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Evolution of the Spatial Distribution of China's Hi-tech Industries: Agglomeration and Spillover Effects*

YUTAO SUN AND FENGCHAO LIU

Spatial distribution is an important dimension of research into the development of high technology (hi-tech) industries due to the knowledge-intensive features of these industries. This paper separates the agglomeration effects and the spillover effects, and analyzes the evolution of the spatial distribution of China's hi-tech sub-industries from the mid-1990s by combining the geographic concentration index (locational Gini coefficient, concentration ratio) and spatial econometrics (Moran's I). The results reveal that, firstly, most hi-tech subindustries tend to be concentrated in the eastern coastal regions of China, while there are significant spillover effects from the eastern coastal regions to the central regions. The development model based on national hi-tech industrial zones is the primary reason for industrial agglomeration, and it is the result of both government direction and market rules. Secondly, on the macro-level, there has been a

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YUTAO SUN (孫玉濤) is a postdoctoral fellow at the Innovation and Development Research Center, Faculty of Management and Economics, Dalian University of Technology. His research interests include technology innovation and regional economic development. He can be reached at <sunyutao82@gmail.com>.

FENGCHAO LIU (劉鳳朝) is a professor at the Innovation and Development Research Center, Faculty of Management and Economics, Dalian University of Technology. His research interests include technology evaluation and technology policy. He can be reached at <fengchaoliu@126.com >.

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certain amount of geographical concentration and interregional division of labor among China's hi-tech industries, but there is low intraregional specialization. Furthermore, in contrast to the findings of most of previous studies, the distribution of China's hi-tech industries and that of its innovation capacity share similar evolutionary trends, although they do not completely overlap.

KEYWORDS: evolution; hi-tech industries; spatial distribution; agglomeration effects; spillover effects.

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With the development of science & technology (S&T) and the increase in the international division of labor, the creation, circulation, and distribution of knowledge have become important activities in the knowledge-based economy and high technology (hi-tech) industries. As the next wave of the technological revolution approaches, countries and regions all over the world are actively adjusting their development strategies, and hi-tech industry has become the cutting edge of competition both in terms of national economies and comprehensive national power.

Spatial distribution is an important dimension of the study of hi-tech industry due to the fact that this industry is knowledge-intensive and space-sticky of tacit knowledge. Over the past two decades, an extensive literature has contributed to our understanding of the role of regional or spatial agglomeration in motivating, facilitating, and maintaining industrial competitiveness and technological vitality.[1] In conjunction with research of

[1]See, for example, Zoltan J. Acs, David B. Audretsch, and Maryann P. Feldman, "Real Effects of Academic Research: Comment," *American Economic Review* 82, no. 1 (March 1992): 363-67; Ash Amin and Nigel Thrift, "Neo-Marshallian Nodes in Global Networks," *International journal of Urban and Regional Research* 16, no. 4 (December 1992): 571-87; Paul Krugman, *Development, Geography and Economic Theory* (Cambridge, Mass.: MIT Press, 1995), 45-67; Nick Henry, "The New Industrial Spaces: Locational Logic of a New Production Era?" *International Journal of Urban and Regional Research* 16, no. 3 (September 1995): 375-96; Michael Storper, *The Regional World: Territorial Development in a Global Economy* (New York: Guilford Press, 1997): 20-31; Luc Anselin, Attila Varga, and Zoltan Acs, "Local Geographic Spillovers between University Research and High Technology Innovations," *Journal of Urban Economics* 42, no. 3 (November 1997): 422-48; Michael E. Porter, "Location, Competition, and Economic Development: Local Clusters in a Global Economy," *Economic Development Quarterly* 14, no. 1 (February 2000): 15-34;

this kind, the focus of regional research into hi-tech industries has shifted from intra- to interregional distribution.

