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FDI Spillovers in Chinese Urban Agglomerations: Comparative Analysis of the Yangtze River Delta and the Pearl River Delta *

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Abstract

Using panel data covering 25 cities in the Yangtze River Delta (YRD) and 21 cities in the Pearl River Delta (PRD) over the 1991-2010 period, the paper applies spatial Durbin model with ML estimation techniques to examine the underlying relationship between the productivity of the host cities and FDI spillovers. The main findings are as follows. First, significant positive impacts of FDI on the local city's growth exist and increase over time, while spatial spillovers of FDI on growth present significantly but behave oppositely in YRD and PRD. Second, spatial interaction plays an important and non-negligible role in urban productivity growth; however, in the long term, YRD and PRD have significant but opposite spatial effects of growth. Third, inclusion of FDI raises the speed of conditional convergence of economic growth in YRD and PRD (for the case of single-regime). Fourth, positively spatial spillover of growth occurs in both regimes of YRD, while negatively spatial spillover for the case of PRD. The results here suggest important policy implications for the two regions to attract FDI and promote urban development.

JEL Classification: C31, F21, F23

Key Words: FDI, spillovers, spatial Durbin model, Yangtze River Delta, Pearl River Delta

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1. Introduction

Since the economic reform of the late 1970s, China has achieved impressive economic development with an average growth rate over 9% in 1979-2011, one of the highest in the world in the same period. The achievement owes much to the adoption of radical and aggressive foreign direct investment (FDI) policies (Zhang, 2006). Actually, since 1992, China has been the largest FDI recipient in the developing world and the second largest globally, behind the United States.[1] Annual FDI inflow was below USD100 million in 1979, but reached nearly USD118 billion in 2011, with an annual growth rate exceeding 16% in 1985-2012. By the end of 2012, the accumulation of FDI had reached USD1,277 billion in China. FDI inflow makes a great direct contribution to the Chinese economy. In 2011, FDI inflow constituted an estimated 6.2% of gross capital formation; taxes paid by foreign-invested enterprise (FIEs) account for 21.2% of China's total tax revenue; FIEs produced 27.2% of the total industrial output and accounted for 49.2 % of China's exports.

With abundant FDI inflow into China, there has been an increasing body of literature on the impact of FDI on Chinese economic growth (e.g. Lardy, 1995; Pomfred, 1997; Zhang, 2006; Hale and Long, 2011). Most of these studies are based on province-level models (Zhang, 2006; Agarwal and Milner, 2011). However, in China, provinces vary greatly in size, which can severely degrade the relevance of research for policy analysis and decision making. City-level analysis may be more informative and useful for policy-making, yet there are only a few empirical analyses at this level due to limited access to data (Madariaga and Poncet, 2007; Hale and Long, 2011).

Theoretical work has extensively discussed the positive effects of FDI on the productivity of domestic firms through technology transfers (Caves, 1982; Helleiner, 1989), management know-how and export marketing (Rodriguez-Clare, 1996), or competition and demonstration effects (Wang and Blomstrom, 1992), or through labor

[1] In 2002, China even surpassed the US with FDI inflows of USD53 billion.

mobility (Kaufmann, 1997; Haaker, 1999; Fosfuri et al., 2001; Glass and Saggi, 2002). However, the results from empirical studies are so far inconclusive or mixed on FDI spillovers (Rodrik, 1999; Javorcik, 2004; Hale and Long, 2011; Madariaga and Poncet, 2007; Crespo et al., 2009). As Rodrik (1999) remarked, "today's policy literature is filled with extravagant claims about positive spillovers from FDI but the evidence is sobering." Javorcik (2004) imputes this deficiency to data limitations and to the difficulties with separating confounding effects.

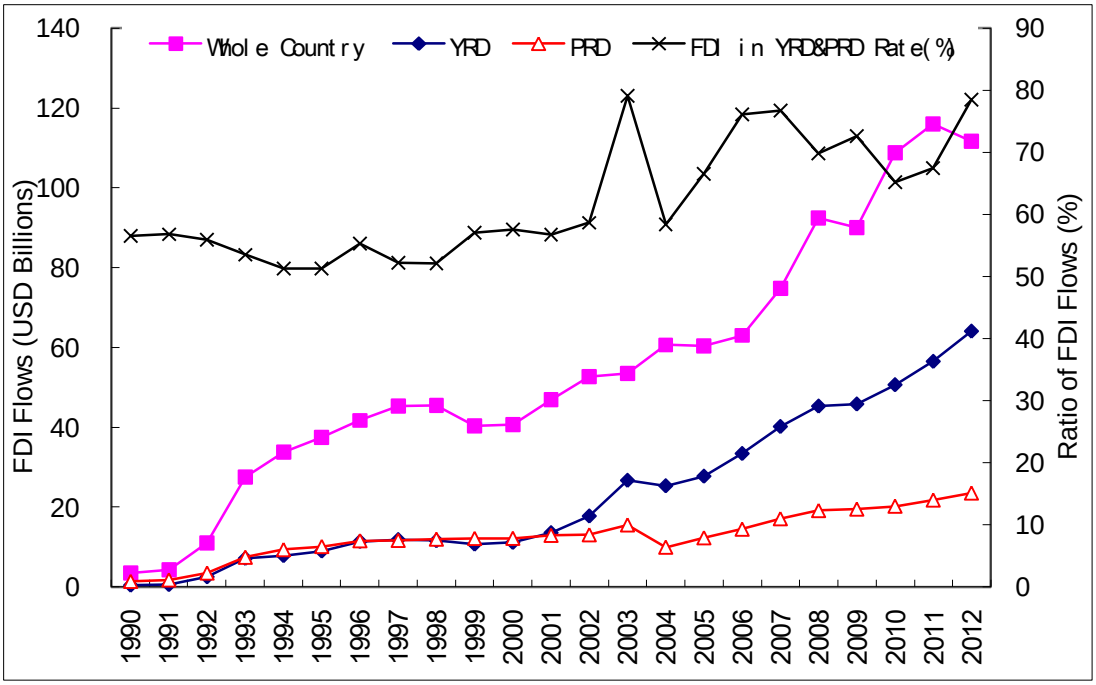

Figure 1. FDI inflows in China, YRD, PRD and the rate of FDI in YRD&PRD over the country

Source: China Statistics Yearbook (1991-2012), published by State Statistical Bureau of China (SSB), Statistical bulletin of national (Shanghai/Jiangsu/Zhejiang/Guangdong) economic and social development 2012.

Note: YRD stands for Yangtze River Delta, PRD stands for Pearl River Delta.

This paper provides a case study of FDI spillover on economic growth in two regions that have experienced high productivity. We choose the Yangtze River Delta (YRD) and the Pearl River Delta (PRD) [2] as the focus of our study since, from the start of economic reform, they have become the two largest recipients of FDI in China and together account for over 51% of the total FDI in China in 1990-2012 (Figure 1)

[2] YRD includes Shanghai, the municipality directed under the central government, Jiangsu and Zhejiang provinces. PRD includes Guangdong province.

and occupy 78% in 2012.[3] FDI inflow in PRD exploded from USD1.46 billion in 1990 to USD23.55 billion in 2012, and that in YRD surged from USD0.51 billion in 1990 to USD64.02 billion in 2012. City-level data are employed, comparatively, to analyze the impact of FDI on economic growth in the YRD and the PRD regions. A panel growth equation is estimated while accounting for spatial dependence and regimes. This study attempts to determine whether FDI is characterized as a complementary or a substitution pattern across the cities in YRD and PRD, and dynamically compares the patterns' evolution over time in the two regions.

The paper is organized as follows. Section 2 presents FDI spillover channels and provides a brief overview of empirical evidence on FDI spillovers. Section 3 gives the analytical framework. Section 4 describes the data and the methodology used in this paper. Section 5 discusses the empirical results obtained on the panel cities in YRD and PRD. Section 6 concludes and policy implications are discussed.

2. Spillover channels and empirical evidence

2.1 FDI spillover channels

Usually, FDI from developed countries typically enjoys technological and managerial superiority and its technologies and management skills can be spread to or imitated by domestic firms in the host regions. According to Spencer(2008), these so-called "spillovers" are defined as positive externalities that benefit domestic firms with the presence of FDI, which can result in productivity increases among domestic firms. FDI spillovers may occur locally and/or inter-regionally. The former is local spillover and the latter is spatial spillover. Local spillover occurs because any benefits from FIEs via diffusing mechanisms would be received first by the neighboring domestic firms before diffusing to other, more distant domestic firms. Spillovers may also extend to neighboring regions via interactions between regions, which are so-called spatial spillovers. It is reasonable to assume that FDI activity first generates

[3] In 2003, FDI inflow rate in YRD and PRD over the country reached its peak 79%.

technology spillovers for local firms that are close to FIEs in terms of geographic proximity and industrial linkage. Next, the local technology spillovers would spread into other firms in surrounding locations through imitation, labor mobility, intermediate transactions, and so on. These spatial interactions and diffusion effects are stronger in nearby locations than distant locations.

