Y/(AL) = k'\beta$, where $k' = K/(AL)$ where A is knowledge; hence (with K/L as capital intensity):

(3) $\qquad lny' = \beta lnk'$

(4) $\qquad lny = \beta lnk + (1-\beta)lnA$

(5) $\qquad \frac{dlny}{dt} = \beta\frac{dlnk}{dt} + (1-\beta)\frac{dlnA}{dt}$

(6) $\qquad \frac{dlny}{dt} = \beta\frac{dlnk}{dt} + (1-\beta)\left(f'\frac{R'}{L} + f''\frac{AK^{**}}{Y} + f'''\frac{dlny}{dt}\right)$

(7) $\qquad (1-(1-\beta)f''')\frac{dlny}{dt} = \beta\frac{dlnk}{dt} + (1-\beta)f'\frac{R'}{L} + f''\frac{K^{**}}{Y}$;

Defining $\beta'' = (1-(1-\beta)f''') > 0$, we have for the growth rate of per capita income:

(8) $\qquad \frac{dlny}{dt} = \left(\frac{\beta}{\beta''}\right)\frac{dlnk}{dt} + \left((1-\beta)\frac{f'}{\beta''}\right)\frac{R'}{L} + (\frac{f''}{\beta''})\frac{K^{**}}{Y}$

Thus we have a useful direct new knowledge decomposition that can be empirically estimated.

Appendix 3: Literature review

Author	Time	Source of variation	Title	Var. Selection	Methodology	FDI impact on regional innovation capacity	Resource
Cheung, K. Y., & Lin, P. (2004).	1995-2000	30 Provinces (excl. Tibet)	Spillover effects of FDI on innovation in China: Evidence from the provincial data.	**DV**: *Patent applications (Invention, utility model, design)* **IV**: FDI, S&T personnel, S&T expenditures, Foreign funded enterprises' export-output ratio, GDP per capita	OLS; Random-effects and Fixed-effects specification	OLS: All: L1_FDI+*** Invention: L1_FDI +*** Utility model: L1_FDI +*** Design: L1_FDI +*** Eastern China: L1_FDI + *** Mid China: L1_FDI + *** Western China: L1_FDI + *** FE&RE: All: L1_FDI +^{0}~*** Invention: L1_FDI +^{0}~** Utility model: L1_FDI +^{0}~ *** Design: L1_FDI +^{0}~***	CSY, CSYST
Lai, M. Y., Bao, Q., Peng, S. J., & Zhang, X. (2005).	1996-2002	30 provinces (excl. Tibet)	外商直接投资与技术外溢: 基于吸收能力的研究 [Foreign direct investment and technology spillover: based on absorptive capacity research]. (in Chinese)	**DV**: *GDP growth rate* **IV**: FDI, labour force quality(H), human capital#FDI, openness#FDI, R&D government expenditures	Random-effects / Fixed-effects specification	All: FDI+** FDI#Openness: +** FDI#H: FDI +** Eastern China: FDI+** FDI#Openness: +** FDI#H: FDI + Mid China: FDI+** FDI#Openness: +* FDI#H: FDI +** Western China: FDI+** FDI#Openness: + FDI#H: FDI +*	CSY, OECD
Xie, J. G. (2006).	1994-2003	29 provinces	外商直接投资对中国的技术溢出——一个基于中国省区面板数据的研究 [The technology spillover of foreign direct investment into China – a study based on panel data of Chinese provinces]. (in Chinese)	**DV**: *Real GDP* **IV**: total FDI (TFDI), actually used FDI （FDI), FDI/capital stock (FDI/K), actually used FDI/GDP (FDI/GDP), human capital, capital stock, (exports+imports)/GPD (openness)	Stochastic frontier analysis (SFA)	National: TFDI －* FDI －* FDI/K －* FDI/GDP －*~** East China#TFDI －* Central China#TFDI －* TFDI － East China#TFDI －* Central#FDI －* FDI －*	CSY

Author	Years	Sample	Title	Variables	Method	Results	Data source

Hou, R. X, & Guan, J. C. (2006).	1998-2003	31 provinces	The impact of FDI on China's regional innovation capacity.	**DV**: *Patent applications (Invention, utility model, design)*
				