Beardsell and Henderson study the process of the spatial evolution of computers in 317 large U.S. cities following the introduction of the personal computer to the market.[2] Fornahl and Brenner analyze the relationship between industrial agglomeration and local knowledge production and diffusion, and they also study the resulting innovation activities, identifying geographic concentrations of these activities and examining different causes for the emergence of these concentrations.[3]

Recently, scholars have devoted more attention to the rapid development of China's hi-tech industries. The existing literature focuses on two aspects: the development performance of hi-tech industries, and the role of government and multinational companies. Taking the policy-supported field of computer-aided design (CAD) as an example, Wen and Kobayashi analyze technological innovation in this area, demonstrating that, in addition to diffusion, factors such as university-industry alliance, the capitalization of intellectual property in universities, and the new model of innovation in CAD all play key roles in technology innovation.[4] Yu and Tong analyze interaction between multinational companies and local executors in the Zhongguan cun (**中關村**) district of Beijing (**北京**).[5] Liu and Buck conclude that learning through import or export may promote the innova-

Martin Kenney, "Introduction," in *Understanding Silicon Valley: Anatomy of an Entrepreneurial Region*, ed. Martin Kenney (Stanford, Calif.: Stanford University Press, 2000), 1-14; Ash Amin, "Industrial Districts," in *A Companion to Economic Geography*, ed. Eric Sheppard and Trevor J. Barnes (Oxford: Blackwell, 2000), 149-68; Douglas Woodward, Octávio Figueiredo, and Paulo Guimarães, "Beyond the Silicon Valley: University R&D and High-technology Location," *Journal of Urban Economics* 60, no. 1 (July 2006): 15-32.

[2]Mark Beardsell and Vernon Henderson, "Spatial Evolution of the Computer Industry in the USA," *European Economic Review* 43, no. 2 (February 1999): 431-56.

[3]Dirk Fornahl and Thomas Brenner, "Geographic Concentration of Innovative Activities in Germany," *Structural Change and Economic Dynamics* 20, no. 3 (September 2009): 163-82.

[4]Jiang Wen and Shinichi Kobayashi, "Impacts of Government High-tech Policy: A Case Study of CAD Technology in China," *Journal of Engineering and Technology Management* 19, no. 3-4 (September 2002): 321-42.

[5]Yu Zhou and Tong Xin, "An Innovative Region in China: Interaction between Multinational Corporations and Local Firms in High-tech Cluster in Beijing," *Economic Geography* 79, no. 2 (April 2003): 129-52.

tion capacity of China's domestic companies.[6] Fan and Scott find that China differs from other economies in East Asia in terms of social history and the trend toward the liberalization of their economies, although they have many similar characteristics in regional development.[7]

Other studies focus on the spatial distribution of hi-tech industries. Sun uses multiple indexes, such as patent licenses, new product sales, and research and development (R&D) expenditure, to study spatial patterns of industrial innovation since the 1990s.[8] The results show that industrial innovation is mainly concentrated in the coastal regions of China. Furthermore, the spatial concentration is higher compared with previous studies.[9] Yao examines the regional development of hi-tech industries based on the spatial overlap of regional innovative capacity and hi-tech industrial zones. According to his results, Guangdong (**廣東**) and Jiangsu (**江蘇**) are the most developed provinces in terms of hi-tech industrial zone development, while Beijing (**北京**) and Shanghai (**上海**) are the top two in terms of innovation ability.[10] Wang and Lin identify a trend toward the agglomeration of information and communication technology (ICT) in the manufacturing sectors of China's eastern coastal regions.[11] Other scholars have also made contributions to the study of spatial distribution and agglomeration in China's hi-tech industries.[12]

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[6]Xiaohui Liu and Trevor Buck, "Innovation Performance and Channels for International Technology Spillovers: Evidence from Chinese High-tech Industries," *Research Policy* 36, no. 3 (April 2007): 355-66.

[7]Cindy C. Fan and Allen J. Scott, "Industrial Agglomeration and Development: A Survey of Spatial Economic Issues in East Asia and a Statistical Analysis of Chinese Regions," *Economic Geography* 79, no. 3 (July 2003): 295-319.

