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Foreign Direct Investment and Technological Spillovers: Evidence from China's Regions

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Abstract

Using patent application data sets for China's 29 provinces between 1989 and 2003, this paper examines intra- and inter-regional technological spillovers arising from foreign direct investment (FDI). Using the conceptual frameworks of 'home-neighbourhood' and 'coast-centre-west step-ladder', the results support the existence of positive intra- and inter-regional spillovers from FDI between China's provinces in general, and between three sub-national areas in particular. However, intra- and inter-regional spillovers differ for each sub-national area and no evidence is found of a 'step-ladder' pattern in the FDI technological spillovers in China.

Keywords: Technological spillovers; foreign direct investment; regional development; innovations; patents.

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1. Introduction

One of the leading motives of Chinese government policy in encouraging inward foreign direct investment (FDI) is the belief that multinational enterprises (MNEs) will bring significant technological benefits to Chinese domestically-owned enterprises. China's FDI policy has been to allow its coastal regions to first achieve technological progress through inward FDI, and then through spatial interaction, to spread the benefits of this to inland areas.

FDI technological spillovers (hereafter "spillovers") arise when indigenous firms enjoy technological benefits from the presence of foreign investment. Externalities from MNEs' activities occur through, for example, forward and backward linkages, competition, market access externalities, employee turnover, and imitation (Blomstrom and Kokko, 1998). These channels largely depend on direct and indirect contacts between MNEs and local firms in the same or different industries, and this accounts for the prevalence of studies of spillovers at the firm and industry levels. Empirical studies have produced mixed results (e.g., Buckley, et al. 2002; Haddad and Harrison, 1993; Hu and Jefferson, 2002; Young and Lan, 1997). The locational dimension to industries and firms mean that all the regional connections through which FDI spillovers impact on the host economy necessarily have a geographical context (Cohen and Paul, 2005). It follows that geographical factors may have a significant influence on the pattern and strength and direction of FDI spillovers.

This paper investigates the hypotheses that (1) there are bi-directional spillovers among China's three sub-national areas, (2) there are both intra- and inter-regional spillovers within each of the sub-national areas, and (3) the strength of these spillovers differs in each sub-national area.

The paper is organized as following. Section 2 reviews the literature, section 3 present the data and methodology, section 4 analyzes the estimation results, and the conclusion is given in section 5.

2. Literature review

2.1 FDI and technological spillovers

Technological spillovers, which are a form of externality arising from market failure, imply the involuntary diffusion of resources, particularly technological knowledge (Saggi, 2002; Sinani and Meyer, 2004). FDI and technological spillovers have been analysed in three streams of research - industrial organization theory, the literature on knowledge spillovers and studies of FDI and growth. The first stream demonstrates that MNEs' operations transfer a package of assets, including superior technologies to host countries, and that the process of international technology transfer is facilitated by internalisation strategies (Caves, 1974; Blomstrom and Kokko, 1998; Buckley and Casson, 1976; Dunning, 1988). The second stream focuses on FDI and international trade as key conduits of international knowledge flows, the scale and magnitude of which technological diffusion varies with geographical and technological distance (Hejazi and Safarian, 1999; Walz, 1997). The third stream analyzes the endogenous relationships between MNEs' production and domestic growth and argues that inward FDI plays the role of a "growth engine" for host countries (Borensztein et al., 1998). Through this mechanism externalities arising from FDI have an impact on the long term growth of a host country. In surveying the three streams, Blomstrom and Kokko (1998) show that FDI spillovers occur not only through direct technology transfer, but also through labour turnover, demonstration effects, vertical linkages, and competition effects.

While the theoretical literature supports the concept of spillovers, the measurement of externalities is not straightforward in practice (Krugman, 1991). Empirical work has been undertaken at both the firm and industrial levels. Firm-specific factors, such as the motives of MNEs transferring technology to their subsidiaries in host countries and the ability of domestic firms to adopt new technology, were found to determine intra- and inter-firm spillovers (Haddad and Harrison, 1993). At the industrial level, results are found to be mixed for both intra- and inter-industry effects. There is supporting evidence of positive spillovers (Blomstrom and Persson, 1983), and evidence of negative or insignificant spillovers arising from competitive effects (Aitken and Harrison, 1999).

The transmissibility of different types of knowledge results in spillovers having a spatial dimension. Demonstration and imitation effects normally involve the diffusion of tacit knowledge (e.g., management) and codified knowledge (e.g., external design of products). In contrast, codified knowledge can be efficiently transferred through remote communication methods, such as the internet, across great distances (Ibert, 2007). Technological spillovers stemming from the diffusion of codified knowledge may occur in any location where the appropriate communications infrastructure is available. On the other hand, tacit knowledge diffusion normally requires face-to-face contact, and the spatial dimension of FDI spillovers results from this (Funke and Niebuhr, 2005).

Previous studies of FDI-related spillovers in China have not used patent activities as an explicit indicator of domestic innovations. The only exception is Cheung and Lin (2004), who investigated the relationship between inward FDI and three types of domestic patent applications in China's provinces. Although they found empirical evidence of a positive impact from FDI, the regional mechanism of spillovers remains unclear.

2.2 Intra-regional spillovers

Intra-regional spillovers occur when FDI activities in a region have impact on domestic innovation activities in the same region. Findlay (1978) emphasizes that "technical innovations are most effectively copied when there is personal contact between those who already have the knowledge of the innovation and those who eventually adopt it" (Findlay, 1978, pp. 3). Krugman (1998) suggested that there might be geographical boundaries to R&D spillovers, particularly because of tacit knowledge.

Joint ventures are likely to be important sources of intra-regional spillovers. Foreign firms tend to choose local partners within the same geographic region. When a joint venture is set up, a mutual learning opportunity is formed for both foreign and local partners (Inkpen, 2000). While one can argue that MNEs do not share all their knowledge with subsidiaries, it is rational to assume that both foreign and local participants in joint ventures have complementary knowledge resources (Buckley and Casson, 1996). Under the imperfect markets assumption, innovative knowledge that is not fully internalised could easily diffuse to local entities that are geographically close to the knowledge resource.