The spillover effects of FDI on productivity or economic growth of domestic firms in the host country have received enormous attention in the literature. As recognized in these studies, FDI spillovers can occur through several channels such as demonstration, competition, labor mobility, exports, input-output relationship between foreign invested enterprises (FIEs) and domestic firms (Görg and Greenaway, 2004; Madariaga and Poncet, 2007; Crespo et al., 2009).

Under the demonstration of multi-national enterprises (MNEs), a classic transmission mechanism for new products and processes is through imitation of foreign firms (Görg and Greenaway, 2004; Crespo et al., 2009); it is probably also the most evident spillover channel (Wang and Blomström, 1992; Crespo et al., 2009). It may be very costly and risky for domestic firms to adopt new technologies due to the uncertain outcome of this introduction. If some technology is already applied successfully by MNEs, domestic firms may be encouraged to use it by imitation. Imitation or demonstration effects may improve local technology and hence induce positive spillovers on local productivity.

Many studies stress that competition may generate spillovers (Wang and Blomström, 1992; Glass and Saggi, 2002; Madariaga and Poncet, 2007; Görg and Greenaway, 2004; Markusen and Venables, 1999). Unless there is a monopoly, incoming MNEs will increase competition with domestic firms. Competition will drive domestic firms to use existing technology and resources more efficiently or even to adopt advanced or new technology, which may lead domestic firms to reduce X-inefficiency and yield productivity gains.

Spillovers may also occur through labor mobility. Domestic firms can improve their productivities by hiring workers who, having previously been employed by MNEs, have managerial know-how and experience of technology, which is argued as

the most important channel for spillovers by some researchers (Haaker, 1999; Fosfuri et al., 2001; Glass and Saggi, 2002; Görg and Strobl, 2005) and has received some empirical support (Djankov and Hoekmann, 2000) . However, it is rather difficult to evaluate the influence of labor mobility on domestic firms' efficiency because it is not easy to track workers and investigate their impact on other workers' productivity (Saggi, 2002). Nevertheless, as mentioned by Sinani and Meyer (2004), labor mobility may also have a negative impact as MNEs attract the best workers from domestic firms by offering higher wages.

Export spillovers are an indirect source of productivity gain. According to Aitken et al (1997), Greenaway et al. (2004) and Görg and Greenaway (2004), domestic firms can learn from MNEs to carry out an exporting strategy. Exporting usually involves fixed costs to establish distribution networks, to create communication and transport infrastructure, and to learn about consumers' tastes and regulations in foreign markets, etc. Local domestic firms may penetrate export markets via collaboration and imitation, and hence get productivity gains.

Input-output relationship between MNEs and domestic firms implies that the latter establish backward linkages with MNEs, i.e. as suppliers of MNEs or forward linkages with MNEs, i.e. as customers of intermediate inputs produced by MNEs (Rodriguez-Clare, 1996; Markusen and Venables, 1999; Crespo et al., 2009). In the case of backward linkages, domestic firms may generally benefit from MNEs when the latter increase the demand for inputs supplied by the former under the condition of increasing returns to scale, which may in turn improve the productivity of domestic firms. In order to get inputs to comply with quality standards, MNEs may provide technical support to domestic firms so as to improve the quality of goods, support for establishing productive infrastructures and for acquiring raw materials, as well as support for organization and management (Driffield et al., 2004; Crespo et al., 2009). As for forward linkages, domestic firms may benefit from MNEs if they supply higher quality and lower price inputs than domestic suppliers (Markusen and Venables, 1999). Domestic customers may also improve their productivity if MNEs introduce new management skills and production processes for them (Dunning, 1993).

Another factor influencing FDI spillover is geographic proximity. According to Tobler's (1970) first law of geography, near things are more related than distant things. That is to say, the local firms who are close to MNEs will be more likely and more frequently to interact with MNEs than those who are not. Some studies argue that FDI spillovers have a circumscribed geographic dimension, or at least, decay with distance (Audretsch, 1996; Agarwal and Milner, 2011). Specifically, labor mobility (Greenaway et al., 2002), demonstration effects (Blomstrom and Kokko, 1998) and competition effects (Agarwal et al., 2011) would take place at circumscribed geographic scale. The closer a local firm to MNEs is, the stronger the interaction is. The probability that mobility of labor, goods, capital, knowledge flows and spatial externalities occur from one agent to another decreases with spatial distance, which will result in high productivity areas as well as low productivity locations tend to cluster geographically (Anselin, 2001). Many scholars, eg. Finleton (1999), Rey and Montouri (1999), Madariaga and Poncet (2007), Garretsen and Peeters (2009), Ledyaeva and Svetlana (2009), Blonigen et al. (2007), Bode et al. (2012) etc., have proved the importance of spatial patterns. These contributions suggest that models are likely to suffer from serious misspecification or omitted variable bias if spatial effects are ignored (Abreu et al., 2005; Baltagi et al., 2007). Recently, some studies tested FDI spatial spillovers on productivity or economic growth and confirmed their existence (Bode et al., 2012; Madariaga and Poncet, 2007).

2.2 Empirical evidence

Theoretical work generally predicts positive spillovers of FDI presence on domestic productivity or economic growth through several channels aforementioned, such as labor mobility, demonstration and imitation, competition, exports and input-output relationship. However, the extensively empirical literature investigating the role of FDI in determining the existence, sign and magnitude of its impacts on productivity or economic growth, as surveyed by Görg and Greenaway (2004), Wooster and Diebel (2010), and pointed out by Hale and Long (2006, 2011), Crespo

et al. (2009), Madariaga and Poncet (2007), either finds inconsistent or inclusive results.

Recently, literature on FDI spillovers in China has expanded and a wide range of estimates for FDI spillovers on domestic productivity or economic growth have been obtained. Studies on Chinese FDI spillovers differ by the level of disaggregation, from the regional level (provinces or cities), to the industry level and finally the firm level (Hale and Long, 2011). Most empirical studies at the regional level are based on provinces and show evidence of positive spillovers. For instance, Cheung and Lin (2004) present evidence of positive FDI spillovers on the number of domestic patent applications in China using province data from 1995 to 2000. Huang (2004) finds evidence of positive FDI spillovers on labor productivity and total factor productivity (TFP) by using cross-provincial data on Chinese industries and suggests that the magnitude of spillovers depends on the technology gap. Zhang (2006) assesses the extent the FDI inflows affecting China's income growth with provincial data over 1992-2004 and the results show that FDI has positive effects on income growth and the effects increase over time. Evidence on city-level effects is still scarce. In this respect, Madariaga and Poncet (2007) is an exception, where FDI spillovers are studied on 180 Chinese cities.

At the industry level, empirical evidence for FDI spillovers is not robust. Li et al. (2001) explore FDI spillovers on domestic labor productivity with manufacturing industry data from the 1995 Third Industrial Census of China and find positive effects. With the same dataset, Buckley et al. (2002) study FDI impacts on firms' high-tech and new product development, export performance as well as labor productivity and also get evidence of positive effects. Using data on 29 manufacturing industries in the Shenzhen Special Economic Zone over the 1993 to 1998 period, Liu (2002) finds significant positive spillovers on both productivity and its growth rate with overall average FDI measure, but insignificant impacts on FDI recipient industries with industrial average FDI measure. Liu et al. (2001) test the spillover hypothesis on 41 sub-sectors of the Chinese electronics industry in 1996 and 1997; the results suggest positive FDI spillovers on the industrial labor productivity.

At the firm level, conclusions are more mixed. Chuang and Hsu (2004) find significant and positive spillover effects on the productivity of domestic firms with both high- and low-technology-gap from MNEs, but the effects are larger for the latter. Tong and Hu (2003), employing 10601 4-digit industry-province data aggregated based on half a million domestic firms, find that FDI sourcing from Hong Kong, Macau and Taiwan have negative impacts on domestic labor productivity while FDI from other areas have positive impacts. Wei and Liu (2006) , using panel data of close to 10,000 domestic and foreign-invested firms for 1998-2001, find positive FDI effects on both domestic intra-and inter-industry productivities within regions; however, FDI from OECD countries plays greater role than that from Hong Kong, Macau and Taiwan. Agarwal and Milner (2011), using a panel of 20,460 Chinese manufacturing firms over the period 2001-2005, find FDI spillovers exist heterogeneity across both 29 provincial-regions and 10 manufacturing sectors within each of the provincial regions, which suggests FDI spillovers may be affected by characteristics of both sectors and provinces. Hale and Long (2006, 2011), using a firm-level data set from a World Bank survey in 2001, find no evidence of systematic positive FDI spillovers on productivity in China.

