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FDI Technology Spillovers and Spatial Diffusion in the People's Republic of China

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Abstract

This paper investigates the geographic extent of foreign direct investment (FDI) technology spillovers and diffusion in the People's Republic of China (PRC). We employ spatial dynamic panel econometric techniques to detect total factor productivity (TFP) innovation clusters, uncover the spatial extent of technology diffusion, and quantify both the temporal and spatial dimensions of FDI spillovers. Our empirical results show that FDI presence (measured as employment share) in a locality will generate negative and significant impacts on the productivity performance of domestic private firms in the same location. Nevertheless, these negative intra-regional spillovers are found to be locally bounded. Domestic private firms enjoy positive FDI spillovers through interregional technology diffusion via labor market channels; these interregional spillovers appear in spatial feedback loops among higher-order neighboring regions. In the long run, the positive interregional spillovers outweigh the negative intra-regional spillovers, bestowing beneficiary total effects on domestic firms through labor market channels. FDI spillovers measured as sales income share, however, are negative in both intra-regional and interregional dimensions.

Keywords: FDI spillovers, spatial diffusion, spatial dynamic panel, PRC economy

JEL Classification: R12, F21, O33

1. Introduction

Firms tend to agglomerate in specific areas so as to reduce transaction costs and exploit external economies (Marshall 1920).[1] The foreign direct investment (FDI) location literature has documented the ensuing self-perpetuating growth or agglomeration pattern of multinational corporations (MNCs) over time (see, among others, Head et al. 1995; Cheng and Kwan 2000a and 2000b; Blonigen et al. 2005; Lin and Kwan 2011). The externalities arising from FDI penetration also have long received attention from both economists and policymakers. Although the previous literature has provided some evidence of FDI spillovers at both the firm and industry level in the People's Republic of China (PRC) (Lin et al. 2009; Abraham et al. 2010; Hale and Long 2011; Xu and Sheng 2012, among other earlier contributions), little is known about the extent to which the regional penetration of FDI affects the aggregate productivity of local private firms in spatial dimension. This paper studies FDI spatial spillovers using county-level data supplemented with precise GPS information for the PRC. Specifically, this paper asks: Do domestic private firms benefit from FDI presence in their local and neighboring regions? What is the geographic extent of FDI spillovers? Do FDI spillovers attenuate with distance? If so, how rapid is the geographic attenuation pattern?

There exists a vast literature on FDI spillovers. FDI may benefit domestic firms via channels like labor market turnover, demonstration of new technology, local capital accumulation, competition in sales markets, and "learning-by-watching" opportunities for local firms (see, among others, MacDougall 1960; Kokko 1994; Fan 2002; Blalock and Gerlter 2008). FDI spillovers from MNCs to domestic firms can also be negative. A leading example is the demand effect, or market-stealing effect (Aitken and Harrison 1999). It is argued that, in the short-run, indigenous firms may be constrained by high fixed cost, which prevents them from reducing their total cost; therefore, foreign firms with cost advantages can steal market share from domestic firms via price competition. As a result, the shrinking demand will push up the unit cost of domestic firms and decrease their operational efficiency. Consequently, while the penetration of MNCs may bestow positive externalities on domestic firms, it could also introduce, at the same time, a negative demand effect, which drags down the productivity of local firms. The net impact from FDI presence on domestic firms depends on the magnitude of these two opposite externalities. Though the theoretical arguments are well established, the empirical literature so far provides mixed evidence in terms of the existence, the sign, and the magnitude of FDI spillovers.

It has been shown in the recent literature that results obtained from a sample of heterogeneous firms may reveal an incomplete and potentially misleading picture of the reality (Crespo et al. 2009). FDI spillovers may occur only among a sub-group of firms that have certain characteristics in common. More specifically, the diffusion and realization of spillovers from MNCs to domestic firms are not universal; instead, they can be affected by many factors drawn from both economic and geographical dimensions (Nicolini and Resmini 2011). On one hand, the absorptive capacity of a domestic firm

[1] Marshall (1920) argues that firms can benefit from two types of external economies: (i) economies arising from "the use of specialized skill and machinery," which depend on "the aggregate volume of production in the neighborhood" and (ii) economies "connected with the growth of knowledge and the progress of the arts," which tie to the "aggregate volume of production in the whole civilized world."

would determine its propensity to engage in knowledge sharing as well as its likelihood to successfully assimilate foreign knowledge (Findlay 1978; Glass and Saggi 1998). On the other hand, geographical distance would determine the costs and then the attenuation pattern of technology diffusion, which may reduce the possibilities for indigenous firms that are geographically distant from MNCs to expropriate spillovers. In this paper, we pursue this line of research by analyzing the role of FDI in the formation of total factor productivity (TFP) spatial autocorrelation processes as well as the geographic extent of FDI spillovers.

Many analyses in previous literature treat each region in the sample as an isolated entity. The role of spatial dependence is neglected, even though interregional knowledge spillovers across regions have been known to be an important factor in the process of productivity growth (Rey and Montouri 1999; Madriaga and Poncet 2007). It is argued that ignoring spatial factors in empirical studies could result in serious misspecification when these factors actually exist (Anselin 2001; Abreu et al. 2005). Most previous studies on the impact of FDI on economic growth or the productivity performance of indigenous firms fail to take into account spatial interactions and, as a result, previous estimates and statistical inference may be questionable (Madariaga and Poncet 2007; Corrado and Fingleton 2012). In this paper, we empirically illustrate that model that fails to consider spatial factors may provide imprecise results when these spatial factors do exist.

There are theoretical reasons why regional TFPs might be spatially correlated. Ciccone and Hall (1996) demonstrate that the density of economic activity (defined as intensity of labor, human, and physical capital relative to physical space) would affect productivity in the spatial dimension through externalities and increased returns. Fingleton (2001) presents a hybrid growth model to explain why TFPs could be spatially correlated. The model receives empirical support from European Union data. In the data explanatory analysis of this paper, we will present in detail the evidence of spatial autocorrelation for both the level and growth rate of regional TFPs in the PRC.

While a common theme in the existing literature is that agglomeration promotes spatial spillovers, the direction of association between geographical distance and spillovers, however, is not as clear as one would expect. Backed by the argument that the exchange of tacit knowledge requires face-to-face contacts, Audretsch and Feldman (1996) and Gertler (2003) emphasize that knowledge sharing is highly sensitive to geographical distance, and geographical proximity will promote knowledge spillovers. Boschma and Frenken (2010), nevertheless, propose the so-called proximity paradox, which states that although geographical proximity may be a crucial driver for economic agents to interact and exchange knowledge with each other, too much proximity between these agents in other dimensions, however, might harm their performances. In the context of this paper, while geographical proximity increases the likelihood of learning and knowledge sharing between domestic private firms and MNCs, similarities in the markets they serve (Aitken and Harrison 1999), their knowledge bases, and their organizational proximity (Boschma and Frenken 2010) may also have negative impacts on the productivity performance of domestic private firms.

We use two proxies to capture spillovers. Many recent studies emphasize the role of labor market pooling in the process of spatial knowledge spillovers. Fallick et al. (2006) and Freedman (2008) illustrate that industry co-agglomeration facilitates labor mobility (moving among jobs). Ellison et al. (2010) further document that industries employing the same types of workers tend to co-agglomerate. Duranton and Puga (2004) explore the micro-foundations based on spatial externalities arising from sharing, matching, and learning among individuals. Kloosterman (2008) and Ibrahim et al. (2009) both argue that industry agglomeration promote knowledge spillovers since it facilities individuals to share ideas and tacit knowledge. In line with these studies, we adopt regional employment share of foreign firms as one of the proxies for FDI spatial knowledge spillovers in this paper. To capture the potential pecuniary externality channel suggested by Aitken and Harrison (1999), such as market stealing or the crowding out of local firms, we also use regional sales income shares of foreign firms as the second proxy for spillovers measurement.