In addition to the effect of joint ventures, intra-regional spillovers arise when employees move to local firms locally (Blomstrom and Kokko, 1998). It is suggested by Zhu and Tan (2000) that employee-related spillovers from FDI are confined to areas such as cities due to the limited spatial mobility of workers. The presence of foreign firms generates employment for local people with specialized skills. Therefore, technological knowledge is transferred within a restricted area because the movement of its carriers, such as employees, is localized (He, 2002).

Intra-regional spillovers from FDI also accumulate. Geographical clustering of economic activities causes FDI spillovers to be more likely to accumulate within a region. New economic geography suggests that the backward and forward linkages in manufacturing generate centripetal forces in agglomerations (Krugman, 1998). Foreign firms and their local suppliers tend to be spatially close for cost reasons. Technological benefits from FDI can be localised through serving local customers and contracting with local suppliers. Intra-regional spillovers could also be enhanced if knowledge accumulation process speeds up through regional innovation networks. “Innovations are hardly the outcome of isolated actions but rather the result of consciously planned market motivated R&D efforts jointly realized by a set of interrelated private and public actors” (Greunz, 2005, p. 453).

2.3 Inter-regional spillovers

Inter-regional technological spillovers from FDI arise when inward FDI has an impact on domestic innovations not only within the same region, but also in other regions. Positive technological spillovers from foreign firms could be felt first by neighbours before diffusion to other domestic firms, and the gradual spread to more distant domestic firms (Aitken and Harrison, 1999).

Empirical work by Javorcik and Spatareanu (2005) suggests that foreign investment related spillovers are more likely to be vertical rather than horizontal. Diseconomies of clustering arise when foreign firms decide to choose suppliers in remote areas where factor prices are low. When such backward linkages are formed between regions, innovations initiated by local suppliers will benefit from foreign investment located in another region. Similarly, forward linkages are likely to be formed when foreign firms decide to produce in one region and serve customers in another. Domestic innovations stimulated by foreign products and services embodying imported technologies could arise within the same region as their final markets are or where their production and R&D platforms are located.

The limited mobility of human capital is derived principally from the geographical concentration of FDI spillovers according to industrial linkages. Additionally the tacitness of knowledge makes it ‘sticky’. Thus a successful transfer of technology may largely depend on the frequency and efficiency of direct contacts between foreign employees and local R&D personnel. With increasing labour mobility knowledge diffusion becomes easier. Thus spillovers from FDI may occur when people travel across regions. In China labour migration is increasing (Bao, et al., 2002). Most of this labour migration is low-skilled labourers. However, the increased travel among knowledge workers will transfer technology regionally.

Studies of growth suggest that inter-regional spillovers reflect the Veblen-Gerschenkron effects from FDI. Local firms in backward regions are hypothesized to benefit more from FDI from advanced regions than their counterparts in more advanced regions. Peri and Urban (2006) argued that while the largest concentration of foreign firms usually occurs in regions and sectors where domestic firms are already highly productive, the largest spillover effects might be felt in backward regions, where FDI concentration is small. Walz (1997) found that some inter-regional spillovers occurred due to the spatial separation of R&D and production activities and inter-regional knowledge spillovers and technological catch-up took effect if the initial technology gap was not wide (Nocco, 2005). In the case of China, there has been a shift from primarily export-oriented FDI (Zhang, 2000) to market-seeking FDI (Buckley, et al. 2002). Local-market-oriented foreign affiliates may need to employ localized strategies to serve domestic markets and compete with local rivals. This can lead to foreign firms' R&D and production activities both being carried out in host country, possibly in different locations. We assume that domestic innovations within a region are determined by foreign investment in neighbouring regions. Put differently, innovations in the "home" region depend on the knowledge pool of its "neighbourhoods".

China, for most purposes, can be divided into three sub-national regions, the coastal area, the central area, and the remote West (Sandberg, 2004). Because of significant geographical differences, the Chinese government has employed a 'step-ladder' developmental strategy during the course of its economic liberalization. There are likely to be spatial differences in FDI spillovers because of historical legacies of industrial development, differences in human capital accumulation, institutional variety, and diverse cultural and ethnic backgrounds. It is therefore hypothesized that there are inter-regional spillovers among China's sub-national regions in general, and there are stronger inter-regional spillovers within each sub-national region.

3. Research methods

3.1 Data

This paper uses panel data from China's 29 provinces, autonomous regions and municipalities ("regions" hereafter) between 1989 and 2003. Innovations are proxied by the number of domestic patent applications examined or granted. The total number of observations is 435. Data were collected from China Statistical Yearbooks and Comprehensive Statistical Data and Material on 50 years of New China (National Bureau of Statistics, 1999).

Our data set runs from 1989 to 2003. For patent data, the available time period starts from 1985 when the patent law was first implemented in China. Other proxies of domestic innovations, such as the transaction value of the domestic technical market and total factor productivity are also used to justify the robustness of the empirical models. Because the data of the transaction value of the domestic technical market was first collected by the Chinese government in 1988, to improve the comparability of the result for all the four proxies of domestic innovations, we choose to examine the period starting from 1989 allowing for a one year lag for measuring the accumulation of spillovers.

Figure 1 and table 1 display the distribution of the total number of domestic patent applications and inward FDI across China's provinces for the year 2003. First, we observe a great level of variations of both patents and FDI across China's provinces. Second, the distribution of patents and FDI are of different nature in three sub-national areas. In 2003 coastal regions hosted most inward FDI (86.95%) and were responsible for more than three quarters (77.77%) of the total patent applications. Central regions seem to be more "innovative" than the Coast in that with a share of 11.24% of inward FDI, they account for 14.92% of domestic patent innovations. Western regions show a significant innovation potential holding 7.32% of total patent applications although hosting only 1.81% of inward FDI. The observation that areas hosting more FDI overlap with those with more patents gives some level of prima facie support for the hypothesis that domestic innovations are positively associated with inward FDI, over the period under consideration. However, the high volume of inward FDI in coastal China does not necessarily predict an equivalent magnitude of domestic innovations in those areas. The difference between the share of FDI and the share of domestic innovations in each area implies that there may be different degrees of inter-regional and intra-regional technological spillovers from FDI in effect.