As mentioned earlier, geographic proximity plays an important role in spillover effects. Now there are quite a few studies examining FDI activity using spatial econometric techniques, although most of them focus on FDI location determinants (Coughlin and Segev, 2000; Blonigen et al., 2007). Empirical work that directly tests FDI spatial spillovers is very limited. Recently, Crespo et al., (2009), employing Portugal firm data over 1996-2000, examine the relevance of geographic proximity between MNEs and domestic firms on the occurrence of FDI spillovers and confirm the decisive importance of considering geographic proximity. Madariaga and Poncet (2007) investigate FDI spillovers on economic growth with 180 cities in China by employing spatial econometric methodology and find the existence of positive spillover effects. Driffield (2006), using data set comprising data for both the foreign- and domestically owned sectors of UK manufacturing, covering 1984–1992 and employing spatial econometric models, shows that FDI spillovers are localized and

contiguity and spatial dependence can significantly change FDI spillovers on productivity growth locally and nationally. Bode et al. (2012)'s research, using data for US states from 1977–2003 and including spatial interdependence, indicates that inward FDI generates positive externalities on domestic TFP.

To sum up, empirical evidence of FDI spillover on productivity or economic growth, whether at the province, city, or firm level, is not robust and far from conclusive. In addition, most of the literature is cross-sectional or does not consider that the impact of FDI would change over time. Considering the scarcity of empirical attempts to examine the presence of FDI spillovers between cities and to test their spatial association or interdependence, this paper selects cities in YRD and PRD, two regions with high economic density and high output in China, to check FDI spillovers on local and inter-city productivity dynamically by taking the spatial dimension into account.

3. Analytical Framework

The previous discussion indicated that different channel factors may affect FDI spillover on domestic productivity or economic growth in the host city. We can assume the role of FDI spillover as one of external factors that impact on productivity or economic growth. Let us consider a city's economy as represented by a Cobb-Douglas production function as follows:

$$Y_{it} = A_{it} \cdot K_{it}^{\alpha} \cdot L_{it}^{1-\alpha} \quad (1)$$

Where Y_{it} denotes real output for city i at time t, K_{it} and L_{it} are stock of domestic capital input and labor input for city i at time t, respectively, A_{it} is the total factor productivity (TFP) which can be seen as an index of knowledge (or the level of technology) available to city i at time t.

The model assumes that FDI spillovers, as other exogenous factors, affect the output of cities through A, the level of technology. Hence the expression of A_{it} can be

given as a function like:

$$A_{it} = f(CFDI_{it}, X_{it}) = e^{c} CFDI_{it}^{a} \prod_{l=1}^{N} CFDI_{lt}^{\gamma w_{il}} \prod_{j=1}^{m} x_{ijt}^{b_j} \qquad (2)$$

Where $CFDI_{it}$ and X_{it} are stock FDI and other determining factors in city i at time t, respectively. The parameter a and b_j (j=1,2,…m) describe the strength of externalities generated by FDI accumulation and factor x_{ijt} (j=1,2,…m) respectively. The third term in equation (2) captures the spatial spillovers of FDI from the neighboring cities and its degree is described by γ, with $0 \leq \gamma < 1$. The parameter γ depends on the relative connectivity between a city i and all the cities belonging to its neighborhood by the exogenous friction terms w_{il}, with $0 \leq w_{il} \leq 1$ (w_{il} =0 when $l=i$), for l=1,2,…,N and $l \neq i$. The terms w_{il} are non-negative, non-stochastic, finite and row-standardized. We also suppose that some proportion of technological progress is exogenous and identical in all cities and denoted by e^{c}, a residual which actually cannot be explained with $CFDI_{it}$ and X_{it}. Let $y_{it} = Y_{it} / L_{it}$, $k_{it} = K_{it} / L_{it}$, replace (2) in (1) and rewrite it in logarithms, then we have:

$$\ln y_{it} = c + \alpha \ln k_{it} + a \ln CFDI_{it} + \gamma \sum_{l=1}^{N} w_{il} \ln CFDI_{lt} + \sum_{j=1}^{m} b_j \ln x_{ijt} \qquad (3)$$

The underlying idea here is that the advanced technological process and efficient organization structure of FIEs are important sources for the higher efficiency of their production process, in comparison to that of domestic firms. However, such knowledge, even though kept secret, may gradually leak out and finally become common knowledge in the market in which both domestic and FIEs operate (Agarwal and Milner, 2011), and hence, the assumption that domestic firms benefit from spillovers from FIEs is reasonable. Nevertheless, the existence, direction and magnitude of FDI spillover on domestic productivity or economic growth depends on the characteristics of the host city, such as the level of economic development, labor quality, population growth, in which both FIEs and domestic firms operate. Although how these external factors influence the nature and extent of FDI spillovers is still

unclear, it can be hypothesized that the technological absorptive capabilities of domestic firms can be affected by the economic development, labor quality and population growth and other factors of the city they are located in. Consequently, domestic firms in the low-income, low-skill cities may be leaving a greater gap for catch-up and competitive effects, ceteris paribus, and may enjoy greater technological spillovers from FIEs (Agarwal and Milner, 2011). However, a large technology gap may be an obstacle for FDI to flow into these cities and may hinder the domestic firms in these cities from acquiring the knowledge transferred through spillover from FIEs.

In addition, considering the probable role of geographical proximity in FDI spillover across cities, the TFP above is assumed to be affected by spatial interdependence, i.e. spatial spillovers of FDI is explicitly to be tested empirically in the model, which will be the focus of the next two sections.

4. Data and Methodology

4.1 Data

The dataset is compiled from various sources including the Urban Statistical Yearbook (various issues over 1991-2011), Shanghai Statistical Yearbook (various issues over 1991-2011), Jiangsu Statistical Yearbook (various issues over 1991-2011), Zhejiang Statistical Yearbook (various issues over 1991-2011), and Guangdong Statistical Yearbook (various issues over 1991-2011), published by State Statistical Bureau of China (SSB). The data are collected for 25 cities in YRD (16 core cities plus 9 peripheral cities) and 21 cities in PRD (9 core cities plus 12 peripheral cities).[4] Figures 2 and 3 map the spatial extent of these cities (the dark areas are core cities and the light ones are peripheral cities). All the cities are prefecture-level and above. The dataset only consists of data in the urban part of those prefecture-level cities and

[4] 21 cities in PRD, excluding Hong Kong and Macau.

above.[5]

Year 1992 can be considered the starting point of the second stage of China's economic reform after the famous "Spring Tour to the South" by China's leader Deng Xiaoping. Subsequently, the economy started to be more market oriented and China became the second largest FDI recipient in the world. Thus, this paper chooses 1991 as the start of the study period. It supports the application of neo-classical growth theory in this study. The description of variables used here is reported in Table 1. GDP, GDP per capita and fixed assets investments for each city are deflated by their corresponding provincial Consumer Price Index (CPI) and Fixed Assets Price Index (FAPI) respectively based on 1990 constant price. Following the method used by Chow (1993), we construct the real capital stock series for each city in 1990 constant price. First, the nominal value of newly added fixed assets for each city is calculated in each year and then deflated by FAPI. Second, taking 1990 as the base year, the initial real capital stock of the base year (1990) is calculated with capital-output ratio 2.58, as suggested by Chow (1993). The annual real capital stock for each city is obtained as the previous year's capital stock plus the increments and minus annual depreciation of fixed assets. FDI inflows are computed with exchange rate first and then deflated by CPI based on 1990 constant price. Similarly, taking 1990 as the base year and assuming the FDI inflow in 1990 for each city roughly as the FDI stock of the city in 1990,[6] the annual FDI stock for each city is calculated with the previous year's FDI stock plus the FDI increment and minus the annual depreciation. Human capital is measured by the share of the population studying at vocational secondary schools and universities,[7] A few missing values are linearly interpolated.

The spatial weight matrix is used to reflect the structure of spatial effects, which contains the spatial interdependence between the cities in the sample. Various alternative weighting methods are suggested in the literature, among which the most

[5] The prefecture-level cities and above in China usually are attached with some rural counties. Spillovers usually are expected to occur more in urban parts than in rural parts due to greater agglomeration, more developed infrastructure and denser interaction between non-agricultural activities (Madariaga and Poncet, 2007).
[6] Considering that FDI inflow was very limited for most cities before 1990, this assumption may be reasonable.
[7] Data on schooling years of the labor force at the city level are unavailable, although this would be a better proxy of human capital than the one used here.

widely used are contiguity and distance between localities. In line with the principle that the spatial weight matrix must be exogenous otherwise the empirical model becomes highly non-linear, as recommended by Keller (2002), the spatial weight matrix based on distance between cities is employed here. The distance-based weight matrix is defined as:

$$w_{ij} = \begin{cases} 0 & i = j \\ 1/d_{ij}^2 & i \neq j \end{cases} \tag{4}$$

Where w_{ij} is an element of the weight matrix, d_{ij} is the distance in kilometers between cities *i* and *j*. The inverse squared distance is used to reflect a gravity relation. The matrix is row-standardized before incorporation in the model so that each row sums to one and each weight can be interpreted as the city's share in the total spatial spillover of the whole region.