[8]Yifei Sun, "Spatial Distribution of Patents in China," *Regional Studies* 34, no. 5 (July 2000): 441-54.

[9]Yifei Sun, "Geographic Patterns of Industrial Innovation in China," *Tijdschrift voor economische en sociale geografie* (Journal of Economic and Social Geography) 94, no. 3 (August 2003): 376-89.

[10]Yongling Yao, "Spatial Overlap of Regional Innovation Capability and High-tech Industry," *International Journal of Technology Management* 28, no. 3/4/5/6 (July 2004): 615-32.

[11]Cassandra C. Wang and George C. S. Lin., "The Growth and Spatial Distribution of China's ICT Industry: New Geography of Clustering and Innovation," *Issues & Studies* 44, no. 2 (June 2008): 145-92.

[12]See, for example, Wang Zilong, Tan Qingmei, and Xu Xiaodi, "Gao jishu chanye jiju

In general, the existing research concludes that the spatial distribution of China's hi-tech industries presents a significant trend toward agglomeration in the eastern coastal area. However, hi-tech industries and innovation capacity do not completely overlap. Additionally, the relationship between industrial agglomeration, innovation, and economic performance is not significant. From the previous studies we discussed above, it is clear that there is a need for further research on the spatial distribution of China's hi-tech industries.

In the past, most scholars examined the hi-tech sector as a whole, or specific hi-tech industries (such as ICT), and less attention was paid to the structure of high-tech sub-industries. Secondly, spatial agglomeration is not the same as spatial spillover, and measuring spatial agglomeration and spatial spillover separately will highlight more aspects of spatial distribution. On the basis of spatial distribution measures, this article analyzes the evolution of the spatial distribution patterns of China's hi-tech industries and provides advice for China's policy makers.

The Development of China's Hi-tech Industries

Every country in the world is exploring the best way to obtain economic benefits on a global scale from the rapid development of innovation. Likewise, the Chinese government has seen hi-tech as an important driving force for sustainable development and has introduced many policies to promote hi-tech industries.

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shuiping cedu fangfa ji shizheng yanjiu" (The metrical method and empirical studies of high-tech industry agglomeration level), *Kexue xue yanjiu* (Studies in Science of Science) (Beijing) 24, no. 5 (May 2006): 706-13; Tang Gennian and Xu Weixiang, "Zhongguo gaojishu chanye chengzhang de shikong yanbian tezheng jiqi kongjian buju yanjiu" (A study of the evolution in time and space of the spatial distribution of hi-tech industrial development in China), *Jingji dili* (Economic Geography) (Changsha) 24, no. 5 (May 2004): 604-7; Liang Xiaoyan et al., "Woguo gaojishu chanye de kongjian juji xianxiang yanjiu: jiyu shenji gaojishu chanye chanzhi de jiliang fenxi" (A study on the spatial distribution of Chinese hi-tech industries: spatial econometrics analysis based on province-level industrial output value), *Kexue xue yanjiu* (Studies in Science of Science) (Beijing) 25, no. 3 (March 2007): 453-59.

The starting point of China's hi-tech industrial development is the Long-range Outline on the Development of Science and Technology, 1956-67 (1956-1967 年科學技術發展遠景規劃), issued in 1956. The Outline promoted the development of technologies in six innovative and hi-tech areas—nuclear power, rocket and jet technology, computers, semi-conductors, automation, and precision machinery. This policy document produced the first generation of hi-tech researchers and laid a foundation for hi-tech research in China and the development of corresponding industries.

With the beginning of economic reform and opening-up, China's hi-tech industries entered a new era of development. Since the 1980s, developed countries have invested large amounts of human and material resources in an effort to occupy the commanding heights of technological development. Examples include the Strategic Defense Initiative ("Star Wars") proposed by the United States in 1983, as well as the Eureka plan launched by the European Union in 1985.