Insert figure 1 and table 1 here

3.2 The estimation model

The empirical approach for intra- and inter-regional analysis is to take into account the source region where technological knowledge is available and the destination region where the knowledge spillover is finally received (Funke and Niebuhr, 2005; Greunz, 2003, 2005). In this paper, they are denoted "home" and "neighbouring" regions, respectively. The "home-neighbourhood" framework refers to not only the geographical proximity (Bode, 2004; Sjoerd and Maarten, 2002), but also the technological distance between regions (Nocco, 2005).

Although geographical distance is straightforward in calculation, technological neighbourhood is defined in various ways. The related calculation is closely linked to terms like "absorptive capacity" (Cohen and Levinthal, 1990; Buckley, et al.,

2002) and “technology gap” (Nocco, 2005). To choose an appropriate measure of each region’s technology level, this paper calculates technological proximity using a ranking index which compares a region’s GDP to the maximum GDP of the nation and sub-national areas, respectively. We assume the closer the two regions are in this ranking index, the closer the level of technology the two regions have.

We use an analytical framework derived from a knowledge production function initiated by Griliches (1979), and adopted by Greunz (2003, 2005). The empirical models are as follows:

$$\begin{aligned} Innovation_{it} &= \beta_0 + \lambda Innovation_{i(t-1)} + \beta_1 FDI_{it} + \beta_2 NFDI_{it} \\ &+ \beta_3 HC_{it} + \beta_4 Communication_{it} + \beta_5 Trade_{it} + \varepsilon_{it} \end{aligned} \tag{1}$$

$$\begin{aligned} Innovation_{it} &= \beta_0 + \lambda Innovation_{i(t-1)} + \beta_1 FDI_{it} + \beta_{coa} CoaFDI_{it} + \beta_{cen} CenFDI_{it} \\ &+ \beta_{wes} WesFDI_{it} + \beta_3 HC_{it} + \beta_4 Communication_{it} + \beta_5 Trade_{it} + \varepsilon_{it} \end{aligned} \tag{2}$$

where subscripts i and t denote provinces and time period, respectively; ε_{it} is the error term. Equation (1) examines spillovers from FDI in the “home” region and the neighbourhood, respectively. Equation (2) further examines these effects for the coastal, central, and western China, respectively. Both models are estimated for both the full-sample (all regions) and sub-samples (three sub-national regions).

$Innovation_{it}$ is the natural logarithm of domestic innovations, measured by three proxies - the number of patent applications granted ($PATG_{it}$) and examined ($PATE_{it}$), the transaction value in the technical market (TVT_{it}), and total factor productivity (TFP)[1]. The last proxy is used to justify the robustness of these models.

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[1] TFP_{it} is calculated in the general growth accounting approach:

$$\mathrm{T}FP_{it} = \frac{Y_{it}}{C_{it}^{\ \beta_i} L_{it}^{(1-\beta_i)}} \tag{7}$$

where Y_{it} is total output in each region, measured by real GDP; C_{it} is the stock of capital, which is calculated from the total investment in fixed assets using perpetual inventory method; L_{it} is employment; β_i is the share of

Previous studies on innovation have used domestic productivity as a proxy for technological progress. However, innovations can be more accurately measured by patent activities. There are good reasons for using this type of data. Patents are a direct proxy for innovations because they record most of the inventions across a wide range of technologies. Patents are also linked with the demand side of innovation. A patent right indicates intellectual products and properties that can be bought or sold in the technology market. Every patent has a finite life period. Therefore, patent data is a dynamic indicator of up-to-date innovations (Griliches, 1990). Using the number of patent applications has disadvantages, however. Some patents are of immense value due to market demand, but some other patents may have no value if there are no industrial applications for them. In patent counting, the skewness caused by this fact may not be corrected because all patents are assumed to be of the equal value. However, for the purposes of this study, this limitation is not a significant drawback.

On the right hand side of the equations, $Innovation_{i(t-1)}$ is the dependent variable lagged for one year. The coefficient λ measures the dynamic effect of knowledge production and captures the accumulating nature of knowledge formation. Doering and Schnellenbach (2006, p. 386) emphasize that 'knowledge is absorbed relatively easier in regions that already have relatively higher productivity level and a larger stock of knowledge'. Maurseth and Verspagen (2002) also stressed that 'localized

capital. β_i is estimated from a Cobb-Douglas production function under the neutral technical change assumption (e.g., Solow, 1956). Following Hofman (1992), capital stock is measured using perpetual inventory methods (PIM), assuming 10% annual depreciation. The standard PIM calculation is:

$$K_t = K_{t-1}(1-\delta) + I_t \tag{8}$$

where K_t is the capital stock in year t; K_{t-1} is the capital stock in year t-1, δ is the depreciation rate; I_t is the capital formation in year t, which is measured as total investment in fixed assets in year t.

nature of innovation processes' was fostered by local milieux and the accumulation of knowledge was geographically concentrated. A general approach to test the accumulation effects is to include the lagged dependent variables on the right hand side of the equation. By so doing, it also captures all the other influential factors of the domestic innovations that are not explained by the rest of the independent variables. There are many examples of this kind of model in the literature, including Driffield (2006) and Cantwell and Piscitello (2005).[2]

FDI_{it} is the inward FDI in the "home" region, measured by the natural logarithm of the realized value of FDI in region i. FDI as one of the most important channels of international technological diffusion (Hejazi and Safarian, 1999) transfers a set of assets including superior technologies to the host country and should significantly benefit domestic firms' innovation activities. This process of direct and indirect technology transfer through FDI contributes to the domestic knowledge pool, and makes inward FDI an important input for domestic knowledge production (Greunz, 2005).