The regional presence of FDI is largely affected by the related policy in the PRC. Five special economic zones (SEZs), which are mainly located in coastal areas, were set up in the PRC in the early 1980s to attract foreign capital by exempting MNCs from taxes and regulations. These five SEZs are Shenzhen, Xiamen, Hainan, Zhuhai, and Shantou. In view of the success of this experiment, similar schemes—such as open coastal cities (OCCs), open coastal areas, economic and technological development zones (ETDZs), and hi-tech parks—were later set up to cover broader and inner regions. Figure 1 compares the FDI spatial density distribution (measured as fixed-asset share of FDI in a specific county) between 1998 and 2007. As shown in the graphs, FDI presence in 1998 mainly clusters in the costal and central regions of the PRC. The graph for 2007 indicates that the clustering pattern became even more pronounced over time. Even while the FDI presence spreads over a broader and inner areas in PRC between 1998 and 2007, the clusters remain in the costal and central regions of the PRC. Notice that the magnitudes of density also become larger over time, indicating a strong FDI self-reinforcing pattern in spatial dimension.

The rest of this paper is organized as follows. Section 2 describes the data and presents the results of exploratory spatial analyses. Section 3 presents a spatial dynamic panel model that incorporates the spatial features observed in the data. Section 4 discusses various econometric issues and presents empirical results. The final section concludes with a summary and suggestions for future research.

2. Data and Exploratory Analysis

2.1 Data

Data employed in this paper come from the annual census of above-average-sized manufacturing firms in the PRC from 1998 to 2007. The National Bureau of Statistics (NBS) of the PRC conducted the census. The database, known as the Chinese Industrial Enterprises database (NBS-CIE database henceforth), includes firm-level census data for both state-owned firms and non-state-owned firms with annual sales revenue over CNY5 million. There are several variables—including the PRC standard location indicator, province code, city code, county code, district code, as well as firm address—that can help us to identify the location of a firm. Of all these variables, province code, city code, and county code are the most complete and consistent over the years. Measurement specifying the distance between individual firms is not available. Hence, we define region as a county in this paper. Consequently, all variables in this paper are aggregate county-level data constructed from firm-level information. This results in an unbalanced panel data set with 1,379 counties in 1998 and 2,133 counties in 2007, respectively. The longitude and latitude data of the PRC's administration division at the county level obtained from the GADM database of Global Administrative Areas function as a supplement to the NBS-CIE database for spatial data exploratory and regression analysis.[2]

The first step of our data analysis is to estimate TFP at the firm-level and then aggregate them at the county level for later spatial data exploratory analysis and regression use. More specifically, we first estimate firm-level TFP industry-by-industry using the Levinsohn and Petrin (2003) algorithm, which corrects for endogeneity bias in production function estimation arising from potential correlation between input levels and unobserved firm-specific productivity shocks. County-level TFP is then constructed by taking the weighted average of firm-level TFPs, with the weights being the value-added shares of the relevant firms located in the same county. Brandt et al. (2012) have thoroughly addressed data preparation and cleaning issues for NBS-CIE database. We follow the data cleaning strategy suggested by their study. We also use the industry concordances and deflators for all nominal variables provided by the same research. Nevertheless, since we do not have the 1993 annual enterprise survey and investment deflator from 1998 to 2007 mentioned in their paper, we are not be able to calculate the real capital stock as in Brandt et al. (2012). Alternatively, we use the sum of circulating funds and net value of fixed assets as a proxy for capital input. The capital input data is deflated by the investment price index obtained from the price information obtained from various issues of *[the People's Republic of] China Statistical Yearbook*. Our results show that this deviation will not affect the TFP estimation too much. Table 1 compares our estimates of the national aggregate TFP growth with those reported in Brandt et al. (2012). Our estimates are very close to their results.

Domestic private firms in this paper are firms that do not receive capital funds from foreign investors or from any level of the PRC's government.[3] Appendix 1 reports the information of firms' ownership structures and their portions in each year in the database. More specifically, in this paper, domestic private firms are firms with ownership structures from column (1) to column (7) in the table presented in Appendix 1. FDI firms correspond to columns with the headings Foreign Firms and Sino–Foreign Joint Ventures.

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[2] GADM is a spatial database of the location of the world's administrative areas (or administrative boundaries) and describes where these administrative areas are (the spatial features), and for each area it provides some attributes, such as the name, geographic area, longitude and latitude, and shape. Available at http://www.diva-gis.org/.

[3] This study does not attempt to address and evaluate the impact of FDI on the productivity of the PRC's state-owned enterprises. This issue may be investigated in future research.

2.2 Exploratory Analysis

In this section, we present exploratory analysis of our data. Our focus is to present and reveal the salient features of spatial autocorrelation for the variable of interest: TFP level (in logarithmic form) of the PRC. By definition, spatial autocorrelation describes the coincidence of value similarity with locational similarity (Anselin 2001). Positive spatial autocorrelation means high (or low) values of a variable tend to cluster together in space, and negative spatial autocorrelation indicates high (low) values are surrounded by low (high) values. As standard measures, both global and local Moran's *I* statistics are commonly adopted in the literature to illustrate the strength and significance of spatial autocorrelation. Global Moran's *I* statistic is defined as

$$I_t = \frac{n}{S_0} \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_{i,t}-\mu_t)(x_{j,t}-\mu_t)}{\sum_{i=1}^{n}(x_{i,t}-\mu_t)^2} \tag{1}$$

where $x_{i,t}$ is the variable of interest (TFP) for county *i* at time *t*; μ_t is the mean of variable x in year *t*; and w_{ij} is the element of spatial weights matrix W, which will be formally defined in the next section. Note that w_{ij} essentially functions as a weight to depict the relative similarity of two localities in terms of space. n is the number of counties. S_0 is a scalar factor equal to the sum of all elements of spatial weights matrix W . Similarly, local Moran's *I* statistic is defined as

$$I_{it} = \frac{(x_{i,t}-\mu_t)\sum_{j=1, j\neq i}^{n} w_{ij}(x_{j,t}-\mu_t)}{S_i^2} \quad \text{where} \quad S_i^2 = \frac{\sum_{j=1, j\neq i}^{n}(x_{j,t}-\mu_t)^2}{n-1} - \mu_t^2. \tag{2}$$

Local Moran's I is also known as an example of Local Indicators of Spatial Association (LISA) defined in Anselin (1995). For both global and local Moran's I, a positive value for the I statistic indicates that a county has neighboring counties with similarly high or low attribute values (TFP); this county is part of a cluster. A negative value for the I statistic indicates that a county has neighboring counties with dissimilar values; this county is an outlier. By comparing equations (1) and (2), it can be shown that, for a row standardized weights matrix, the global Moran's I equals the mean of the local Moran's I statistics up to a scaling constant. Finally, both local and global Moran's I statistics require underlying variable is normally distributed. We employ normality test suggested by Shapiro and Francia (1972) and perform statistic test on both TFP level and growth rate. At the 5% significance level, the null hypothesis that the value of interest is normally distributed cannot be rejected.

Table 2 reports the global Moran's I statistics for aggregate county level ln(TFP). As shown in the table, Moran's I statistics are significant and positive in all cases, implying the presence of positive spatial autocorrelation for ln(TFP). Notice that the statistics for domestic privates' ln(TFP) increase significantly over time, indicating an enhancing process of spatial clustering in terms of TFP innovation for domestic private firms during the sample period.

Equation (1) essentially describes the correlation between spatially weighted (spatial lag) variable, Wz , and z itself, where z is the variable of interest (TFP) that has been standardized. Consequently, Moran's *I* statistic can also be illustrated by plotting Wz against z while the statistic is equivalent to the slop coefficient of the linear regression of Wz on z. Figure 2 presents these Moran scatterplots for ln(TFP). In each graph, the four quadrants in the plot group the observations into four types of spatial interaction: (i) high values located next to high values (high–high cluster in upper right-hand corner), (ii) low values located next to low values (low–low cluster in lower left-hand corner), (iii) high values located next to low values (high–low outlier in lower right-hand corner), and (iv) low values located next to high values (low–high outlier in upper left-hand corner). Since variables are standardized, plots over time are comparable. It is clear that, over time, there is a tendency that most observations are located in the upper-right quadrants, corresponding to high–high values. The data show clearly that the spatial distribution of TFP level is becoming more clustered.

Figure 3 presents a comparison of local Moran statistic for ln(TFP) of domestic private firms between 1998 and 2007. The color code on the map indicates the corresponding quadrant in the Moran scatterplots (Figure 2) to which the counties belong. The graphs show significant changes in clustering locations during the sample period. In 1998, there are only several clusters covering limited regions. The high–high clusters are mainly in (i) the province of Yunnan; (ii) around the provinces of Shanxi, Henan, and Hebei; and (iii) some areas in Inner Mongolia Autonomous Region. There are also high–low outliers or low–low clusters in (i) provinces of Guangxi Zhuang Autonomous Region and Guangdong and (ii) provinces of Heilongjiang and Jilin. In 2007, however, high–high clusters are spread over central and central-northern parts of the PRC, while the high–low outliers and low–low clusters shift to southern parts of the PRC. It is apparent that for TFP level of domestic private firms the locations of clusters spread to broader regions over time and the spatial clustering pattern became much salient in 2007.