China's National Science and Technology Planning Project (國家科學技術計劃專案) contains three programs related to hi-tech industry (see table 1). The earliest of these is the "National Key Technology R&D Program" (科技攻關), launched in 1983. In March 1986, four fellows of Chinese Academy of Sciences (CAS, 中國科學院), Wang Dayan (王大衍), Wang Ganchang (王淦昌), Yang Jiachi (楊嘉墀), and Chen Fangyun (陳芳允), wrote a letter to the Central Committee of the Communist Party of China (CCCPC,中國共產黨中央委員會) suggesting that China should develop high technologies in order to catch up with the rest of the world. This proposal was affirmed by Deng Xiaoping (鄧小平). Soon after, more than two hundred experts collaborated in drawing up a development strategy for China's hi-tech sector, which then contributed to the successful implementation of the State High-Tech Development Plan, or "863 Program" (國家高技術發展計劃，即 863 計劃). The "Torch Program" (星火計劃), designed to develop new and hi-tech industries in China, was approved by the State Council (國務院) in August 1988. Implementation of this program is now the responsibility of the Ministry of Science and Technology (MOST, 科技部) (formerly the State Science and Technology Commission,

Table 1
Main Hi-tech Research Programs in China

Program	Time	Objects	Main fields
National Key Technology R&D Program* (Keji zhicheng)	1983	Facing the national economic and social development needs, resolving the major scientific and technological problems in economic and social development	Agriculture, ICT, energy, resources, biology, environment, medicine and health.
863 Program (State High-Tech Development Plan)	1986	Promoting innovation ability of hi-technology, especially the international competitiveness of strategic hi-technology	Biological technology, information technology, aerospace, laser, advanced materials, advanced manufacturing and automation technology, energy technology, agriculture
Torch Program	1988	Picking the winners. Projects are selected and organized to develop new and high technology products and related industries, meeting the international standard of high technology products	Electronics and information technology, biotechnology and new medicines, new materials and their application, mechatronics, new energy, high-efficiency energy conservation technology and environmental protection technology.

Note: *National Key Technology R&D Program (**科技支撐**) is designed to implement the Mid-Long-term Plan Outline for National Science and Technology Development (**國家中長期科學和技術發展規劃綱要**) (2006-2020) (MLP), facing national economic and social development needs, mainly focused on important scientific and technological problems in the process of economic and social development, and based on the old National Key Technology R&D Program (**科技攻關**).

Source: Ministry of Science and Technology, http://www.most.gove.cn.

國家科學技術委員會). All these programs have played a powerful role in promoting the further development of China's high technologies.

In the early 1990s, China made several world-class achievements in science and technology, and hi-tech industries, in such areas as electronics, space exploration, fine chemicals, and instruments, have established a firm basis for development.[13] Despite these achievements and China's all-round effort to catch up with the developed world in science, technology, and economic development, the country is suffering from such adverse circumstances as lack of capital and talent, scattered investment, and a weak investment environment.