$NFDI_{it}$ is the natural logarithm of FDI in the "technological neighbourhood", measured by a weighted mean of FDI inflows in the neighbouring regions of region i. Following Greunz (2003) and Funke and Niebuhr (2005), a set of spatially conditioned indices of technological gaps are used in this paper as a weighting index for $NFDI_{it}$. The analytical method of technological gaps between two regions is developed from Nelson and Phelps (1966) in a work of formalizing the Veblen-Gershcenkron effect, where the technological gap was defined as the lag between the "best practice" and the actual technology that could be readily adapted.

[2] For more discussion of the econometric specifications, see Baltagi (1996, chap. 8, 125-148).

Following the Nelson-Phelps approach, technological gaps are defined here by the difference between the GDP per capita of the province and the maximum GDP per capita of other provinces. The Gap indexes, GAP_{it}, are calculated as follows:

$$GAP_{it} = \frac{GDP_{\max,t} - GDP_{it}}{GDP_{it}} \tag{3}$$

$$NFDI_{it} = \frac{\sum_{j=1, j\neq i}^{28} (FDI_{jt} \times GAP_{jt})}{\sum_{j=1, j\neq i}^{28} GAP_{jt}} \tag{4}$$

where t is the year, indicating the index should vary with time; $GDP_{max,t}$ is the maximum GDP per capita of each year. $NFDI_{it}$ is calculated as a weighted mean of FDI in all the other provinces excluding the province i itself. The above two formulations show that the smaller the technological gap of a region is relative to the "best practice" region, the larger the impact of this region's inward FDI on domestic innovations.

$CoaFDI_{it}$, $CenFDI_{it}$, and $WesFDI_{it}$ are the natural logarithm of "neighbouring" FDI in coastal, central, and western areas, respectively.[3] For a coastal region i, its $CoaFDI_{it}$ is zero since the region itself is located in the coastal area, and its $CenFDI_{it}$ and $WesFDI_{it}$ are the weighted values of total FDI in each of these two areas, respectively. The weight is the ratio of GDP per capita of province i to the average GDP per capita of the area that province i belongs to. For example, the weight calculated for $CoaFDI_{it}$ is as follows:

$$CoaFDI_{it} = \frac{GDP_{it}}{GDP_{average}^{(coa,cen,wes)}} \times Dummy_i \times \sum_{j=1}^{12} FDI_{jt} \tag{5}$$

[3] Central provinces include Heilongjiang, Jilin, Inner Mongolia, Shanxi, Henan, Anhui, Hubei, Jiangxi, and Hunan. Western provinces include Xinjiang, Qinghai, Sichuan, Gansu, Shaanxi, Guizhou, Yunnan, and Ningxia. Coastal provinces are the rest. Due to data availability, the two western regions, Chongqing and Tibet, have been excluded in all estimations.

where the superscripts, *coa*, *cen*, and *wes*, denote that $GDP_{average}$ is calculated as the average GDP per capita of the area where the province is located; $Dummy_i$ denotes dummy variables, taking the value of 1 for the province in coastal area, and 0 otherwise.

HC_{it} is human capital, measured by the number of students enrolled in higher education. Human capital is a proxy for technological knowledge stock (Greunz, 2003). It is assumed that most graduating students choose to work within the same region, reinforcing the human capital stock of the region in question. $Communication_{it}$ is the degree of information exchange, measured by the first difference of per capita business volume of post and telecommunication services. By including this variable, we expect that the improvement in communication services lowers the transaction costs of knowledge transmission, and partly explains those technological spillovers that may be stimulated through incoming publicly available information (Cassiman and Veugelers, 2002). $Trade_{it}$ is the growth of per capita trade volume, measured by the first difference of per capital imports plus exports. Trade is an important channel of international knowledge transfer (Saggi, 2002). Innovative knowledge could be embodied in traded goods and domestic innovations could benefit from the openness of a region's economy to international markets, for which the growth of total trade volume is a conventional indicator.[4]

[4] We also estimate the models with other control variables such as domestic investment, measured by the rate of total investment of fixed assets in each province to the provincial GDP. However, the revised models do not significantly improve the adjusted R^2. The results are available from the authors upon request. Ideally, domestic investment in R&D activities as well as the number of domestic R&D personnel would be more suitable variables to be included because they measure the inputs for the domestic innovation activities. Unfortunately, data of these variables, such as the intramural expenditure for science and technology, national R&D expenditure, and the number of scientific and technical personnel in state-owned enterprises and institutes, were not systematically collected by the National Bureau of Statistics (NBS) until 1990s. Despite these constraints, our model can minimize the problem of omitted variables bias through the inclusion of the lagged dependent variable on the right hand side of the equation, which helps capture unobserved influential factors that are not explained by those independent variables.

Both two stage least square (TSLS) and generalized moment method (GMM) estimation techniques can solve the potential endogeniety problem arising from the inclusion of lagged dependent variables as explanatory factors (Bhargava and Sargan, 1983; Baltagi, 1996; Crepon and Duguet, 1997). These two techniques can also minimize the possible simultaneity bias problem arising from the 'performing regions' effect by controlling region-specific effects. While inward FDI is expected to have a positive effect on the innovation activities of China's provinces, foreign MNEs are more likely to be attracted to provinces where domestic innovative capability is higher so that they may be able to draw on a larger 'pool' of technological and scientific knowledge (Wang, et al., 2008). Generally, TSLS is a special form of GMM, which uses a weighting matrix for the suspicious endogenous variables to eliminate the endogeneity. To verify whether a right weighting matrix has been chosen for GMM method, Sargan test (Bhargava and Sargan, 1983) is used. We also use TSLS for comparison.