Table 1. Summary statistics for log-transformed of variables

	YRD				PRD			
Variable	Mean	SD	Min	Max	Mean	SD	Min	Max
Ln(Initial income)	7.248	0.481	5.974	7.868	9.338	0.818	7.918	10.665
Ln(Income per capita)	9.240	0.744	6.789	10.995	10.156	0.691	7.918	11.912
Ln(Capital stock per capita)	5.363	1.382	2.325	9.491	8.807	0.869	6.537	11.035
Ln(Human capital)	-4.153	1.242	-9.020	-1.935	-0.076	1.106	-4.490	2.414
Ln(Population growth+g+δ)	-2.925	0.052	-3.101	-2.763	-2.844	0.074	-3.042	-2.533
Ln(FDI stock per capita)	7.277	1.776	0.059	10.313	7.817	1.261	2.690	9.990

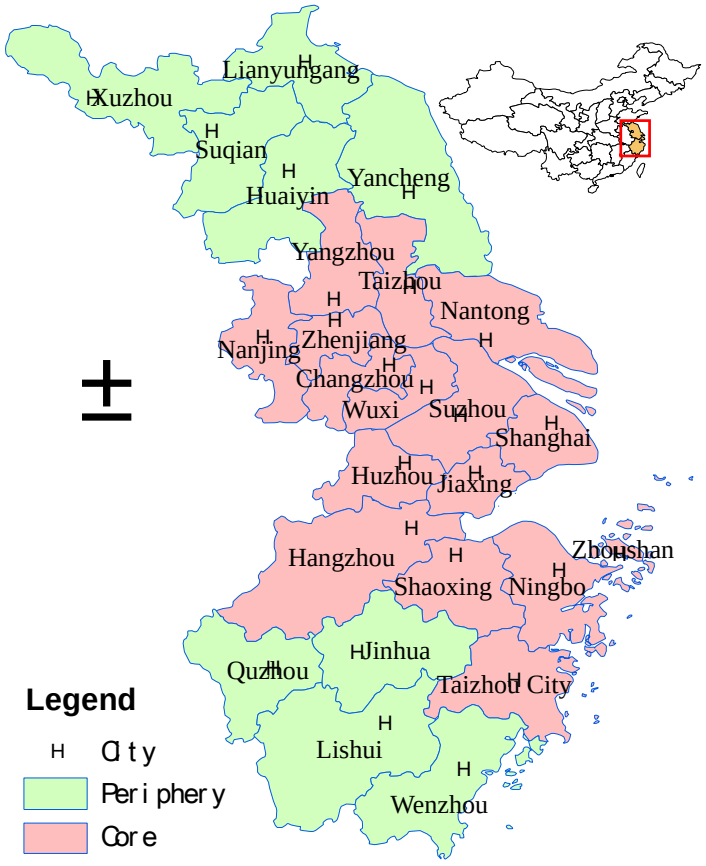

Figure 2. 25 cities in the Yangtze River Delta (YRD)

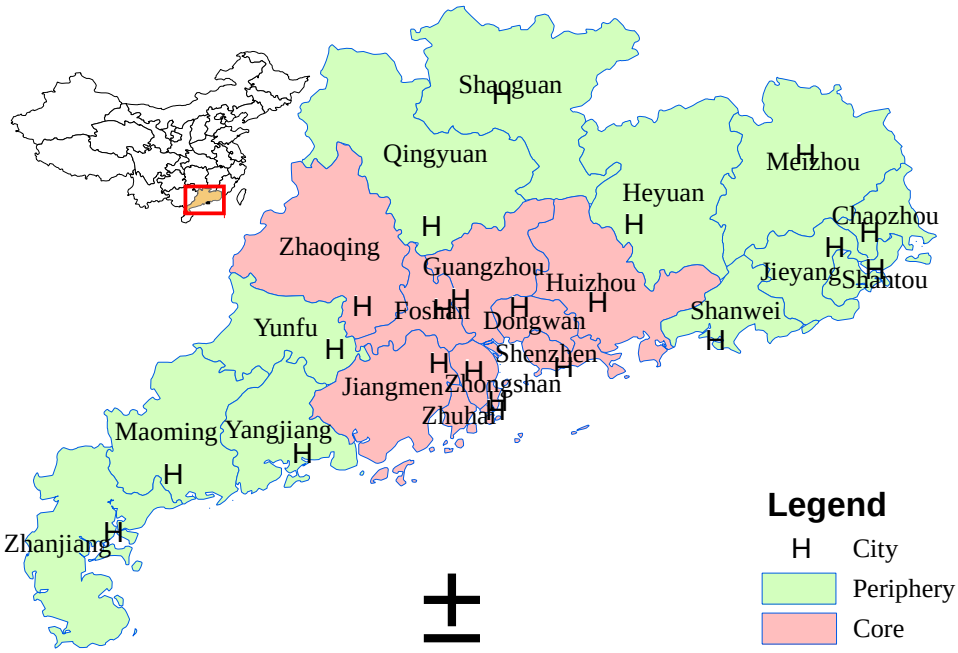

Figure 3. 21 cities in the Pearl River Delta (PRD)

4.2 Model Specification

With reference to Aitken et al. (1999) and Madariaga and Poncet (2007), a traditional cross-country empirical framework of FDI spillover on economic performance is adopted here. The specific autoregressive form is an augmented Solow growth model that incorporates an FDI term in order to determine its impact on productivity or economic growth. To estimate FDI spillovers, two types of model specifications are defined on the basis of whether the spatial effects are included in the model. According to Barro and Sala-i-Martin (2004), two more variables, i.e., initial development level (real per capital GDP lagged T period) and human capital are introduced in the model. Here the potential endogeneities of the externality variables, which making it difficult to interpret the impacts of these variables on regional productivity, have to be considered. The issue of endogeneity is a complext problem and usually instrument approach is employed to alleviate it. According to Driffield(2006) and Crespo et al.(2009), here we instrument the FDI and other external variables with their one-year lags. Then the first model with no spatial effect is given by:

$$\begin{aligned}\ln y_{i,t} = {} & \beta_1 \ln y_{i,t-T} + \beta_2 \ln k_{i,t-1} + \beta_3 \ln H_{i,t-1} + \beta_4 \ln\left(n_{i,t-1} + g + \delta\right) + \\ & \beta_5 \ln CFDI_{i,t-1} + \eta_i + \mu_t + \varepsilon_{it}\end{aligned} \tag{5}$$

Where i is a city index, t is the time index, the dependent variable, $y_{i,t}$, is the real per capita GDP; $y_{i,t-T}$, the initial real per capita GDP, is the lagged dependent variable T years ago; $k_{i,t}$ is the per capita capital stock; $H_{i,t}$ is the human capital proxied by the share of the population studying at vocational schools and universities; $n_{i,t}$ is average annual population growth rate; $g+\delta$ is the sum of technical progress rate (g) and common depreciation rate (δ), here its value is 0.05 following Mankiw et al. (1992) and Madariaga and Poncet (2007); $CFDI_{i,t}$ is per capita FDI stock; ε_{it} is the iid

error term with zero mean and variance σ^2; η_i and μ_t capture the unobservable city fixed effects (constant through time) and unobserved time effects (common across cities). To eliminate or reduce endogeneity, the regressions are run with one-year lags for per capita capital stock ($k_{i,t-1}$), per capita FDI stock ($CFDI_{i,t-1}$) as well as other external variables.

Before giving the model specification including spatial spillover effects, spatial dependence should be diagnosed. Spatial dependence may take two forms, one is spatial lag form where spatial dependence is captured by a lagged dependent variable and often referred to spatial autoregression. Another is spatial error form where spatial dependence exists when shocks in neighboring localities are correlated. To test spatial interaction effects, we start with a linear regression model without any spatial specifications. Then, based on the residuals of the linear regression, the Lagrange multiplier (LM) tests for a spatially lagged dependent variable and spatial error autocorrelation are calculated. Results are reported in Table 2. These test results suggest spatial Durbin model is the best choice to interpret the data for both YRD and PRD. Further analysis finds that, first, the likelihood ratio (LR) test of whether the spatially lagged explanatory variables are jointly significant in the models for YRD and PRD respectively, which indicates the spatially lagged explanatory variables should be included; second, regardless of whether spatially lagged explanatory variables are controlled, the empirical evidence supports that a spatially lagged dependent variable is stronger than a spatially autocorrelated error term in both YRD and PRD. We also perform LR tests to investigate whether the spatial fixed effects and the time-period fixed effects are jointly significant respectively, the results indicate that the spatial Durbin model (SDM) should be extended to include spatial and time-period fixed effects.