To sum up, exploratory data analysis reveals a salient spatial autocorrelation feature for ln(TFP). There is a strong tendency of ln(TFP) for domestic private firms becoming more clustered over the sample period. In the next section, we further explore these results in a spatiotemporal model that incorporates both spatial interactions across regions and the technology diffusion of FDI.

3. The Empirical Model

To estimate the extent of FDI spillovers and their diffusion pattern over time and across space, we generalize the spatiotemporal partial adjustment model in LeSage and Pace (2009, Chapter 7) to come up with the spatial dynamic panel regression equation in (3) as the platform for our empirical analysis, where the spatial weights w_{ij} are inversely proportional to the geographical distance d_{ij} between two regions i and j as stated in (4):

$$\begin{aligned}\ln TFP_{it} = {} & \tau \ln TFP_{it-1} + \rho\sum_{j=1}^{N} w_{ij} \ln TFP_{jt-1} + \beta_1 SOE\_presence_{it} + \gamma_1 \sum_{j=1}^{N} w_{ij} SOE\_presence_{jt} \\ & + \beta_2 FDI\_employment_{it} + \gamma_2 \sum_{j=1}^{N} w_{ij} FDI\_employment_{jt} \\ & + \beta_3 FDI\_sales_{it} + \gamma_3 \sum_{j=1}^{N} w_{ij} FDI\_sales_{jt} \\ & + \delta_t + \alpha_i + \varepsilon_{it} \qquad i = 1,2,...,N; \quad t = 1999-2007\end{aligned} \tag{3}$$

where

$$w_{ij} = \begin{cases} (d_{ij})^{-1} & if \quad i \neq j \\ 0 & if \quad i = j \end{cases} \tag{4}$$

The dependent variable $\ln TFP_{it}$ in (3) is the county-level TFP (in logarithmic format) described in section 2. We include two explanatory variables to proxy for FDI penetration, namely, the employment share and sales income share of foreign firms in a county:

$$FDI\_Employment_{it} = \frac{Employment_{it}^{FDI}}{Employment_{it}^{T}} \quad \text{and}$$
$$FDI\_Sales\ Income_{it} = \frac{Sales\ Income_{it}^{FDI}}{Sales\ Income_{it}^{T}} \tag{5}$$

where superscript T refers to all firms (both domestic and foreign) in a county, and superscript *FDI* refers to foreign firms only. The two proxies are expected to identify different channels of FDI spillovers. FDI employment share is expected to capture spillover effects that diffuse through labor market channels (e.g., positive spillovers such as technology transfer, learning-by-watching, and knowledge spillovers via labor turnovers; negative spillovers via poaching of local talents). In contrast, sales income share is expected to capture the pecuniary externality channel such as market stealing, crowding out of local firms, and competition effect. In view of the prominence of the state-owned sector in the PRC and its well documented impact on the private sector, we also include the fixed-asset share of state-owned enterprises in a county as a third explanatory variable:

$$\left(SOE\ Presence\right)_{it} = \frac{FA_{it}^{SOE}}{FA_{it}^{T}} \tag{6}$$

where FA denotes fixed assets, and superscripts T and *SOE* refer to all firms and state-owned firms, respectively. Finally, our panel data structure allows us to include two fixed effects that mitigate the problem of omitted variables. Time-specific fixed effect δ_t captures macroeconomic or policy events that have nationwide impact on productivity, while region-specific fixed effect α_i captures unmeasured local characteristics such as institutions, geography, and education.

With spatial interactions and temporal adjustments explicitly incorporated by the two autoregressive terms, $\sum_{j=1}^{N} w_{ij} \ln TFP_{jt-1}$ and $\ln TFP_{it-1}$, equation (3) implies that a change in a single observation associated with any explanatory variable, located in region i as of time t, will generate direct impact on the region itself (i.e. intra-regional impact $\partial \ln TFP_{it+s} / \partial x_{it}$) and potentially indirect impact on other region j (i.e. interregional impact $\partial \ln TFP_{jt+s} / \partial x_{it}$), starting from time t and extending all the way to indefinite future. These multipliers include the effect of spatial feedback loops. For instance, a second-order feedback effect means a change of observation x_{it} in region i affects $\ln TFP_{jt}$ in region j which in turn affects $\ln TFP_{it}$ in region i via the spatial autoregressive term. These feedback loops arise because region i is considered as a neighbor to its neighbors, so that impacts passing through neighboring regions will create a feedback impact on region i itself. The path of these feedback loops can be extended with the order of neighbors getting higher.

Often interest centers on the accumulated multiplier matrix $S_k(W)$ whose (i, j) element is the accumulated impact $\sum_{s=t}^{\infty} \partial \ln TFP_{jt+s} / \partial x_{it}$. Averaging over the *n* regions gives the following summary measures of spatial impacts introduced by LeSage and Pace (2009):

$$Average\ Total\ Direct\ Impact\ (ATDI) = n^{-1} tr S_k(W) \tag{7}$$

$$Average\ Total\ Impact\ (ATI) = n^{-1} \iota' S_k(W) \iota \tag{8}$$

$$Average\ Total\ Indirect\ Impact = ATI - ATDI \tag{9}$$

By rewriting (3) as a distributed lag model and then differentiate, it can be shown that the accumulated multiplier matrix follows the formula

$$\begin{aligned} S_k(W) &= (I - \rho^* W)^{-1} (\beta_k^* I + \gamma_k^* W) = \left(I + \rho^* W + \left(\rho^*\right)^2 W^2 + \cdots \right) \left(\beta_k^* I + \gamma_k^* W \right) \\ &= \left[\beta^* I + \gamma^* W \right] + \rho^* \left[\beta^* W + \gamma^* W^2 \right] + \left(\rho^*\right)^2 \left[\beta^* W^2 + \gamma^* W^3 \right] + \cdots \end{aligned} \tag{10}$$

where

$$\rho^* = \frac{\rho}{1-\tau}, \quad \beta_k^* = \frac{\beta_k}{1-\tau}, \quad \gamma_k^* = \frac{\gamma_k}{1-\tau} \tag{11}$$

It is of interest to examine the profile of decaying impacts imbedded in the power series expansion of the accumulated multiplier as shown in (10). The profile reveals the extent to which the impact of explanatory variable k spreads from lower-order neighbors to higher-order neighbors. The speed of diffusion is parsimoniously parameterized by ρ^*, which in turn is determined by the spatiotemporal autoregressive parameters τ and ρ. The squared bracket terms in the second line of (10) represent spatially partitioned effects, where powers of W capture the weights associated with the observations themselves (zero-order impacts with W^0), immediate neighbors (first-order impacts with W^1), neighbors of neighbors (second-order impacts with W^2), and so on.

4. Estimation Issues and Empirical Results

4.1 Estimation Issues

System-Generalized Method of Moments (GMM) estimator is employed in this paper. Recent Monte Carlo studies document that, in the context of dynamic spatial panel model, system-GMM estimator performs well in terms of bias, root mean squared error, and standard error accuracy (Kukenova and Monteiro 2009; Jacobs, Ligthart, and Vrijburg 2009). The setup of moment conditions follows Kelejian and Prucha (1999), i.e., both the spatially lagged dependent variable and independent variables are included in the instrument list on top of the conventional instrument set for system-GMM suggested by Arellano and Bover (1995) and Blundell and Bond (1998).

4.2 Empirical Results

Table 3 reports the estimation results of the spatiotemporal autoregressive panel model in (3) and a conventional dynamic panel model without spatial effects. Both time and spatial autocorrelation coefficients are positive and significant under different model specifications, suggesting fairly strong time and spatial self-reinforcing effects of TFP for domestic private firms at the county level. Estimated coefficients of proxies for own-regional (intra-regional) FDI presence are negative and significant across different regression models, indicating negative immediate impacts from FDI on domestic firms located in the same county. Notice that, however, the absolute magnitude of the coefficients for intra-regional FDI presence proxies are lower in the model without spatial effects, suggesting that conventional regressions ignoring spatial interactions may under-estimate the negative direct (intra-regional) impact of FDI penetration.