				IV: FDI, R&D personnel, R&D expenditures
					K-mean Cluster Analysis; Fixed-effects specification	All: FDI+** Invention: FDI +***
						Utility model: FDI +** Design: FDI +
						High innovative regions: All: FDI+
						         Invention: FDI +
						         Utility model: FDI +
						         Design: FDI +***
						Medium innovative regions: All: FDI+
						         Invention: FDI +
						         Utility model: FDI +
						         Design: FDI +*
						Low innovative regions: All: FDI +
						         Invention: FDI +**
						         Utility model: FDI +
						         Design: FDI +
							CSY, CSYST

Bo, W. G. (2007).	1999-2008	29 Provinces (excl. Tibet, Chongqing)	外国直接投资对中国技术创新的影响——基于地区层面的研究 [The impact of foreign direct investment on China's technological innovation – based on regional studies]. (in Chinese)	**DV**: *Patent accepted applications (Invention, utility model, design)* **IV**: FDI adjusted by fix-assert investment deflator, S&T researchers, S&T intramural expenditures, Foreign enterprises' export-output ratio	Random-effects / Fixed-effects specification	Invention: FDI +* Utility model: FDI +*** Design: FDI +*** Eastern China: FDI + *~** Mid China: FDI + *~** Western China: FDI + **	MOST, CSY, CSDMNC
Chen, Y.F. (2007)	-	30 Provinces (excl. Tibet)	Impact of Foreign Direct Investment on Regional Innovation Capability: A Case of China	**DV**: *Patent applications (Invention, utility model, design)* **IV**: FDI, GDP per capita, S&T expenditures	OLS	Total: FDI+*** Invention: FDI + Utility model: FDI + Design: FDI +***	CSY, CHISY, CSYST
X. Fu. (2008)	1998-2004	31 provinces	Foreign Direct Investment, Absorptive Capacity and Regional Innovation Capabilities: Evidence from China	**DV**: *Patent granted applications/10,000 population; Weighted patents granted* **IV**: FDI intensity, R&D researchers, human capital, R&D expenditure/GDP, labour force quality, computers/1000 households, high-technology value-added/total value added, transaction value in technological markets	Random-effects / Fixed-effects specification Data envelopment analysis (DEA), Tobit model	(All explanatory variable lagged 1 year) Innovation capacity: FDI +*** FDI#R&D expenditure intensity +*** FDI#labour force quality +*** FDI#computers intensity +* FDI#high-tech value-added intensity +*** FDI#transaction value in tech market + Innovation efficiency: FDI +**	CSY, MOST

Liu, Z.Q. (2008)	1995-1999	17,675 industrial firms	Foreign direct investment and technology spillovers: Theory and evidence	**DV**: *Total factor productivity (TFP)* **IV**: FDI_firm, FDI_sector_same 4-digit industry (FDI_sector), FDI_sector_same 2-digit industry (FDI_sector2), Herfindhal index (HHI)	Fixed-effects specification	All: (L1_) FDI_firm + 　FDI_sector －** 　L1_FDI_sector － 　Time#FDI_sector +** 　L1_Time#FDI_sector + 　(L1_) FDI_downstram_sector －** 　Time#FDI_downstream_sector +** 　L1_Time#FDI_downstream_sector + 　(L1_) FDI_upstream_sector － 　Time#FDI_upstream_sector + 　L1_Time#FDI_upstream_sector +* Domestic industries: FDI_sector －*** 　　　　L1_FDI_sector － 　　　　(L1_) Time#FDI_sector + 　　　　FDI_downstram_sector － 　　　　L1_FDI_downstram_sector －*** 　　　　(L1_) Time#FDI_downstream_sector +** 　　　　FDI_upstream_sector + 　　　　L1_FDI_upstream_sector －** 　　　　(L1_) Time#FDI_upstream_sector + 　　　　(L1_) FDI_sector2 － 　　　　(L1_) Time#FDI_sector2 －	NBSCC
Zhao, H., & Li, H. Y. (2010).	1999-2008	29 provinces (excl. Tibet, Xinjiang)	外商直接投资对中国高技术产业自主创新能力影响的实证分析 [An empirical analysis of the impact of foreign direct investment on the capability of China 's high–tech industry independent innovation]. (in Chinese)	**DV**: *Deflated high-tech new products revenue* **IV**: FDI, H, real GDP per capita, deflated S&T expenditures, regulation factor	EGLS; Random-effects / Fixed-effects specification	All: FDI+***~° Eastern China: FDI －** Mid China: FDI+** Western China: FDI+**	CSY, CHISY
Tian, X.W.; Lo, V.I.; Song,	1996-1999	Domestic firms: Overall:	The 'insider' and 'outsider' effects of FDI technology	**DV**: *Value added for output constant to 1990 price*	OLS	National: FDI_industrial insider +** 　　　　FDI_industrial insider#regional 　　　　insider +***	NIES(NBS CC), self calculation