Table 2. Diagnostic tests for spatial dependence in YRD and PRD

Condition	Test	For YRD	For PRD
Excluding spatially lagged explanatory variables	LM_lag	8.53 (1df, p<0.01)	7.02 (1df, p<0.01)
	LM_err	5.04 (1df, p<0.04)	4.67 (1df, p<0.05)
	LogL	145.6	120.1

Including spatially lagged explanatory variables	LM_lag	4.11 (1df, p<0.07)	3.54 (1df, p<0.08)
	LM_err	3.01 (1df, p<0.11)	2.65 (1df, p<0.12)
	LogL	150.2	126.1
	LR test for spatial lag	12.16 (5df, p<0.03)	10.03 (5df, p<0.03)
	LR test for spatial fixed effect	412. 47 (25df, p<0.01)	301.31 (21df, p<0.01)
	LR test for time-period fixed effect	92.33 (20df, p<0.01)	105.21 (20df, p<0.01)

In addition, in order to test whether the degree of interaction between core and peripheral cities differs significantly, the SDM is extended again to two regimes. Then model (5) with spatial spillovers is a SDM model given by:

$$\begin{aligned}\ln y_{i,t} = {} & \delta_1 d_{it}\sum_{j=1}^{N} w_{ij}\ln y_{j,t} + \delta_2\left(1-d_{it}\right)\sum_{j=1}^{N} w_{ij}\ln y_{j,t} + \alpha + \gamma_1 \ln CFDI_{i,t-1} \\ & + \gamma_2\sum_{j=1}^{N} w_{ij}\ln CFDI_{i,t-1} + x_{i,t-1}\beta + \sum_{j=1}^{N} w_{ij}x_{j,t-1}\theta + \eta_i + \mu_t + \varepsilon_{it}\end{aligned} \tag{6}$$

Where i is an index for the cities, with i=1,…,N; t is an index for the time dimension, with t=1,…,T. $x_{i,t}$ is a 1×K vector of observations of explanatory variables, with the associated parameters β contained in a K×1vector. d_{it} is a binary variable that equals to 1 if city i in the core regime and 0 if city i in the peripheral regime. The variables $d_{it}\sum_{j=1}^{N} w_{ij}\ln y_{j,t}$ and $\left(1-d_{it}\right)\sum_{j=1}^{N} w_{ij}\ln y_{j,t}$ denote the interaction effects of the dependent variable $\ln y_{i,t}$ with dependent variable $\ln y_{j,t}$ in neighboring cities, which belong to regime 1 and regime 2 respectively. w_{ij} is an element of spatial weight matrix **W** that construct the spatial arrangement of cities in the sample. $\sum_{j=1}^{N} w_{ij}\ln CFDI_{i,t-1}$ denotes the interaction effects of per capita FDI stock in city i with per capita FDI stock in neighboring cities. $\sum_{j=1}^{N} w_{ij}x_{j,t-1}$ denotes a 1×K vector of spatial interaction effects of the explanatory variables $x_{i,t-1}$ with the associated parameters θ contained

in a K×1 vector. Here, $x_{i,t-1} = \left[\ln y_{i,t-T}, \ln K_{i,t-1}, \ln H_{i,t-1}, \ln\left(n_{i,t-1} + g + \delta\right)\right]$ is a vector of controlled variables. The coefficients δ_1 and δ_2 reflect and measure the degree of spatial interaction of cities that belong to regime one (core) and regime two (periphery), respectively. If spatial interaction in the core cities is stronger than that in the peripheral cities, δ_1 should be significantly greater than δ_2 and vice versa. While a positive and significant spatial autoregressive coefficient δ in a single-regime spatial lag model only suggests the spatial interaction between all the cities, but it offers no evidence of the interaction deviation between the core cities and the peripheral cities. The other variables have the previously stated meaning. It is assumed that $\sum \eta_i = \sum \mu_t = 0$ to avoid dummy variable traps.

The estimation of equation (6) for YRD and PRD will determine whether GDP per capita in a city is indirectly affected by income per capita and FDI as well as other controlled variables from the neighboring cities. The estimation results will reveal the patterns of income, FDI and other controlled variables across the cities as well as their strength measured by the spatial lag coefficients for YRD and PRD respectively. The results will also shed light on the economic convergence and growth as well as the role of spatial spillover effects. From a spatial perspective, the results will indicate how a city's per capita income is influenced by that of surrounding neighbors. Conditional on controlling other variables, the estimation of direct and indirect impacts of FDI on productivity can be obtained by including the local and the spatially lagged FDI respectively. In addition, the evolution of the spatial patterns of income, FDI as well as other control factors, can be demonstrated by analyzing the economic characteristics for both YRD and PRD in two successive sub-periods.

5. Empirical Results

5.1 Empirical methodology and strategy

Following Elhorst and Fréret (2009), estimation of the spatial Durbin model (6) for spatial panel data is conducted by Maximum Likelihood Estimation (MLE). Estimation results for YRD and PRD are listed in Tables 3 to 6, respectively. We check the robustness of the results by successively estimating one-way single-regime SDM, two-way single-regime SDM and one-way two-regime SDM. For the purpose of comparisons, the main regression results are given following the order of exclusion and inclusion of the determinant FDI in the spatially restricted augmented Solow model.

5.2 Results for single-regime SDM

Estimation results for single-regime SDM are listed in Tables 3 and 4. In line with the neoclassic Solow model, the capital stock per capita (k) has positive and significant coefficients in all regressions in both YRD and PRD. In accordance with the theory and most empirical studies (Madariaga and Poncet, 2007), human capital (H) is positively related to productivity in all relevant cases for both YRD and PRD although insignificant in a few cases. Consistent with the theory and some empirical analyses (Tian et al., 2010; Madariaga and Poncet, 2007), the variable population growth ($n+g+\delta$) is negatively associated with city productivity for PRD in all regressions except column (5) in Table 4 while, on the contrary, in contradiction with the theory and the empirical results above, ($n+g+\delta$) is positively associated with city performance for YRD in all regressions except column (3) and (4) of Table 3 although all the estimations are insignificant for both YRD and PRD. This phenomenon occurs probably because that YRD and PRD experienced different population growths.[8]

[8] The YRD experienced a largely decreasing population growth over the study period. For example, the population growth rate was 3.03‰ in 2001 but declined to 2.62‰ in 2010, while the PRD experienced an increasing population growth and its rates were 6.21‰ and 9.58‰ in 2001 and 2010 respectively.

Estimation results are robust for the traditional extended Solow model when inter-city heterogeneity in terms of FDI is introduced. The FDI stock per capita (*CFDI*) seems to exert a positive and significant impact on productivity in all specifications for both YRD and PRD with only one exception (column (2) in Table 4). As many previous empirical studies on China's growth widely recognized (Démurger and Berthélemy, 2000; Madariaga and Poncet, 2007; Zhang, 2006), the findings here also suggest that FDI inflow benefits the cities' growth in YRD and PRD. Here the results underline that the more a city's FDI stock per capita, the greater its economic performance. In addition, the coefficient of *CFDI* for PRD is greater than that for YRD, which indicates that the contribution of FDI to the growth in PRD is more than in YRD.

Table 3. FDI spillovers on productivity in YRD cities (1 regime)

	One-way single-regime SDM				Two-way single-regime SDM	
Variable	1991-2010(1)	1991-2010(2)	1991-2010(3)	1991-2010(4)	1991-2010(5)	1991-2010(6)
Initial income	-0.146(-0.000)	-0.145(-0.000)	0.496(13.301)	0.415(10.060)	-0.121(-0.000)	-0.108(-0.000)
Capital stock per capita	0.179(6.792)	0.176(6.637)	0.355(10.398)	0.275 (7.611)	0.186(6.914)	0. 176(6.440)
Human capital	0.116 (7.465)	0.099(6.152)	0.009(0.625)	-0.009(-0.645)	0.107 (6.532)	0.010(5.764)
Population growth+g+δ	0.299(1.585)	0.281(1.513)	-0.338(-1.334)	-0.397(-1.602)	0.248(0.182)	0. 241(1.307)
FDI stock per capita		0.041(2.902)		0.091(5. 342)		0.022(1.914)
W* Initial income	0.035(0.000)	-0.007(-0.000)	-0.006(-0.054)	0.139 (1. 056)	-0.199(-0.000)	-0.154(-0.000)
W* Capital stock per capita	-0.021(-0.521)	0.096 (2.226)	0.176 (1.889)	0.240(2.597)	0. 063 (0.852)	0.079(1.069)
W* Human capital	0.005(0.188)	0.006 (0.202)	-0.137(-3.241)	-0.094(-2.235)	0.008(0.181)	0.045(0.991)
W* Population growth+g+δ	-0.638(-4.719)	-0.371(-3.947)	-0.891(-1.272)	-0.536(-0.788)	-1.683(-3.747)	-1.633(-3.6516)
W* FDI stock per capita		-0.010(-0.583)		-0.146(-3.338)		-0.104 (-2.133)
δ_1	0.555(11.185)	0.421(7.121)	0.167(2.552)	0. 207 (3.321)	0.124(1.684)	0.149(1.974)
δ_2						
Spatial FE	Yes	Yes	No	No	Yes	Yes
Time-period FE	No	No	Yes	Yes	Yes	Yes

Regime Dummy	No	No	No	No	No	No
LogL	281.614	296.371	38.993	55.196	311.992	316.217
R^2	0.968	0.969	0.910	0.916	0.970	0.970
$\overline{R}^2$	0.965	0.966	0.904	0.910	0.966	0.966
No. of observations	500	500	500	500	500	500
λ-implied	-0.096(-0.000)	-0.097(-0.000)	0.035(13.301)	0.044(10.060)	-0.106(-0.000)	-0.111(-0.000)

Notes: t-values are in parentheses. λ-implied is the conditional convergence speed calculated according to the coefficient of initial income, i.e. λ=-(lnb)/T when b>0, λ=(ln(-b))/T when b<0, where b is the regressive coefficient of initial income and T is the lagged period.