To account for spatial feedback effects and draw inferences from the long-term equilibrium perspective, we report estimates of summary measures of direct, indirect, and total impacts as well as spatial partitioning of these impacts. Drawing reliable statistical inferences from the sampling theory perspective on these impacts is not a straightforward task as they are complicated functions of underlying model parameters; see (10) and (11). On the other hand, a simulation-oriented Bayesian approach would have been relatively straightforward if the posterior distribution of the underlying parameters were easy to sample from. We apply the asymptotic theory in Kwan (1998) to interpret the asymptotic normal distribution of the GMM estimator as an approximate posterior distribution, which in turn allows us to use simulation method to compute the posterior distribution of various impact measures and their spatial partitioning. More specifically, a random drawn from the approximate posterior distribution of the parameter vector $\theta = (\tau, \rho, \beta, \gamma)$ is $\theta_d = P\delta + \hat{\theta}$, where $\hat{\theta}$ is the value of the GMM estimator; P is the lower-triangular Cholesky decomposition of the asymptotic covariance matrix of the GMM estimator; and δ is a vector containing random draws from a standard normal distribution. Each draw will result in one parameter combination for calculating impacts based on equations (7), (8), and (9). Based on 5,000 random draws, we can then compute very accurate estimate of the moments and percentiles of the posterior distribution of the impacts.

Table 4 reports the marginal posterior distributions of direct, indirect, and total impacts for the two proxies of FDI penetration. Both posterior means of direct impact for FDI employment share and sales income share are negative, suggesting that FDI in a specific county may have negative impacts on domestic private firms in the same county by taking over talented employees and market share from local firms. Nevertheless, the impacts from market stealing or crowding out of local firms may pass through neighboring counties, as suggested by the negative indirect spillovers for FDI sales income share measurement. The technology transfer or knowledge spillovers through labor turnovers, however, generate positive spillovers interregionally.

Table 5 reports statistics for spatially partitioned impacts based on 5,000 simulations. The results indicate that, for both of the two FDI measurements we adopted in this study, the intra-regional (direct) spillovers and interregional (indirect) spillovers present very different spatial decay pattern. On average, the intra-regional spillovers become negligible even in the first-order feedback loop (impact from immediate neighbors with W^1 being the weight). Notice that the first-order feedbacks in both cases are very small, implying that the penetration of FDI in a specific county will affect its immediate neighbors, which in turn will generate some but negligible feedback impacts on the domestic private firms in this specific county. The magnitudes of interregional spillovers, however, are still large even in the second-order feedback loop (impact from neighbors of neighbors) and could even extend to the fourth-order feedback loop. These results suggest that the negative intra-regional FDI spillovers are bounded locally, while the interregional FDI spillovers could extend to higher order neighbors. Specifically, FDI presence in a county will generate significant negative spillovers to domestic private firms in the same locality. Moreover, these negative spillovers are contained in the underlying county and the magnitude of the impact that extends to its neighbors through feedback loops is almost negligible, even for the underlying county's immediate neighbors. Domestic private firms, however, mainly benefit from FDI penetration in their neighboring regions through labor market channels. These positive and significant FDI spillovers not only come from a county's immediate neighbors but also from its higher-order neighbors. In the long-run, the positive interregional spillovers outweigh the negative intra-regional spillovers in almost every spatially partitioned feedback loop, resulting in the overall total impact being positive for FDI presence when measured as employment share. When FDI presence is measured as sales income share, both direct and indirect spillovers are negative, while the spillovers decay pattern remain the same; that is, direct spillovers are locally bounded and indirect spillovers could extend to higher order neighbors.

In Table 6, we present the posterior probabilities of spillovers for both FDI employment share and FDI income share. In each 2 by 2 table, based on 5,000 simulations, we calculate the probabilities of positive or negative spillovers for both direct and indirect impacts. The statistics reveal that the probabilities are not evenly distributed across the four scenarios. As for FDI employment share (Panel A), the probability that average total indirect impact is positive and the average total direct impact is negative is the highest. This further confirms that by poaching talented or cherry picking local employees MNCs could generate negative effect on the productivity performance of domestic firms located in the same county. Knowledge spillovers, however, are positive and could diffuse to neighboring regions. As for FDI sales income share (Panel B), the probabilities that both average total direct and indirect impacts are negative is the highest among all four scenarios, indicating that the negative FDI market-stealing effect is not restricted to a single county but can also diffuse to neighboring counties. Figure 6 illustrates the density-distribution sunflower plots following Dupont and Plummer (2003).[4] With the aid of these plots we are able to display the density of bivariate data (direct and indirect impacts) in a two dimensional graph. As presented in Figure 6, for FDI employment share, high- and medium-density regions are mainly located in the quadrant of negative direct spillovers and positive indirect spillovers. For FDI sales income share, high- and medium-density regions are mainly located in the quadrant signifying that both direct and indirect spillovers are negative.

5. Conclusions and Policy Implications

In this paper, we investigate the geographic extent of FDI spillovers to domestic private firms in the PRC. Previous literature has argued that the diffusion and realization of FDI spillovers are not automatic; instead, they can be affected by factors drawn from both the economic and geographical dimensions. We show that well-developed techniques in spatial econometrics can be employed to detect TFP clusters and to present them visually, to reveal the spatial extend of technology diffusion, and to estimate empirical models that incorporate spatial interactions explicitly. By making use of the geographic information at the county level, our data exploratory analysis reveals strong spatial autocorrelation for TFP in the PRC. We then further explore these findings by presenting a spatiotemporal model incorporating both the spatial interaction for TFPs of domestic private firms and the FDI spillovers. We show that this spatiotemporal model can be justified by generalizing the well-known partial adjustment model by assuming that the variable of interest, ln(TFP) of domestic private firms, in a specific region is influenced by its own and other regions' past period values. Consequently, a spatial partial adjustment mechanism can result in a long-run equilibrium characterized by simultaneous spatial dependence and time-space interactions. We generalize the LeSage and Pace (2009) setup to include time-specific and region-specific effects, and also extend some of their formula to cover the specification in which the spatial weights matrix may not be row-

4 These sunflower plots are obtained with the aid of Stata (version 11.2) "sunflower" function. In sunflower plots, a sunflower is presented as several line segments with equal length, called petals. These petals radiate from a central point. There are two varieties of sunflowers, light and dark. Each petal of a light sunflower represents one observation and each petal of a dark sunflower represents several observations. Dark and light sunflowers represent high- and medium-density regions of the data, and marker symbols represent individual observations in low-density regions.

normalized. We work out the long-run equilibrium representation of this model and use it as the benchmark model in regression analysis.

Our empirical results confirm the findings from exploratory analysis, indicating that high or low TFPs tend to cluster together over time. Our estimations also reveal the geographical extend of FDI spillovers in terms of the sign, the magnitude, and the geographic attenuation pattern. Given all other things being equal, FDI penetration in one county will generate significant negative spillovers to the productivity performance of the domestic private firms in the same locality. These negative intra-regional FDI spillovers, as shown by the data, are bounded within the underlying county as the feedback effects from higher order counties are found to be negligible. Domestic private firms, however, obtain positive FDI spillovers through interregional technology diffusion via labor market channels. Moreover, these interregional spillovers appear in spatial feedback loops among higher-order neighboring counties. In the long-run, the positive interregional spillovers outweigh the negative intra-regional spillovers, resulting in positive total effects through labor market channels. FDI spillovers measured as sales income share, however, are negative in both intra-regional and interregional dimensions, suggesting that negative market-stealing effects could extend from a local market to the whole country.

In order to attract FDI and, most importantly, to obtain advanced technology, the PRC's government has been providing incentive packages for MNCs since the early 1990s. Corresponding strategies provided by both central and local governments include tax holidays or reductions, job creation subsidies, preferential loans for FDI, and construction of industrial facilities (with subsidized land and infrastructure). Many local governments compete with their neighbors in this regard, which can result in severe strategic tax competition and a "race-to-the-top" or "race-to-the-bottom" problem (Yao and Zhang 2008). In this paper, we show that domestic firms mainly benefit from FDI presence in their neighboring regions, while intra-regional FDI impacts are mainly negative. Consequently, as a particular local government is concerned, it is important to re-think the strategic tax competition approach for attracting FDI as the benefits from doing so may not be as large as commonly believed. A better strategy for local governments would be to cooperate with each other to provide a better environment for both MNCs and domestic firms, such as providing better infrastructure for transportation across regions, lower regional tariffs for capital and labor, and fair tax treatment for both MNCs and domestic firms. To this end, coordination between local governments is of the utmost importance.