4. Estimation results

4.1 Results from estimations under the "home-neighbourhood" framework

The estimation results using GMM method are shown in tables 3, 4 and 5. The results for $PATE_{it}$ are similar to those of $PATG_{it}$. Results for TVT_{it} are insignificant in general, which reflects the immaturity of technical markets in China. For simplicity, results for $PATE_{it}$ and TFP_{it} are shown in tables 3, 4 and 5. Table 2 presents the descriptive statistics for all variables.

Insert table 2, 3, 4 and 5 here

Under the 'home-neighbourhood' framework intra- and inter-regional spillovers are reflected by the coefficients for FDI_{it} and $NFDI_{it}$, respectively. Two main findings follow. First, in the full-sample estimations (table 3), it is found that there are significant spillovers from FDI on domestic innovations in general, and all significant spillovers are positive. This is consistent with many studies supporting the profound technological spillovers in China during last decade (Hu and Jefferson, 2002; Liu, 2002; Cheung and Lin, 2004).

Second, it is found that inter-regional spillovers among China's regions seem to be much more pervasive than intra-regional spillovers. The coefficients for $NFDI_{it}$ are positive and significant in all estimations and the coefficients of $NFDI_{it}$ are generally larger than those of FDI_{it} in all regressions except for the one for TFP_{it}. Sub-sample estimations show that the coefficients for FDI_{it} are only significant in central China (table 4) while there seems to be limited evidence of intra-regional spillovers in the Coast and the West. In table 4, intra-regional spillovers in the Centre are found only significant for TFP_{it} but not for patent activities. In terms of the western area, little evidence of intra-regional spillovers is found for any of the proxies for domestic innovations. There may be different reasons for insignificant results found for the Coast and the West.

The evidence of strong inter-regional spillovers demonstrates that within each area, with the passage of time, FDI spillovers arising within a province gradually roll out of the geographic boundary where they originate, reaching domestic firms in nearby provinces (Aitken and Harrison, 1999) through deepening supplier-buyer relationships between foreign and local firms and labour movement across the provinces within the area. A strong element of the FDI policy of Chinese government is 'local contents'. Under this policy, foreign firms must use a certain percentage of raw materials or intermediate inputs produced by local firms in their production process. Earlier Chinese policy for FDI also featured strong encouragement of formation of joint ventures between foreign and local firms. These policies, in combination with significant flow of labour between foreign and local firms and between different regions, are the key sources of inter-regional spillovers.

Furthermore, linkages between foreign affiliates and local suppliers may be first developed within a region for considerations of cost and financial incentives, but are likely to extend gradually into geographically contiguous and far regions according to Javorcik and Spatareanu (2005) who finds more evidence in favour of vertical rather than horizontal spillovers in developing countries. Also, innovations, especially those of fundamental in nature, often involve a high level of inter-provincial cooperation for reasons of cost sharing. The impact of FDI on innovations is thus not necessarily greater for the home province than for other neighbouring provinces.

Next, the results for each sub-national area are explained. Central China is found to benefit from FDI through both intra- and inter-regional spillovers. This may be due to its geographical advantage of being close to the coast, benefiting from low transaction costs and supplying a large proportion of the workforce migrating in the coastal economy. It is also due to the close industrial linkages between central provinces and the rest of China. Central China acts as a bridge supplying and transferring industrial inputs and outputs for the Coast and the West. This result is consistent with the study by Cheung and Lin (2004), who found only design patents were significantly influenced by FDI in coastal regions while spillovers were found to be significant for all types of patents in central China.

Hosting most of inward FDI, coastal provinces benefit from productivity spillovers from FDI through channels such as export access, production hardware upgrading and supplier training. However, in terms of technology specific innovations like patents, the insignificant intra-regional spillovers in the coastal region might arise for the following reasons. Coastal China hosts most foreign activities, but the intra-regional technology diffusion from FDI has moderated due to competition, imitation and other externalities. Technological benefits from FDI are arguably productivity spillovers, because in the early stages of China's economic liberalization most foreign firms aimed to take advantage of the abundant rural low-skilled labour resources. This could have resulted in only minor incentives to domestic R&D being stimulated by foreign activities (Young and Lan, 1997). Another explanation is that spillovers may tend to be exhausted within a particular region as all local firms in the same province will learn less and less from foreign firms after a certain period of time. After the initial significant transfer of technology from parent firms to their foreign affiliates, the transfer of key technology will be of gradual and incremental nature when the period of start-up is over. Hence, the scope for positive spillovers from assimilating foreign technology will tend to decline gradually (Buckley et al. 2006).

Western China has historically had a very low density of inward FDI. State-owned enterprises (SOEs) still dominate the economic landscape of the West and there is no a strong non-state sector. The low absorptive capacity and incentive to learn of SOEs limit their ability to reap spillovers arising from foreign presence. The limited spillovers may also be associated with the still significant barriers to exit for SOEs, causing spillovers not be fully realized through competition effects (Wang and Yu, 2006). These findings are consistent with the perspective of economic geography which suggests that regions with contrasting features produce different patterns of spillovers from FDI. Under this scenario, should foreign operations lead to technological diffusion to the neighbouring domestic enterprises, it is not surprising to see domestic innovations in the West benefit little from foreign activities. Nevertheless, it is found that there are significant inter-regional spillovers to the western area. With relatively competitive technological capability (as shown in table 1) domestic innovations in the West actually benefited from ‘neighbouring’ FDI as a whole.

4.2 Results from estimations under the “step-ladder” framework

According to the ‘step-ladder’ hypotheses, the coefficients for $CoaFDI_{it}$, $CenFDI_{it}$, and $WesFDI_{it}$ measure spillovers between three sub-national regions. In table 3, it is found that all inter-regional spillovers are significant and positive in full sample estimations. There seem to be compatible impacts from FDI in coastal, central, and western areas, while the coefficient of FDI_{it} becomes insignificant for the patent proxy, indicating that technological spillovers are more sensitive to technological proximity than geographical closeness. The significant results for the TFP_{it} proxy confirm the spatial dimension to the findings of many studies that FDI spillovers in China are mainly productivity spillovers (e.g. Buckley et al., 2002).