As stated in section 4, to avoid estimation biase, the neoclassic Solow model is extended to SDM with both spatial fixed and time-period fixed effects, i.e. two-way SDM. LR tests show obvious improvements of the overall fitness (R^2 and $\overline{R}^2$) and log likelihood values when this specification is implemented. Therefore it can be concluded that the model of SDM with spatial fixed and time-period fixed effects is the appropriate specification and the following analyses are mainly based on it.

Table 4. FDI spillovers on productivity in PRD cities (1 regime)

	One-way single-regime SDM				Two-way single-regime SDM	
Variable	1991-2010(1)	1991-2010(2)	1991-2010(3)	1991-2010(4)	1991-2010(5)	1991-2010(6)
Initial income	0.504(0.000)	0.510(0.000)	0.117(3.791)	0.100(3.247)	0.483(0.000)	0.369(0.000)
Capital stock per capita	0.521(16.360)	0.479(10.857)	0.669(19.572)	0.548(12.675)	0.501(13.684)	0.395(8.395)
Human capital	0.107(4.073)	0.090(3.408)	0.025 (1.755)	0.040(1.819)	0.075(2.851)	0.071(2.752)
Population growth+g+δ	-0.040(-0.149)	-0.050(-0.187)	-0.030(-1.107)	-0.241(-0.898)	0.146(0.561)	-0.151(-0.562)
FDI stock per capita		0.045(1.503)		0.112(4.416)		0.109(3.437)
W* Initial income	0.168(0.000)	0.164(0.000)	0.028(0.379)	-0.044(-0.581)	-0.141(-0.000)	-0.162(-0.000)
W* Capital stock per capita	-0.327(-6.753)	-0.152(-2.178)	-0.057(-0.618)	0.028(0. 271)	-0.118(-1.288)	-0.183(-1.837)
W* Human capital	-0.140(-3.143)	-0.089(-1.739)	0.142(2.928)	0.177(3.675)	-0.021(-0.332)	-0.051(-0.803)
W* Population growth+g+δ	0.361(0.833)	0.833(1.794)	0.309(3.611)	0.197(3.504)	0.701(2.675)	0.552(0.794)
W* FDI stock per capita		-0.121(-3.384)		-0.056(-1.142)		0.143(2.253)
δ_1	0.237(3.567)	0.195(2.847)	-0.230(-2.956)	-0.255(-3.293)	-0.062(-0.815)	-0.128(-1.647)

δ_2						
Spatial FE	Yes	Yes	No	No	Yes	Yes
Time-period FE	No	No	Yes	Yes	Yes	Yes
Regime Dummy	No	No	No	No	No	No
LogL	-18.375	-12.734	- 108.268	- 98.713	5.897	13.524
R^2	0.868	0.871	0.797	0.806	0.881	0.885
$\overline{R}^2$	0.857	0.860	0.781	0.791	0.865	0.869
No. of observations	420	420	420	420	420	420
λ-implied	0.034(0.000)	0.034(0.000)	0.107(3.791)	0.115(3.247)	0.036(0.000)	0.050(0.000)

Notes: t-values are in parentheses. λ-implied is the conditional convergence speed calculated according to the coefficient of initial income, i.e. λ=-(lnb)/T when b>0, λ=(ln(-b))/T when b<0, where b is the regressive coefficient of initial income and T is the lagged period.

Now let us focus on estimates of spatially lagged variables. The introduction of the spatially lagged variable of GDP per capita (*Y*) behaves differently in the two regions. For YRD, *Y* in a given city is positively and significantly related to that in neighboring cities for all regressions (Table 3), which suggests that a city in YRD can benefit from the productivity of its neighbors and that positive spatial spillover effects exist. Conversely, for PRD, *Y* in a given city seems to have no stable relation to its surrounding cities across specifications. Its spatial coefficients are negative but insignificant under two-way SDM, which may point to competition between PRD cities and some negative spatial spillover effects of productivity. Different spatial effects of economic performance in YRD and PRD may actually be relevant to the characteristics of regional development in these two regions.[9]The spatial coefficients of *CFDI* are negative and significant for YRD in all specifications except for column (2) of Table 3, which points out that FDI inflows have intensive negative spatial spillover effects on economic performance and the FDI-induced growth in a given location seems to occur at the expense of neighboring cities; this also means there is

[9] Relatively, the regional development of YRD has been more balanced than that of PRD in the past decade. Coefficients of Variation (CVs) of GDP per capita for the cities in YRD and PRD are 45.79%~46.63% and 48.34%~81.28% in 2001-2010 respectively. With the rapid development of regional integration in YRD, the cities have gradually established tight economic network and formed a co-operation relationship, which makes them benefit from each other via mutual-promotion of economy and economic complementarities. As for PRD, the economic center is located in the core cities while the peripheral cities (including western, eastern and northern Guangdong province) are underdeveloped areas and a few cities even under the average development level of the country. This unbalanced situation makes them compete in product factors and markets to some extent.

keen FDI flow competition between the cities in this region. On the contrary, under the two-way SDM, the positive coefficient on the spatially lagged *CFDI* for PRD suggests that cities benefit from the FDI flows into the surrounding locations and positive spatial spillover effects occur, which is consistence with studies offered by Madariaga and Poncet (2007) and Zhang (2006). Opposite spatial impacts of FDI spillover in YRD and PRD probably are related to spatial distribution of FDI in the two regions.[10]

With two-way SDM, the coefficients of the spatially lagged *K* for YRD are insignificant whether including the term CFDI or not, which indicates there is no clear sign whether a city's productivity can benefit from its neighbors' capital accumulation. In PRD, the estimation shows that the capital accumulation in surrounding cities has negative effects on a given city's productivity and this effect becomes greater and significant when CFDI term is considered. The insignificantly spatial coefficient suggests that the human capital investment *H* in the surrounding cities has no clear effects on the productivity of a given city in both YRD and PRD, which indicates that human capital investment mainly benefits the local productivity and little spatial spillover occurs. The population growth ($n+g+\delta$) of the neighbors has negative effects on the economic performance of a given city in YRD while it has positive effects in PRD although it becomes insignificant when including CFDI term.

According to neoclassical economic growth convergence theory (Barro, 2000; Barro and Sala-i-Martin, 2004), the initial real-income level approximates the initial level of development and is inversely related to subsequent growth. Therefore, the coefficient of the initial income per capita may indicate whether conditional convergence exists after controlling some control variables and spatial spillover effects. Unfortunately, when controlling *CFDI*, human capital, population growth and

[10] Unlike the overall economic development, PRD is close to Hong Kong and Macau and has a longer history of opening-up and utilizing FDI than YRD and experienced FDI diffusion from the center to the peripheral areas. While YRD has a shorter period of using FDI relative to PRD and most of the FDI clusters in the large cities, especially in the core cities. CVs of accumulated FDI in cities of YRD and PRD in 2001-2010 are 184.5%~251.8% and 127.9%~140.9% respectively, which indicates more spatial disparity of the FDI distribution in YRD than that in PRD. So the cities in YRD compete in FDI inflow even though YRD is experiencing a tighter regional integration. After all, FDI is an effective driver to local economy. In PRD, because of imbalanced regional economy, in terms of FDI utilization, the cities has established a vertical industrial linkages of division of labor, which makes them benefit from each other even though there is competition in the overall economy.

the spatial effects of all controlled variables, there is no significant evidence of conditional convergence in either YRD or PRD under the two-way SDM, which appears to indicate that economic inequality shows no sign to eliminate in either region over the study period. These results are contradictory to the estimations when long-term estimates employed which will be discussed in detail in the next section. In addition, the spatially lagged initial income has no systematic influence on the growth in the two regions either under two-way SDM.