Appendix 1: Information of Ownership Structure and Their Corresponding Portions in NBS-CIE Database

		Domestic Firms											Foreign Firms				Sino–Foreign Joint Ventures (JVs)				Others	
		Privates								SOEs												
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8): sum of (1) to (7)	(9)	(10)	(11): (9) + (10)	(12)	(13)	(14)	(15): (12) + (13) + (14)	(16)	(17)	(18)	(19): (16) + (17) + (18)	(20)	
Year	**No. of Firms**	**Pure Privates**	**Other Domestic Private Firms**	**Collective Enterprise**	**Joint-Stock Enterprise**	**Associated Economics**	**Limited Liability Company**	**Corporation Limited Enterprises**	**All Domestic Privates**	**Pure SOEs**	**SOEs-Domestic JVs**	**SOEs**	**Pure F-type FDI**	**Pure HMT-type FDI**	**Joint Ventures between F and HMT**	**FDI**	**Sino–F JVs**	**Sino–HMT JVs**	**Other Sino–Foreign JVs**	**Sino–Foreign JVs**	**Undefined**	**Total: (8) + (11) + (15) + (19) + (20)**
1998	102,830	11.25	3.36	30.44	4.44	1.54	2.49	1.18	54.70	16.48	5.87	22.35	2.84	3.88	0.03	6.75	6.43	6.76	0.27	13.46	2.74	100
1999	111,715	13.17	4.53	27.44	4.48	1.43	3.17	1.39	55.60	14.80	5.96	20.76	3.13	4.97	0.04	8.14	5.89	6.60	0.25	12.75	2.76	100
2000	110,090	19.10	5.80	22.25	4.08	1.19	4.27	1.47	58.17	11.99	5.34	17.33	3.41	5.50	0.05	8.96	5.77	6.84	0.23	12.85	2.69	100
2001	125,235	26.56	7.86	16.84	3.66	0.95	5.57	1.52	62.96	8.97	4.32	13.29	3.83	5.82	0.05	9.70	5.44	6.19	0.22	11.85	2.21	100
2002	136,163	32.63	9.12	13.26	2.84	0.71	5.98	1.52	66.06	7.26	3.65	10.90	4.28	5.69	0.07	10.04	5.34	5.36	0.20	10.89	2.10	100
2003	153,585	37.94	10.95	9.38	2.22	0.52	6.46	1.47	68.95	5.30	2.70	8.00	4.72	6.35	0.05	11.12	5.01	4.89	0.16	10.06	1.88	100
2004	219,335	44.28	11.83	5.59	1.56	0.31	7.70	1.21	72.47	3.21	1.76	4.97	5.72	6.58	0.05	12.36	4.79	4.11	0.13	9.03	1.18	100
2005	218,401	44.93	13.76	4.47	1.28	0.26	7.44	1.19	73.34	2.44	1.37	3.81	5.97	6.88	0.05	12.91	4.41	3.68	0.10	8.19	1.76	100
2006	239,352	47.68	14.12	3.75	1.36	0.21	7.08	1.01	75.21	1.89	1.09	2.98	5.89	6.70	0.05	12.64	4.09	3.31	0.09	7.49	1.69	100
2007	266,311	48.43	16.27	2.96	1.14	0.17	6.90	0.92	76.78	1.42	0.86	2.28	5.92	6.55	0.05	12.52	3.67	2.91	0.09	6.67	1.75	100

CIE = Chinese Industrial Enterprises; FDI = foreign direct investment; HMT = Hong Kong, China; Macao China; and Taipei,China; JV = joint venture; NBS = National Bureau of Statistics; SOE = state-owned enterprise.

Notes: Total record of 503,079 firms with 1,683,017 observations. All statistics reported are results after data cleaning. A firm's ownership structure is determined by its source and structure o f paid-in capital and their registered type. "Pure" means the paid-in capital is 100% from the corresponding source; for instance, "Pure Private" means all the paid-in capital of these firms are from privates.

Source: Authors' calculation based on NBS-CIE database.

Appendix 2: Summary Statistics

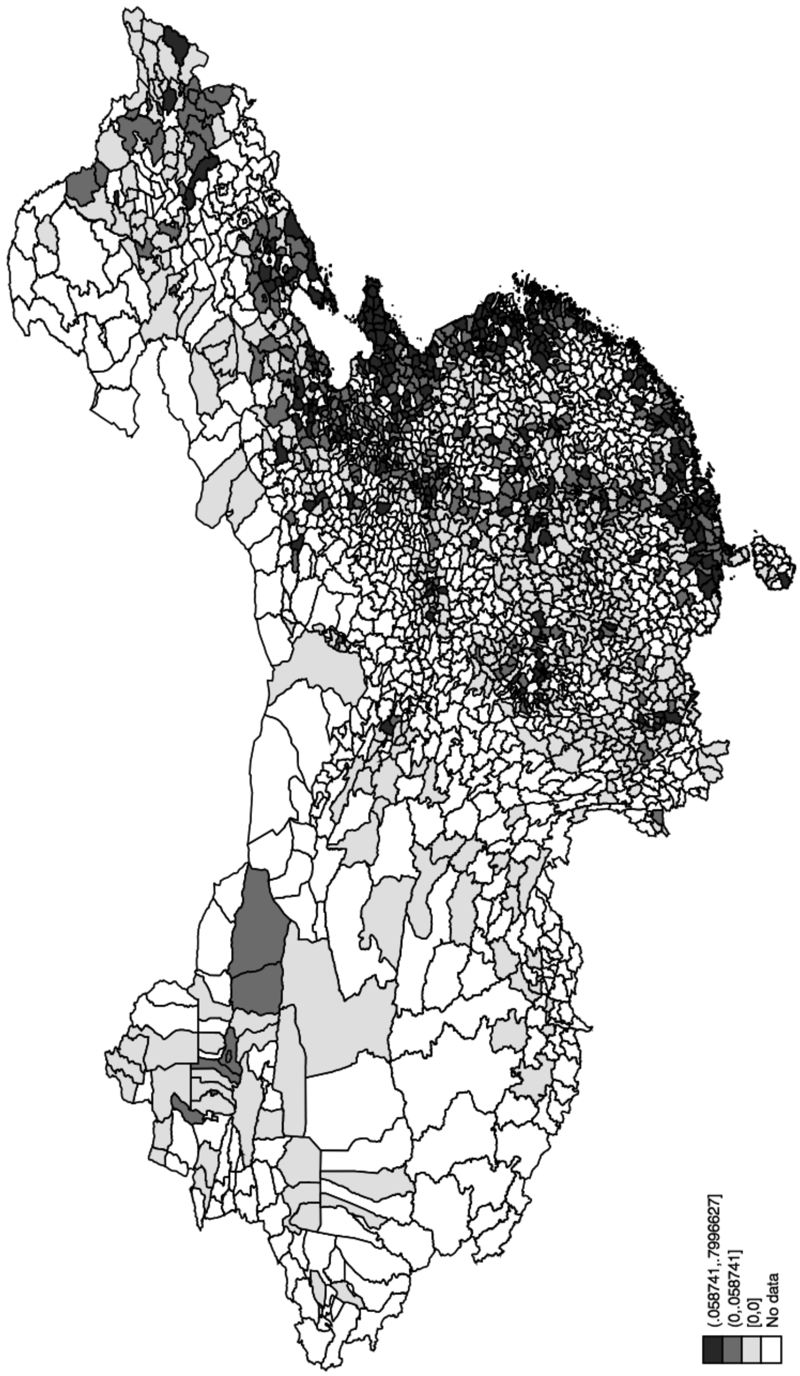
			Percentile					
	Mean	Standard Deviation	5%	25%	50%	75%	95%	Obs.
ln(TFP)	7.8713	2.6339	2.7981	6.1227	8.3869	9.9854	11.2401	12,942
W * ln(TFP)	4.5237	1.5630	1.8476	3.3631	4.6325	5.7123	6.9525	12,942
Space-time lagged of ln(TFP)	4.3879	1.5211	1.8370	3.2546	4.4616	5.5473	6.7952	11,014
FDI-employment	0.1056	0.1661	0.0000	0.0000	0.0311	0.1427	0.4655	19,054
FDI-sales	0.1123	0.1695	0.0000	0.0000	0.0332	0.1622	0.4757	19,054
W * FDI-employment	0.0637	0.0262	0.0237	0.0435	0.0622	0.0823	0.1091	19,054
W * FDI-sales	0.0673	0.0254	0.0261	0.0485	0.0673	0.0871	0.1079	19,054
SOE-Fixed Asset	0.2860	0.3090	0.0000	0.0114	0.1680	0.4920	0.9435	19,054

FDI = foreign direct investment; SOE = state-owned enterprise; TFP= total factor productivity; W= spatial weights matrix.