In table 5, sub-sample estimation results are consistent with those of full sample. It is found that there is little evidence of a ‘step-ladder’ pattern of FDI spillovers. For the coastal region, domestic patent innovations are found to benefit from FDI in central and western regions but not in the coastal region. Central provinces similarly seem to enjoy spillovers from both the Coast and west. Western provinces seem to be also able to benefit from inward FDI without spatial constraints. This may reflect the fact that western regions are technologically closer to the rest of China than they are geographically close.

It is plausible that FDI in the coastal area produces positive effects on the innovations of central area and these effects further extend to the western area through channels such as industrial linkages and possibly through labour movement as well. The relatively strong technological base and (thus) absorptive capacity in the central and western regions helps to facilitate materialization of such spillovers. It is also not surprising that FDI in the central area is important for the other two areas since this area acts as a bridge linking economic and technological activities to both coastal and western areas due to both geographical and technological proximity.

It appears counterintuitive, however, to the ‘step-ladder’ hypothesis that results in table 3 and 5 consistently show FDI in the western regions producing positive impacts on the innovation activities of central and coastal areas. One possible explanation relates to the nature of investments by foreign firms in the West. Inward investment in this area is characterised by a concentration in natural resources and raw material industries. This is the result of the policy of Chinese government on regional development, which assign the central and western China the mission to back up the Coast with natural, agricultural and mineral resources (Zhao and Tong, 2000). Foreign firms in this area therefore provide raw materials that become initial inputs of production for firms in the central and coastal regions, which in turn promotes innovation. Our results could also be caused if foreign firms' reinvestment and FDI relocation within China leads to the greater observance of comparative advantage between the regions. Foreign investors in the coastal provinces may choose to place subsequent investments further inland, or relocate productive activities away from the coast that are losing locational advantage. This reorganisation investment would raise productivity, and could raise innovation, in both the coast and the newly invested regions.

The coefficients of the lagged dependent variable are significant in all full sample and sub-sample estimations. This offers evidence of the existence of a knowledge accumulation process in China's economic development. The coefficients of other variables: human capital, communication, and trade, are generally significant for patent applications. This confirms that these three factors are important channels for regional spillovers (Cassiman and Veugelers, 2002; Saggi, 2002; Greunz, 2003).

5. Conclusion

Our results support the existence of positive intra- and inter-regional spillovers from FDI between China's provinces in general, and between three sub-national areas in particular. However, intra- and inter-regional spillovers differ for each sub-national area and no evidence is found of a 'step-ladder' pattern in the FDI technological spillovers in China.

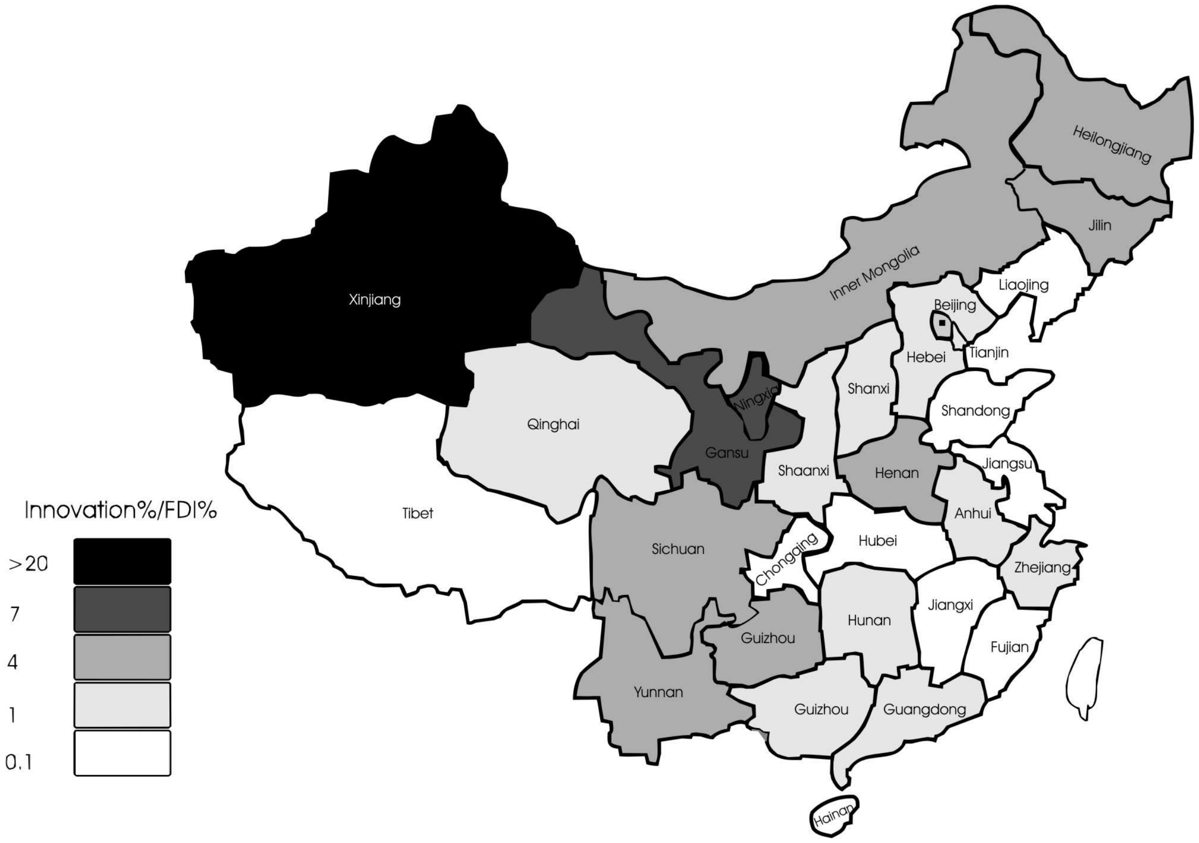
Our findings suggest that attraction of inward investment emerges as a very successful general policy that betters domestic innovations in China through the channels of spillovers. More specific policy implications follow. First, attracting more inward investment has been gaining prominence in the policy agenda of China's provincial governments. This policy is based on the expectation of a positive association between the amount of FDI attracted and economic growth of the region in question. Our findings suggest that this policy is myopic because it ignores the positive role of FDI in neighbouring regions in promoting economic and technological development in the 'home' region. Future provincial policy should therefore aim not only to attract more foreign investment into the 'home' region but also to create conditions for reaping more spillovers from FDI in other regions by encouraging relevant industrial linkages and labour movement. In other words, absorption of inter-regional spillovers can be viewed as an integral part of the provincial FDI policy towards the enhancement of technological development.