5.3 Results for two-regime SDM

In line with Partridge (2005) and Erhorst and Fréret (2009), models with controls for spatial fixed effects only use the time-series component of the data and tend to give short-term estimates, whereas models without those controls can give long-term estimates. So in this paper, to offer long-term estimates to reflect time variations for the economic patterns and the FDI spillover effects for YRD and PRD when considering two regimes (core and peripheral cities), one-way SDM with only time-period fixed effects is adopted and the results are presented in Tables 5 and 6. Actually, for a single regime, column (3) and (4) of Table 3 and Table 4 are long-term estimates. Comparing Tables 3 and 5, Tables 4 and 6, under the context of two regimes, one-way SDM produces very similar estimation results as one-way single-regime SDM over the period 1991-2010 for both YRD and PRD except for individual cases. In a long term, positive and significant spatial spillover effects of productivity occur in both regimes of the YRD, while opposite spatial spillover affects performance in PRD. For both YRD and PRD, the spatial coefficients of the core regimes (δ_1) are greater than those of the peripheral regimes (δ_2), which indicates that spatial interactions between cities in core regime are stronger than that in the peripheral regime. Viewed by phases, for YRD, spatial interactions in neither regime is significant and even turns negative in sub-period 1991-2001 for the peripheral regime while becoming positive and significant in sub-period 2002-2010. This indicates that, after China's access to WTO and in the context of economic transition

and rapid regional integration, the cities in YRD experienced stronger spatial interdependence in economic growth, but the spatial interaction in the core regime is much stronger than that in the peripheral regime as distinguished by their spatial coefficients. As for PRD, the cities in the core regime experienced from insignificant growth competition in sub-period 1991-2001 to significant sharp competition in sub-period 2002-2010, while inversely, the peripheral regime experienced from sharp growth competition in sub-period 1991-2001 to positive spatial spillover in sub-period 2002-2010, which seems to indicate that there remains a long way to go to achieve regional integration in PRD.

Table 5. FDI spillovers on productiviey in YRD cities (2 regimes)

	One-way two regimes SDM			
Variable	1991-2010(1)	1991-2010(2)	1991-2001(3)	2002-2010(4)
Initial income	0.402(11.775)	0.347(9.554)	0.582(10.034)	0.229(5.344)
Capital stock per capita	0.291(9.578)	0.224(7.061)	0.056(1.186)	0.274(7.025)
Human capital	0.035(2.635)	0.020(1.514)	0.033(2.041)	0.005(0.241)
Population growth+g+δ	0.192(0.842)	0.095(0.432)	-0.221(-0.860)	0.881(2.531)
FDI stock per capita		0.075(4.970)	0.034(1.835)	0.136(6.124)
W* Initial income	-0.628(-5.757)	-0.373(-2.987)	0.071(0.372)	-0.534(-3.191)
W* Capital stock per capita	-0.062(-0.748)	0.031(0.377)	-0.353(-2.761)	0.256(2.563)
W* Human capital	-0.122(-3.295)	-0.071(-1.935)	0.054(1.316)	-0.358(-4.621)
W* Population growth+g+δ	-0.110(-0.179)	-0.152(-0.257)	0.222(0.330)	0.774(0.655)
W* FDI stock per capita		-0.192(-4.926)	-0.214(-4.537)	-0.070(-1.099)
δ_1	0.461(4.944)	0.478(5.153)	0.116(0.816)	0.675(5.891)
δ_2	0.146(2.188)	0.180(2.823)	-0.045(-0.481)	0.265(3.009)
Spatial FE	No	No	No	No
Time-period FE	Yes	Yes	Yes	Yes
Regime Dummy	Yes	Yes	Yes	Yes
LogL	102.479	122.528	82.970	84.134
R^2	0.931	0.936	0.901	0.918
$\overline{R}^2$	0.926	0.932	0.892	0.909
No. of observations	500	500	275	225
λ-implied	0.046(11.775)	0.053(9.554)	0.027(10.034)	0.074(5.344)

Notes: t-values are in parentheses. λ-implied is the conditional convergence speed calculated according to the coefficient of initial income, i.e. $\lambda=-(\ln b)/T$ when $b>0$, $\lambda=(\ln(-b))/T$ when $b<0$, where b is the regressive coefficient of initial income and T is the lagged period.

Table 6. FDI spillovers on productiviey in PRD cities (2 regimes)

	One-way two regimes SDM			
Variable	1991-2010(1)	1991-2010(2)	1991-2001(3)	2002-2010(4)
Initial income	0.031(0.859)	0.047(1.301)	0.026(1.113)	0.137(2.472)
Capital stock per capita	0.638(18.326)	0.574(12.944)	0.457(8.585)	0.583(8.435)
Human capital	0.038(1.761)	0.043(1.974)	0.110(3.561)	0.072(3.128)
Population growth+g+δ	-0.039(-0.143)	-0.074(-0.271)	-0.576(-1.385)	-0.059(-1.411)
FDI stock per capita		0.017(2.290)	0.018(1.886)	0.016(2.302)
W* Initial income	-0.104(-1.279)	-0.098(-1.220)	-0.031(-0.529)	-0.021(-0.571)
W* Capital stock per capita	-0.056(-0.617)	-0.006(-0.059)	-0.097(-0.775)	-0.141(-0.883)
W* Human capital	0.174(3.605)	0.183(3.787)	0.446(6.271)	0.043(0.780)
W* Population growth+g+δ	0.222(3.566)	0.166(3.484)	0.862(3.624)	0.794(2.804)
W* FDI stock per capita		-0.029(-0.569)	-0.107(-1.632)	0.132(2.332)
δ_1	-0.317(-3.394)	-0.330(-3.461)	-0.170(-1.389)	-0.717(-5.778)
δ_2	-0.209(-2.073)	-0.215(-2.135)	-0.704(-5.970)	0.459(4.402)
Spatial FE	No	No	No	No
Time-period FE	Yes	Yes	Yes	Yes
Regime Dummy	Yes	Yes	Yes	Yes
LogL	- 97.859	- 95.186	- 37.347	-16.902
R^2	0.807	0.809	0.828	0.811
$\overline{R}^2$	0.792	0.794	0.809	0.791
No. of observations	420	420	231	189
λ-implied	0.174(0.859)	0.153(1.301)	0.182(1.113)	0.099(2.472)

Notes: t-values are in parentheses. λ-implied is the conditional convergence speed calculated according to the coefficient of initial income, i.e. λ=-(lnb)/T when b>0, λ=(ln(-b))/T when b<0, where b is the regressive coefficient of initial income and T is the lagged period.

In the context of two regimes, for YRD, FDI shows positive and significant spillovers on local productivity and the spillovers become stronger over time, but the spatial spillovers are negative though they decline over time. For PRD, FDI inflow has positive impacts on the productivity of a city but the impacts decrease over time, unlike YRD, where the FDI spatial spillovers on productivity experienced from insignificantly negative in 1991-2001 to positive and significant in 2002-2010. This indicates that a given city's productivity begins to benefit from its neighbors' FDI inflow in the later period. The above changes of patterns over time show a trend that FDI spatial spillovers are experiencing a process from spatial competition to

complementarity or weak competition in YRD and PRD, and FDI and its technology begin to diffuse across cities and make impacts on neighbor's economic performance.

The contribution of controlled variables *K* to local productivity improves over time while *H*'s contribution to the productivity decreases over time for both YRD and PRD. Population growth ($n+g+\delta$) is not significant in either YRD or PRD. The spatially lagged *K* and ($n+g+\delta$) are not significant for the full sample in YRD but the former experienced from significant negative effect in 1991-2001 to significant positive effect in 2002-2010 while the latter kept insignificant in two sub-periods. In PRD, a city's productivity does not get significant spatial effects from neighbors' capital accumulation over the two sub-periods, but gains positive spatial spillovers from *H* in 1991-2001 though these spillovers decline and become insignificant in 2002-2010. Surprisingly, ($n+g+\delta$) keeps its positively spatial effects on productivity significantly over time, which may be associated with continuous labor population immigration under rapid urbanization in the study period.

Finally to focus on the variable of initial income level, for YRD, its positive and significant coefficients indicate presence of conditional converging forces within the region. Table 5 shows the speed of convergence (λ-implied) rises from 4.6% per annum to 5.3% per annum when inclusion of FDI and its spatial lag,[11] the speed rises from 2.7% per annum in 1991-2001 to 7.4% per annum in 2002-2010. These estimates yield higher speed of convergence than those of Weeks and Yao's (2003) study on China's growth for the period 1978-1997 where they found a maximum convergence speed of 2.5% and Tian et al.'s (2010) analysis on China's growth for the period 1991-2007 where they got a maximum convergence speed of 2.3%, but lower than Madariaga and Poncet's (2007) estimate on China's growth for the period 1991-2002 where they reached a maximum speed of 8%. As mentioned above, these results are not consistence with those under two-way single-regime SDM. Considering the views of Partridge (2005) and Erhorst and Fréret (2009), one-way (time-period fixed effect) SDM tends to provide a long-term estimate while two-way

[11] Table 3 indicates the speed of convergence rises from 3.5% per annum to 4.4% per annum when inclusion of FDI and its spatial lag under time-period fixed effect and single-regime for YRD.