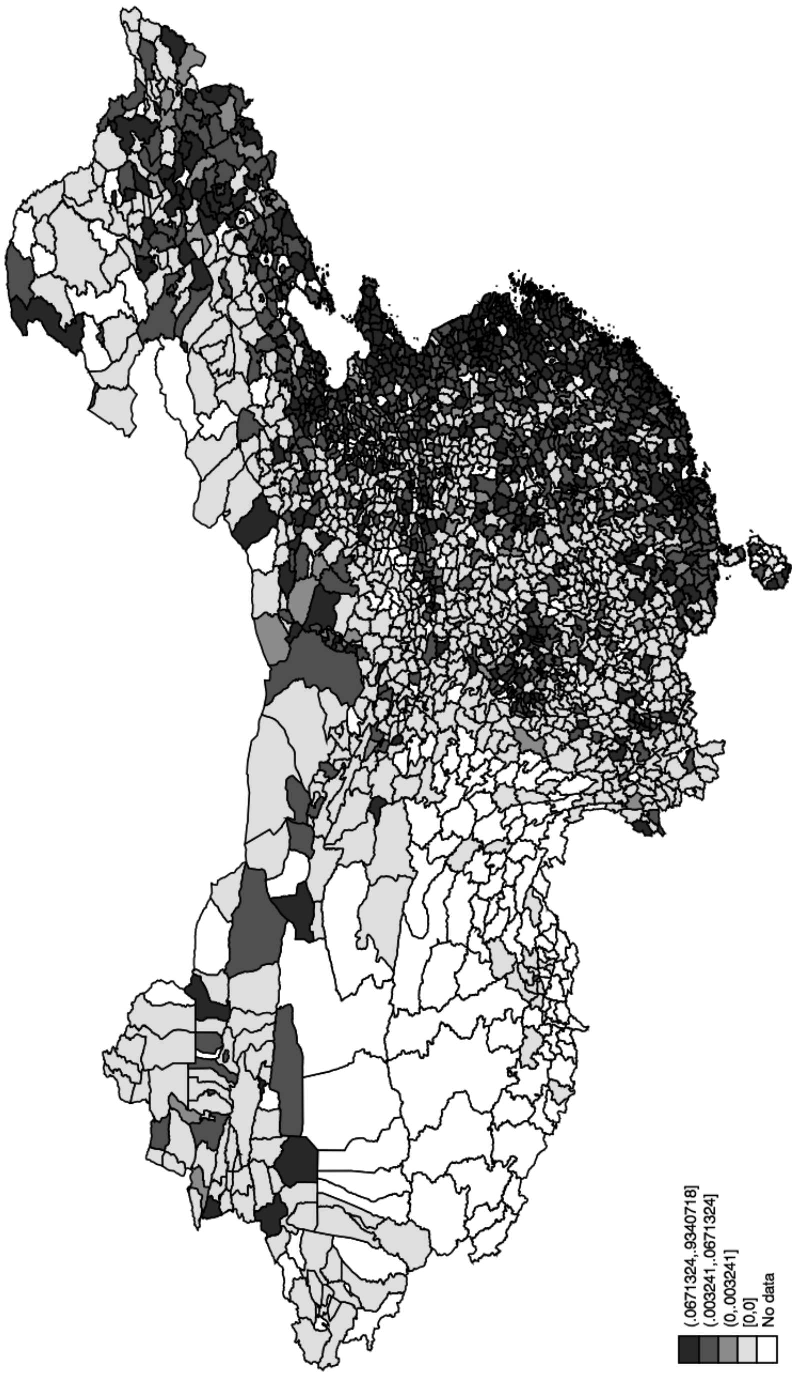
Source: Authors' calculation based on NBS-CIE database.

Figure 1: FDI Spatial Density Distribution at County Level

FDI Density (Fixed Asset Share) at County Level (1998)



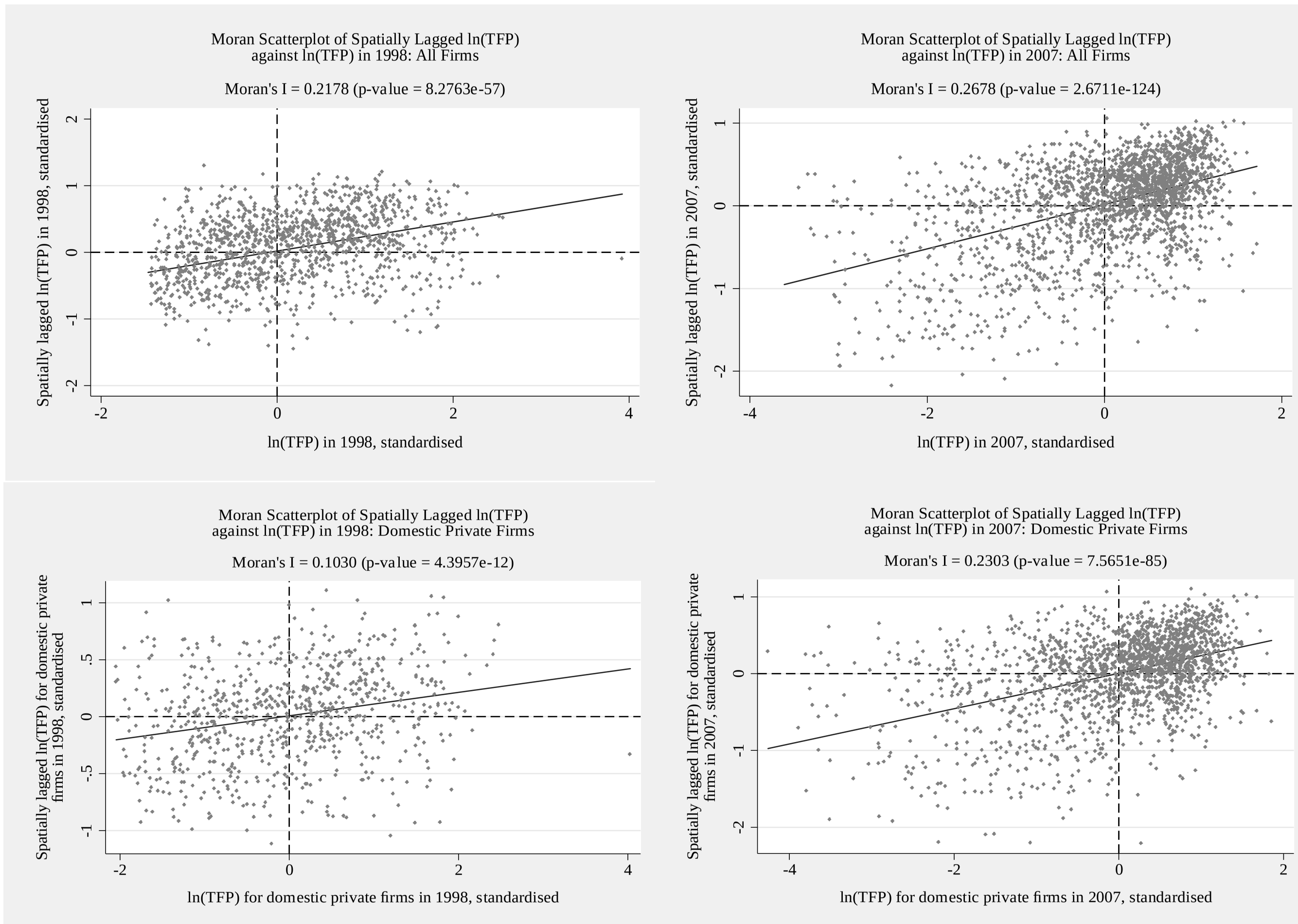
FDI Density (Fixed Asset Share) at County Level (2007)



FDI = foreign direct investment.