28

M.X. (2016)		10158 Coastal regions: 26060 Inland regions: 10160	spillovers Some evidence	**IV**: 'insider' FDI, 'outsider' FDI, capital stock, employment		FDI_industrial insider#regional outsider + FDI_industrial outsider −*** FDI_industrial insider#regional insider − FDI_industrial outsider#regional outsider −*** Interior: FDI_industrial insider#inland insdier +** FDI_industrial insider#inland outsider −*** FDI_industrial outsider#inland insider + FDI_industrial outsider#inland outsider −*** Coast: FDI_industrial insider#coast insdier +*** FDI_industrial insider#coast outsider + FDI_industrial outsider#coast insider + FDI_industrial outsider#coast outsider −*	based on ISIC
Wang, Y., Ning, L., Li, J., & Prevezer, M. (2016)	1999-2008	30 regions	Foreign direct investment spillovers and the geography of innovation in Chinese regions: The role of regional industrial specialization and diversity	**DV**: *Patent applications/10000 inhabitants* **IV**: R&D expenditures/GDP, residents with a tertiary degree, GDP growth rate, FDI, industry specification, industry diversity	OLS; ML spatial regression	FDI: + FDI*industry specification: - FDI*industry diversity: +	CIESY, DCMSTI, NBSCC, CSY, SIPO, MOST

Note: NIES: National Industrial Enterprise Survey; CIESY: Chinese Industry Economy Statistics Yearbooks; DCMSTI: the Database of China Main S&T Index; CSDMNC Comprehensive Statistical Data and Materials on 50 years of New China; CHISY: China High-tech Industry Statistical Yearbook, CSYST: China Statistical Yearbook on Science and Technology; CTSY: China Technology Statistical Yearbook.

＋ − refer to positive and negative effects, respectively; L1 is lagged one year; 0 shows no significant impact; ~ means "from"

*, **, *** mean significant at, respectively 10%, 5%, 1%

Appendix 4: Descriptive statistics of main regression variables

Var.	Obs.	Mean	Std. Dev.	Min	Max
LN_PAT_i Patent domestic applications accepted (item) per 10,000 inhabitants in logarithm	496	0.94	1.39	-2.88	4.28
LN_PAT_i_i Invention patent domestic applications accepted (item) per 10,000 inhabitants in logarithm	496	-0.38	1.54	-4.22	3.71
LN_PAT_u_i Utility models patent domestic applications accepted (item) per 10,000 inhabitants in logarithm	496	0.08	1.35	-4.48	3.41
LN_PAT_d_i Designs patent domestic applications accepted (item) per 10,000 inhabitants in logarithm	496	-0.48	1.43	-3.80	3.47
L1_LN_FDI_i Lagged 1 year FDI stock intensity (annual %)	464	-4.15	1.20	-8.90	-1.65
L2_LN_FDI_i Lagged 2 years FDI stock intensity (annual %)	433	-4.15	1.21	-8.90	-1.65
L3_LN_FDI_i Lagged 3 years FDI stock intensity (annual %)	402	-4.14	1.23	-8.90	-1.65
L1_LN_RGDPpc Lagged 1 year regional real gross domestic product per capita (yuan/man) in logarithm	465	2.70	0.69	1.00	4.44
L1_LN_RDpt Lagged 1 year full–time equivalent of R&D Personnel (man–year) in logarithm	465	10.37	1.38	5.39	13.14
L1_LN_X_i Lagged 1 year export intensity (annual %) in logarithm	465	-2.37	0.97	-4.78	-0.09

Source: Author's calculation

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