SDM a short-term estimate, so this paper, in terms of conditional convergence, prefers to the specification of one-way SDM and supports that the speed of convergence rises when including FDI and its spatial lag. For PRD, shown as Table 6 under two-regime model, in the whole study period 1991-2010, there is no clear sign of convergence either with or without FDI, while viewed by phases, PRD does not show convergence in sub-period 1991-2001 but indicates convergence (speed of 9.9%) in sub-period 2002-2010. When taking PRD as a single regime, as shown in Table 4, the convergence speed (λ-implied) rises from 10.7% per annum to 11.5% per annum when FDI and its spatial lag are included and both of them even greater than Madariaga and Poncet's (2007) estimate. To sum up, in a long term, conditional convergence exists and FDI is an important converging force in both YRD and PRD.

5.4 Sensitivity analysis

A couple of sensitivity analyses are conducted to check the robustness of the results. Firstly, since one of the paper's centers of interest is to account for local and spatial spillovers of FDI among cities, alternative weight matrices are examined in the regressions. As we know, whether the results of spatial econometric analysis are correct depends not only on the model specification but also on the selection of the weight matrix. In order to test the robustness of the results under different weight matrices, several alternative weight matrices, such as contiguity matrix (constructed with Root, Queen and K-nearest), inverse distance weight (IDW, including simple inverse distance weight and inverse squared distance weight) matrix, weight matrix weighted with GDP and population of cities, are incorporated in equation (6) for both one-regime and two-regime. However, we found no essential difference for the estimation results with alternative weight matrices even though the variables changed the magnitudes of their coefficients or significance slightly and a few of them even became insignificant, which confirms this paper’s results.

Secondly, equation (6) is reexamined by using GDP per worker instead of GDP per capita as the dependent variable and using capital stock per worker instead of

capital stock per capita, FDI stock per worker instead of FDI stock per capita as the independent variables in equation (6). The signs and significance levels are largely not affected by swaping dependent and independent variables, which again confirms the paper's results even though the magnitudes of the regressive coefficients vary a bit across specifications.

Thirdly, different values such as 0.06, 0.07 and 0.09 are assigned to $(n+g+\delta)$ and regress equation (6) and no essential variation is found in the estimate results.

Finally, agglomeration effects, measured with ratio of the employment over the urban area of a city and economic density of firms per km^2 respectively and jointly, are incorporated in equation (6) and tested. The findings indeed confirm agglomeration's impacts on economic performance but do not matter much for the overall spatial patterns of FDI spillovers on the productivity of cities. So the results of our estimates are reliable on the whole.

6. Conclusions

This paper focused on examining the spillover of FDI on the recent growth experience of YRD and PRD, the dominant economic regions of China, through a comparison from a spatial econometric perspective. The study covers 25 cities in YRD and 21 cities in PRD over the period 1991-2010. A GDP per capita convergence model that includes an explicit consideration for the spatial interaction effects of variables is estimated with both one-regime and two-regime spatial Durbin models (SDM) for YRD and PRD respectively. The paper verifies the robustness of the results by successively estimating one-way single-regime SDM, two-way single-regime SDM and one-way two-regime SDM and conducting a couple of sensitivity analyses. The analysis reaches five main conclusions.

Firstly, significant spatial spillover effects of FDI are observed in both YRD and PRD when the model is extended to SDM; estimates of FDI spillovers that do not consider spatial dependence must be dealt with caution.

Secondly, FDI has significant positive impacts on the local city's growth for both of YRD and PRD and keeps positive impacts over time, which suggests that a policy of promoting FDI inflow can be justified since it highlights spillover effects of FDI presence on local productivity.

Thirdly, FDI has opposite spatial spillover effects on productivity in YRD and PRD. There exist negative FDI spatial spillovers and FDI inflow competition in YRD but positive FDI spatial spillovers and spatial complementarity of FDI in PRD, The implication is that differential policies should be implemented to deal with FDI allocation among YRD cities, whereas city policies should be coordinated to attract FDI inflow in PRD. For YRD, policy should emphasize inter-city industrial linkages to avoid vicious competition for FDI flow. In PRD, policy should be strengthened to further improve infrastructure and other facilities to facilitate inter-city communication in order to turn FDI into a more effective force to promote economic performance.

Fourthly, in a long term, inclusion of FDI raises the speed of conditional convergence of economic growth in both YRD and PRD (only in case of single regime for PRD). So, cities in both YRD and PRD can take advantage of FDI inflow to promote convergence of growth and accelerate regional integration. In the future, to improve favorable conditions for more FDI inflow for those relatively backward cities in both regions is also an important way to promote coordinated development of all cities, afterall FDI is an effective driver of regional growth.

Finally, spatial interaction plays an important and non-negligible role in growth of cities. In a long term, YRD and PRD experience significant but opposite spatial effects of growth, positively spatial spillover occurs in both regimes of YRD, while negatively spatial spillover for the case of PRD. Spatial interactions in core regimes are stronger than in peripheral regimes for both YRD and PRD but show positive impacts for the former while negative for the latter. Dynamically, all the cities in YRD experience stronger spatial interdependence in economic growth over time while, for PRD, the core cities experience increasing growth competition but the peripheral cities undergo a process from sharp growth competition to positive spatial spillover

over the study period.

In addition, the FDI spillover heterogeneity observed across YRD and PRD suggests that the national-average spillover effect reported by previous studies should be interpreted with caution as it might be misleading for such a great and diverse country as China.

The analysis can be extended in several directions in the future. First, if data available, disaggregation by industrial sector and according to the investor origin (foreign versus domestic firms) would enable us to identify FDI spillover on productivity in sectors within a city rather than identifying FDI spillover on productivity in just a city and even capturing the heterogeneity of foreign firms that has got considerable attention in recent studies. Second, we propose to explore proper estimation methodologies to avoid endogeneity problems induced by an ML estimator which cannot cope with endogenous explanatory variables other than the spatially lagged dependent variable (Fingleton and LeGallo, 2008). Third, we can carry out the analysis with more flexible production functions such as CES (constant elasticity of substitution) to reexamine the conclusions. Fourth, this analysis can be extended to other major economic regions in China and other countries to assess the generality of our results.

Appendix 1. Cities in YRD and PRD

Table A1. Cities in YRD and PRD and the regimes they belong to

City	Region	Province or Municipality	Regime	City	Region	Province or Municipality	Regime
Shanghai	YRD	Shanghai	1	Tai Zhou	YRD	Zhejiang	1
Nanjing	YRD	Jiangsu	1	Lishui	YRD	Zhejiang	2
Wuxi	YRD	Jiangsu	1	Guangzhou	PRD	Guangdong	1
Xuzhou	YRD	Jiangsu	2	Shaoguan	PRD	Guangdong	2
Changzhou	YRD	Jiangsu	1	Shenzhen	PRD	Guangdong	1
Suzhou	YRD	Jiangsu	1	Zhuhai	PRD	Guangdong	1
Nantong	YRD	Jiangsu	1	Shantou	PRD	Guangdong	2
Lianyungang	YRD	Jiangsu	2	Foshan	PRD	Guangdong	1
Huai'an	YRD	Jiangsu	2	Jiangmen	PRD	Guangdong	1
Yancheng	YRD	Jiangsu	2	Zhanjiang	PRD	Guangdong	2

Yangzhou	YRD	Jiangsu	1	Maoming	PRD	Guangdong	2
Zhenjiang	YRD	Jiangsu	1	Zhaoqing	PRD	Guangdong	1
Taizhou	YRD	Jiangsu	1	Huizhou	PRD	Guangdong	1
Suqian	YRD	Jiangsu	2	Meizhou	PRD	Guangdong	2
Hangzhou	YRD	Zhejiang	1	Shanwei	PRD	Guangdong	2
Ningbo	YRD	Zhejiang	1	Heyuan	PRD	Guangdong	2
Wenzhou	YRD	Zhejiang	2	Yangjiang	PRD	Guangdong	2
Jiaxing	YRD	Zhejiang	1	Qingyuan	PRD	Guangdong	2
Huzhou	YRD	Zhejiang	1	Dongguan	PRD	Guangdong	1
Shaoxing	YRD	Zhejiang	1	Zhongshan	PRD	Guangdong	1
Jinhua	YRD	Zhejiang	2	Chaozhou	PRD	Guangdong	2
Quzhou	YRD	Zhejiang	2	Jieyang	PRD	Guangdong	2
Zhoushan	YRD	Zhejiang	1	Yunfu	PRD	Guangdong	2
Tai Zhou	YRD	Zhejiang	1				

Notes: YRD stands for the Yangtze River Delta; PRD stands for the Pearl River Delta. 1 denotes core city and 2 denotes peripheral city.

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