Source: Authors' calculation and representation based on NBS-CIE database.

Figure 2: Moran Scatterplot of ln(TFP) in 1998 and 2007

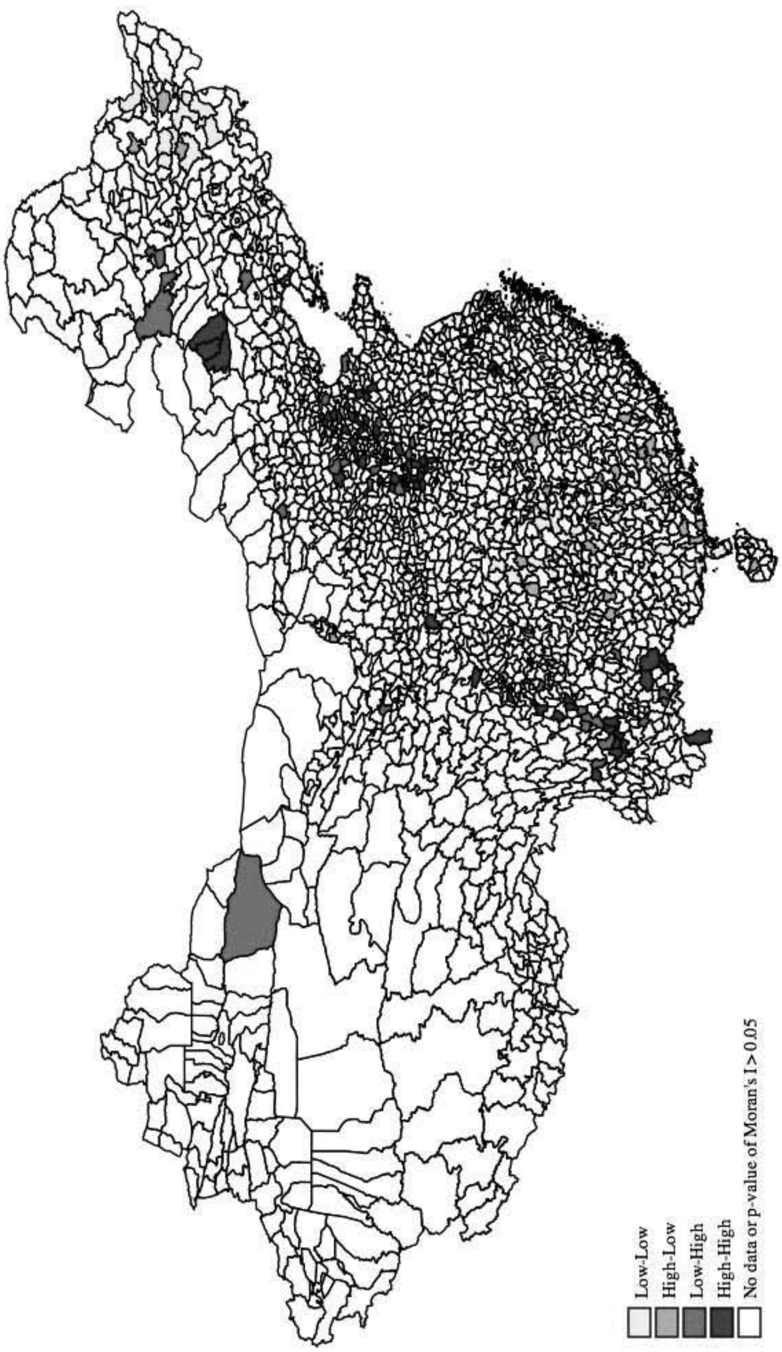


TFP= total factor productivity.

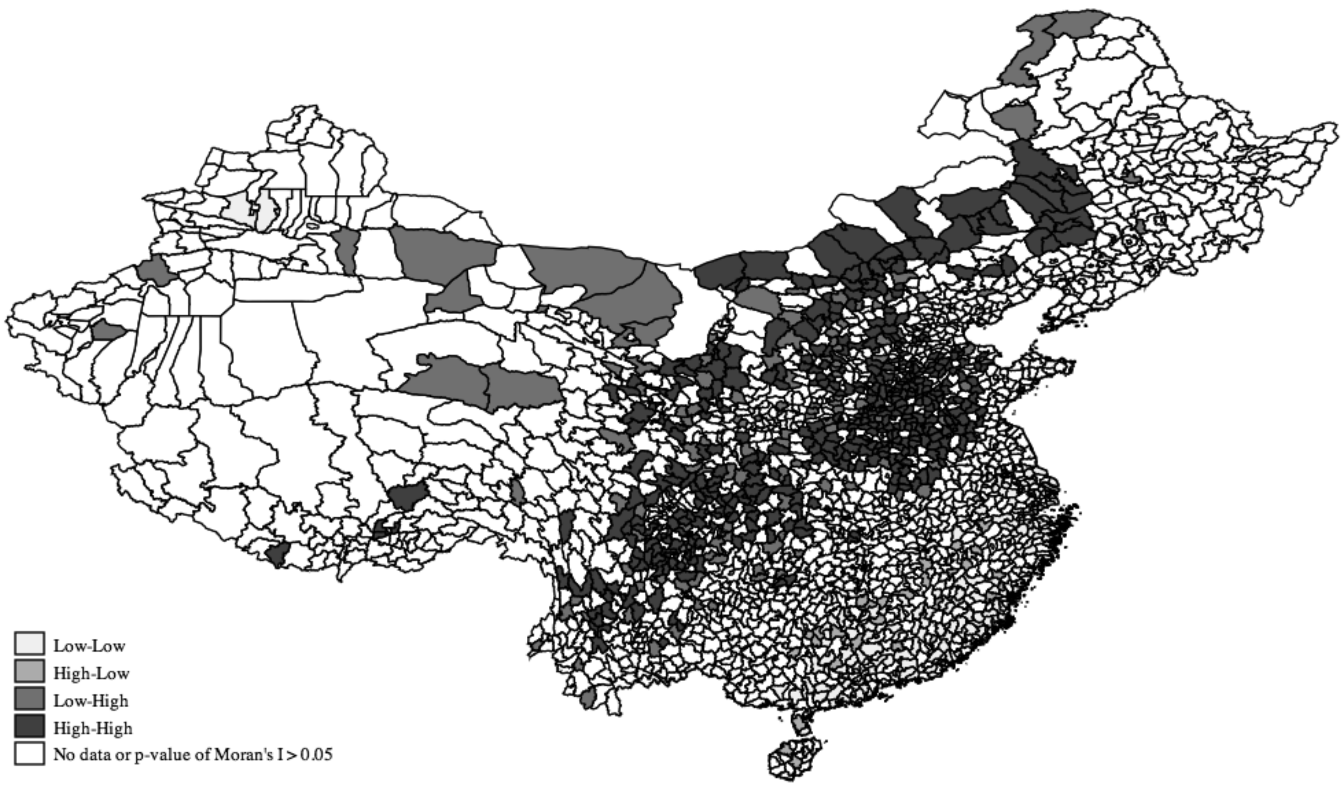
Source: Authors' calculation based on NBS-CIE database.