Second, the explicit regional policy of the Chinese central government has been to first develop the eastern coastal provinces through attracting inward FDI, and subsequently to roll the FDI policy westwards through the interior towards the western provinces. Our finding of evidence of spillovers across the three macro regions suggest that this policy goal may be partly reached by encouraging local firms in the central and western regions to absorb spillovers arising from FDI in the coastal region, in addition to attracting inward FDI to these two regions.

Third, the findings of declining spillovers in the coastal China and the lack of intra-regional spillovers in terms of patent applications argue for policy measures to attract technology-intensive foreign firms, to provide effective competition to foreign firms, to improve the efficiency of knowledge transfer especially within provincial boundaries.and to strengthen the regime of intellectual property protection in order that spillovers can be sustainable.

Lastly, a single investment policy may be not applicable for a large country like China. The different geographical and technological features of each region result in significant differences in the degree of technological impact from inward FDI, which in turn will lead to further disparities. The policy framework needs to recognize that western China is able to absorb technology and develop its own technological capability from other parts of China. On this evidence, policies encouraging investors to go to the western region are likely to generate strong local technological spillovers and therefore help the West develop technologically and, at the same time, enable the more developed regions to grow further through upgrading their industrial structures.

Figure 1 The relative performance of domestic innovations compared against inward FDI among China’s provinces.



Notes: The value of “Innovation%/FDI%” is the quotient of each province’s share of domestic patent applications relative to its share of inward FDI. This measure reflects whether provinces hosting a higher proportion of inward FDI are also more innovative than others, or vice versa. For details of domestic innovations and FDI see table 1.

Table 1 Table of rankings for patents and inward FDI in China

Coastal China					Central China					Western China				
Province	Patents	Patents in %	FDI	FDI in %	Province	Patents	Patents in %	FDI	FDI in %	Province	Patents	Patents in %	FDI	FDI in %
Guangdong	72421	20.09%	782294	14.85%	Hubei	9506	2.64%	156886	2.98%	Sichuan	11494	3.19%	41231	0.78%
Shanghai	39045	10.83%	546849	10.38%	Hunan	9229	2.56%	101835	1.93%	Shaanxi	5030	1.40%	33190	0.63%
Zhejiang	35865	9.95%	498055	9.45%	Henan	8222	2.28%	53903	1.02%	Yunnan	3179	0.88%	8384	0.16%
Jiangsu	28233	7.83%	1056365	20.05%	Heilongjiang	7766	2.15%	32180	0.61%	Xinjiang	2225	0.62%	1534	0.03%
Beijing	25251	7.01%	219126	4.16%	Jilin	5957	1.65%	19059	0.36%	Guizhou	1965	0.55%	4521	0.09%
Shandong	24861	6.90%	601617	11.42%	anhui	4286	1.19%	36720	0.70%	Gansu	1435	0.40%	2342	0.04%
Liaoning	19201	5.33%	282410	5.36%	Jiangxi	3672	1.02%	161202	3.06%	Ningxia	779	0.22%	1743	0.03%
Fujian	12613	3.50%	259903	4.93%	Shanxi	2918	0.81%	21361	0.41%	Qinghai	263	0.07%	2522	0.05%
Tianjin	9317	2.58%	153473	2.91%	Inner Mongolia	2210	0.61%	8854	0.17%					
Hebei	9195	2.55%	96405	1.83%										
Guangxi	3581	0.99%	41856	0.79%										
Hainan	741	0.21%	42125	0.80%										
Total	280324	77.77%	4580478	86.95%	Total	53766	14.92%	592000	11.24%	Total	26370	7.32%	95467	1.81%

Notes: Patents data is the total number of domestic patent applications examined and granted in 2003. FDI data is the realized value of inward FDI in 2003. All data in percentage is the quotient of each provincial value relative to national total. Chongqing and Tibet are not included in this table.

Table 2 Statistics for the variables and correlation matrix of explanatory variables

		Mean*	S.D.*	2	3	4	5	6	7	8
1	FDI_{it}	111434.51	209696.58	0.18	-0.34	0.41	0.44	0.47	0.42	0.43
2	$NFDI_{it}$	55420.32	28619.40		0.52	0.50	0.45	0.37	0.41	0.10
3	$CoaFDI_{it}$	1671680.88	1909930.68			-0.03	-0.04	0.04	-0.05	-0.24
4	$CenFDI_{it}$	208208.97	241705.59				0.28	0.26	0.57	0.48
5	$WesFDI_{it}$	57933.21	59177.99					0.41	0.47	0.39
6	HC_{it}	14.18	13.32						0.38	0.33
7	$Communication_{it}$	40.54	56.68							0.45
8	$Trade_{it}$	46.99	145.22							
9	$PATG_{it}$	1896.95	2877.09							
10	$PATE_{it}$	3176.86	4443.06							
11	TVT_{it}	136008.99	255040.47							
12	TFP_{it}	1.00	0.71							

Notes: * is the statistics of variables in original form without natural logarithm.

Table 3 Estimation results from the full sample for model (1) and (2) (N = 435)

Variables	$PATG_{it}$	TFP_{it}	$PATG_{it}$	TFP_{it}
$Innovation_{i(t-1)}$	0.56*** (651.43)	0.87*** (109.64)	0.55*** (429.69)	0.89*** (58.65)
FDI_{it}	0.02*** (19.72)	0.01*** (5.21)	0 (-1.15)	0.01*** (3.53)
$NFDI_{it}$	0.09*** (59.53)	0.05*** (8.73)		
$CoaFDI_{it}$			0.04*** (7.74)	0.02*** (5.17)
$CenFDI_{it}$			0.06*** (22.72)	0.01*** (3.02)
$WesFDI_{it}$			0.06*** (8.67)	0.03*** (8.44)
HC_{it}	0.01*** (20.80)	0 (0.17)	0.01*** (3.54)	0 (-0.03)
$Communication_{it}$	0.01*** (7.56)	0 (0.35)	0.01* (1.89)	0 (0.63)
$Trade_{it}$	0.01*** (20.47)	0 (0.29)	0.01*** (5.13)	0 (0.09)
Adjusted R^2	0.58	0.97	0.58	0.97
Sargan p value	0.608	0.186	0.166	0.203

Notes: Data are coefficients (t statistics). *, **, *** denote the coefficient significant at 10%, 5% and 1% level respectively. Data of $Communication_{it}$ are not available at the province level for the year 1999 and 2000. They are estimated using the national annual growth rate of 1998 and 2001.

Table 4 Estimation results for sub-sample areas (model (1))

Variables	Coastal area (N=180)		Central area (N=135)		Western area (N=120)	
	$PATG_{it}$	TFP_{it}	$PATG_{it}$	TFP_{it}	$PATG_{it}$	TFP_{it}
$Innovation_{i(t-1)}$	0.54*** (29.51)	0.85*** (48.88)	0.40*** (7.19)	0.82*** (40.51)	0.42*** (11.70)	0.87*** (35.53)
FDI_{it}	-0.17 (-1.36)	0.03*** (3.97)	0.01*** (6.90)	0.01*** (8.24)	-0.01 (-1.12)	0 (0.47)
$NFDI_{it}$	0.35** (2.00)	0.03*** (2.95)	0.16*** (4.81)	0.08*** (12.76)	0.20*** (8.59)	0.04*** (5.20)
HC_{it}	0.01*** (5.22)	0 (-0.21)	0.01*** (4.87)	0 (1.20)	0.01* (1.72)	0 (0.36)
$Communication_{it}$	0 (1.32)	0.01* (1.69)	0.01*** (5.16)	0 (1.20)	0.01* (1.67)	0 (0.51)
$Trade_{it}$	0.01*** (3.10)	0.01 (1.30)	0.01** (2. 81)	0 (-0.94)	0.01** (2.40)	0 (-1.02)
Adjusted R^2	0.57	0.98	0.69	0.96	0. 64	0.94

Notes: Data are coefficients (t statistics). *, **, *** denote the coefficient significant at 10%, 5% and 1% level respectively. Data of $Communication_{it}$ are not available at the province level for the year 1999 and 2000. They are estimated using the national annual growth rate of 1998 and 2001.

Table 5 Estimation results for sub-sample areas (model (2))

Variables	Coastal area (N=180)				Central area (N=135)				Western area (N=120)			
	PATG $_{it}$	*TFP* $_{it}$	*PATG* $_{it}$	*TFP* $_{it}$	*PATG* $_{it}$	*TFP* $_{it}$	*PATG* $_{it}$	*TFP* $_{it}$	*PATG* $_{it}$	*TFP* $_{it}$	*PATG* $_{it}$	*TFP* $_{it}$
$Innovation_{i(t-1)}$	0.56*** (89.76)	0.85*** (49.24)	0.57*** (61.23)	0.87*** (62.59)	0.42*** (7.33)	0.80*** (37.36)	0.53*** (13.10)	0.87*** (47.66)	0.41*** (12.25)	0.85*** (35.49)	0.45*** (17.25)	0.88*** (41.81)
FDI_{it}	-0.07 (-1.44)	0.03*** (4.35)	-0.02 (-0.63)	0.042*** (8.51)	0.01*** (5.85)	0.01*** (7.26)	0.01*** (4.44)	0.01*** (7.67)	-0.01 (-1.42)	0.01 (0.33)	-0.01 (-1.29)	0 (0.55)
$CoaFDI_{it}$					0.15*** (4.42)	0.09*** (12.74)			0.21*** (8.13)	0.05*** (6.54)		
$CenFDI_{it}$	0.15** (2.94)	0.02** (2.46)									0.14*** (8.36)	0.03*** (3.78)
$WesFDI_{it}$			0.13*** (3.04)	0.01** (2.27)			0.10*** (4.98)	0.06*** (8.67)				
HC_{it}	0.01*** (4.79)	0 (-0.73)	0.01*** (4.65)	0 (-1.13)	0.01*** (4.61)	0 (1.07)	0.01*** (5.20)	0 (-0.03)	0.01 (1.39)	0 (0.77)	0 (1.30)	0 (-0.06)
$Communication_{it}$	0.01** (2.25)	0.01* (1.74)	0.01*** (2.59)	0.01* (1.93)	0.01*** (5.04)	0.01* (1.83)	0.01*** (4.59)	0 (0.74)	0 (1.59)	0 (0.82)	0 (1.37)	0 (0.74)
$Trade_{it}$	0.01*** (3.33)	0.01* (1.81)	0.01*** (3.69)	0.01* (1.77)	0.01*** (2.85)	0 (-0.62)	0.01*** (3.63)	0 (0.96)	0.01** (2.44)	0 (-1.02)	0.01*** (2.30)	0 (-1.22)
Adjusted R^2	0.56	0.98	0.56	0.98	0.68	0.97	0.69	0.96	0.64	0.95	0.65	0.94

Notes: Data are coefficients (t statistics). *, **, *** denote the coefficient significant at 10%, 5% and 1% level respectively. Data of $Communication_{it}$ are not available at the province level for the year 1999 and 2000. They are estimated using the national annual growth rate of 1998 and 2001.

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