Figure 3: Local Indicator of Spatial Association Cluster Map of ln(TFP) for Domestic Private Firms

LISA Cluster Map of ln(TFP) for Domestic Private Firms in 1998



LISA Cluster Map of ln(TFP) for Domestic Private Firms in 2007

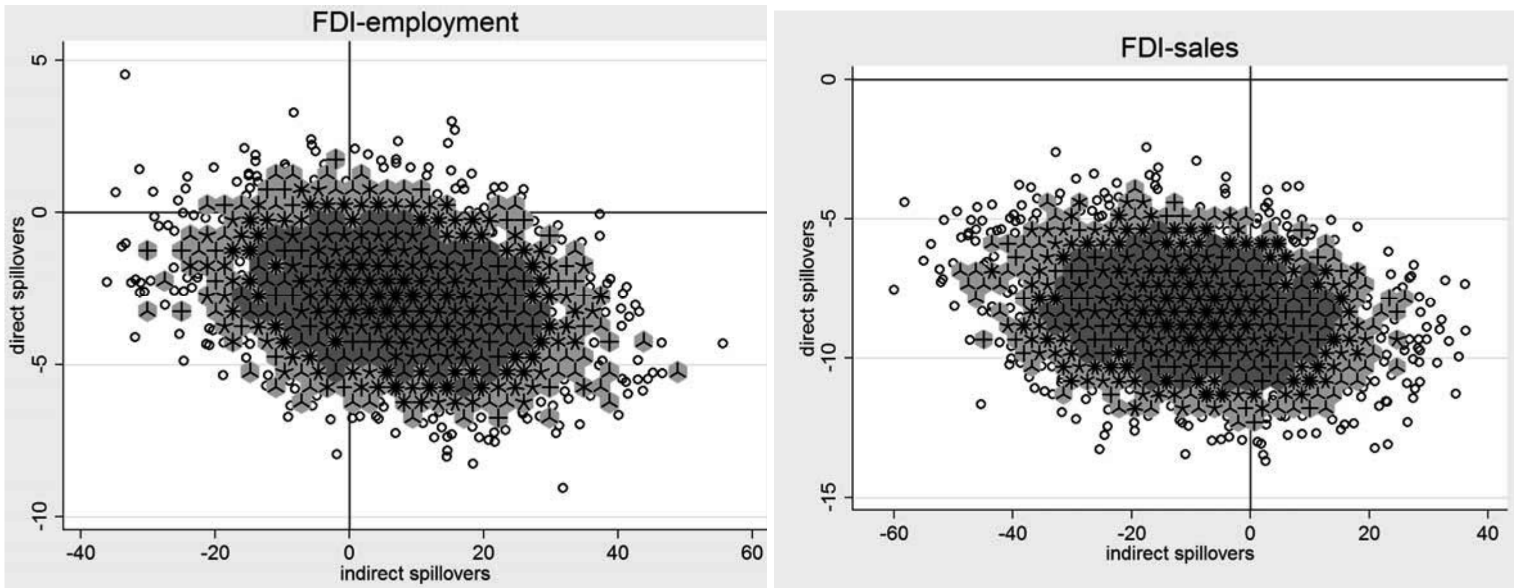


TFP= total factor productivity.

Note: LISA = Local Indicator of Spatial Association.

Source: Authors' calculation and representation based on NBS-CIE database.

Figure 4: Density-Distribution Sunflower Plots



FDI = foreign direct investment.

Source: Authors' calculation based on simulated data.

Table 1: Aggregate TFP Growth Rate of the PRC

Period	Brandt et al. (2012): Figure 4		Our Results	
	Value-Added Function	Revenue Function	Value-Added Function	Revenue Function
1998-2007	7.96%	2.85%	7.01%	2.46%

PRC = People's Republic of China; TFP = total factor productivity.

Notes: Firm-level TFP is estimated by following Levinsohn and Petrin (2003) approach. The national aggregate TFP is the weighted average of firms' TFP for each year with the weight being the value added share of a firm in that particular year. In this paper, our TFP are estimates based on value-added production function.

Source: Authors' calculation based on NBS-CIE database.

Table 2: Global Moran's *I* Statistics

		Moran's *I*	Standard Deviation	*p*-value
All Firms	ln(TFP) in 1998	0.2178	0.0131	< 0.001
	ln(TFP) in 2003	0.1693	0.0105	< 0.001
	ln(TFP) in 2007	0.2678	0.0106	< 0.001
Domestic Private Firms	ln(TFP) in 1998	0.1030	0.0146	< 0.001
	ln(TFP) in 2003	0.1451	0.0109	< 0.001
	ln(TFP) in 2007	0.2303	0.0112	< 0.001

TFP = total factor productivity.

Notes: All statistics are calculated based on row-standardized spatial weights matrix with 10 nearest neighbors.

Source: Authors' calculation.

Table 3: Benchmark Regression

Dependent Variable: ln(TFP)	No Spatial Effects	Spatiotemporal Model: Inverse-Distance Matrix
Time lag ln(TFP)	0.141***	0.129***
	(0.035)	(0.033)
SOE presence	-6.824***	-7.399***
	(0.967)	(0.686)
FDI presence: Employment	-2.223*	-2.378*
	(1.274)	(1.405)
FDI presence: Sales Income	-7.167***	-7.258***
	(1.423)	(1.434)
Space-time lagged of ln(TFP)		0.190***
		(0.042)
Spatially lagged SOE presence		-2.838
		(1.816)
Spatially lagged FDI presence: Employment		9.059
		(16.251)
Spatially lagged FDI presence: Sales Income		-11.052
		(17.785)
Hansen Statistic	4.669	9.678
Hansen Statistic P-value	0.700	0.785
D.O.F of Hansen Statistic	7	14
Number of Instruments	20	31
Arellano-Bond test for AR(1) in first differences	-11.989	-11.799
P-value for AR(1) Test	0.000	0.000
Arellano-Bond test for AR(2) in first differences	-1.389	-1.676
P-value for AR(2) Test	0.165	0.094
N	8,642	8,642

AR= arellano-bond test; FDI = foreign direct investment; GMM= generalized method of moments; SOE = state-owned enterprise; TFP = total factor productivity.

Notes: Results reported are two-step system-GMM estimates. Standard errors in parentheses. Windmeijer's (2005) correction method for the two-step standard errors is employed. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$. Year dummies are included in all regressions. Collapsed instrument matrix technique is employed to reduce the instrument count.

Source: Authors' calculations.

Table 4: Marginal Posterior Distributions of Cumulative Spillovers

			Percentile				
	Mean	SD	5%	25%	50%	75%	95%
FDI-employment							
Direct spillovers	-2.750	1.622	-5.480	-3.828	-2.741	-1.663	-0.095
Indirect spillovers	6.921	12.841	-14.096	-1.913	6.842	15.655	27.759
Total spillovers	4.171	12.489	-16.214	-4.282	4.050	12.565	24.563
FDI-sales							
Direct spillovers	-8.320	1.606	-10.892	-9.421	-8.353	-7.192	-5.639
Indirect spillovers	-10.192	14.017	-32.979	-19.415	-10.126	-0.630	12.452
Total spillovers	-18.513	13.760	-41.440	-27.483	-18.417	-9.192	3.920

FDI = foreign direct investment, SD = standard deviation.

Notes: All statistics reported are results from 5,000 simulations.

Source: Authors' calculations.

Table 5: Marginal Posterior Distributions of Partitioned Spillovers

		FDI Presence: Employment Share		FDI Presence: Sales Income Share	
		Mean	SD	Mean	SD
Direct spillovers	zero-order feedback loop (W^0)	-2.7515	1.6231	-8.3185	1.6066
	first-order feedback loop (W^1)	0.0013	0.0025	-0.0017	0.0027
	second-order feedback loop (W^2)	0	0.0002	-0.0004	0.0002
	third-order feedback loop (W^3)	0	0	0	0
	fourth-order feedback loop (W^4)	0	0	0	0
Indirect spillovers	zero-order feedback loop (W^0)	6.37	11.1454	-7.7263	12.1441
	first-order feedback loop (W^1)	0.4824	1.5237	-2.1411	1.732
	second-order feedback loop (W^2)	0.0662	0.2402	-0.3133	0.2927
	third-order feedback loop (W^3)	0.0021	0.0112	-0.0118	0.0156
	fourth-order feedback loop (W^4)	0	0.0001	0	0.0001
Total spillovers	zero-order feedback loop (W^0)	3.6186	10.7712	-16.0448	11.8661
	first-order feedback loop (W^1)	0.4837	1.5262	-2.1427	1.7347
	second-order feedback loop (W^2)	0.0662	0.2404	-0.3136	0.2929
	third-order feedback loop (W^3)	0.0021	0.0112	-0.0118	0.0156
	fourth-order feedback loop (W^4)	0	0.0001	0	0.0001

FDI = foreign direct investment; SD = standard deviation.

Notes: All statistics reported are results from 5,000 simulations.

Source: Authors' calculations.

Table 6: Posterior Probabilities

Panel A: FDI-employment		
Indirect spillovers	Negative	Positive
Direct spillovers		
Positive	0.0230	0.0212
Negative	0.2772	0.6786
Panel B: FDI-sales		
Indirect spillovers	Negative	Positive
Direct spillovers		
Positive	0	0
Negative	0.7636	0.2364

FDI = foreign direct investment.

Notes: All statistics reported are results from 5,000 simulations.

Source: Authors’ calculations.

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