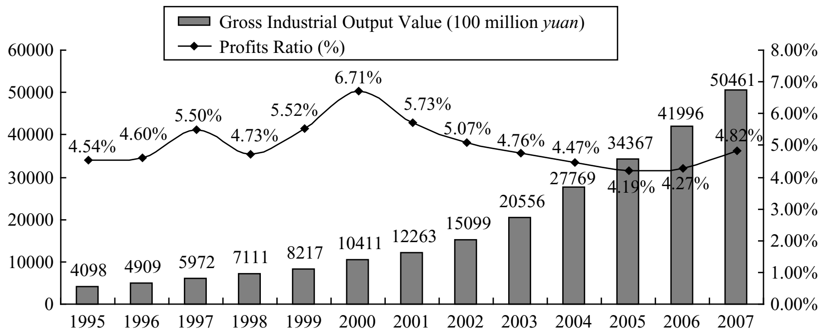
In order to meet the challenge of the new S&T revolution by accelerating the development of hi-tech industries, China's State Council approved a motion in 1991 to establish twenty-six national hi-tech industrial zones in medium and large intellectual resource-intensive cities, twenty-five of which were approved in 1992. There are currently fifty-six of these zones, including the Beijing New Technology Industry Development Trial Zones (established in 1988), the Yangling (楊淩) High-tech Agriculture Industrial Zone (established in 1997 in Shaanxi Province [陝西]), the Ningbo (寧波) National Hi-Tech Zone (January 2007), the Xiangtan (湘潭) National Hi-Tech Industrial Development Zone (March 2009), and the Taizhou (泰州) National Medical Hi-Tech Development Zone (March 2009). According to official statistics,[14] in 2007, the gross revenue of fifty-four national hi-tech industrial zones and the Suzhou (蘇州) Industrial Park (excluding Xiangtan and Taizhou) was RMB5.58 trillion, and they had a gross industrial output value of RMB4.61 trillion and value added of RMB1.13 trillion. They paid more than RMB500 billion in taxes.

In August 1999, a National Technology Innovation Conference, organized by the CCCPC and the State Council, was held in Beijing to look into the implementation of the Decision on Strengthening Technology Innovation, Developing High and New Technology, and Accomplishing Industrialization (加強技術創新，發展高新技術，實現產業化的決定). In January 2006, the National Science and Technology Conference issued the Mid- to Long-Term Plan Outline for National Science and Technology Development (2006-2020) (MLP, 國家中長期科學和技術發展規劃綱要).

[13]Shijun Qin, "High-tech Industrialization in China: An Analysis of the Current Status," *Asian Survey* 32, no. 12 (December 1992): 1124-36.

[14]http://theory.people.com.cn/GB/49169/49170/7063410.html

Figure 1
China's Hi-tech Industrial Development (1995-2007)



Source: *Zhongguo gaojishu chanye tongji nianjian* (China Statistics Yearbook on High Technology Industry) (Beijing: Zhongguo tongji chubanshe, 1996-2008).

In order to put this MLP into operation, MOST, along with the National Development and Reform Committee (NDRC, **國家發展和改革委員會**), the Ministry of Land and Resources (**國土資源部**), and the Ministry of Housing and Urban-Rural Development (**住房和城鄉建設部**), issued a document entitled, Several Opinions on Promoting the Further Development of National New & Hi-tech Development Zones and Enhancing Independent Innovative Ability (**關於促進國家高新技術產業開發區進一步發展增強自主創新能力的若干意見**), which suggested that "a new undertaking be started" (**二次創業**) for enhancing innovation within national hi-tech industrial zones.

The construction of national hi-tech zones and a series of policies aimed at encouraging innovation have enabled China to make dramatic gains since the 1980s, although these gains have been made in spurts. The hi-tech sector is playing an increasingly important role in industrial development, and its production has increased sharply since 1995 (see figure 1). In 2007, the gross output value of China's hi-tech industry exceeded RMB5 trillion, nearly five times that of 2002 and twelve times the 1995 total. The growth in sales revenue is similar to that in output value. The rapid growth of hi-tech industry prompted a readjustment of the industrial structure and made it a new pole for national economic growth.

Although the scale of hi-tech industry has increased sharply, its profitability is low. The profit ratio (profit divided by sales revenue) of China's hi-tech industry increased from 4.54 percent to 6.71 percent between 1995 and 2000; it decreased to 4.19 percent in 2005, and began to show an increasing trend again in 2006 and 2007. According to the *Statistical Yearbook of China* (**中國統計年鑒**), China's overall industrial profit ratio increased from 2.15 percent in 1998 to 6.70 percent in 2007;[15] it was higher than the hi-tech industrial profit ratio after 2001, and the gap between them is increasing. This indicates that China's hi-tech industry is less profitable than other industrial sectors.

Agglomeration has become an important feature of China's hi-tech industries based in hi-tech industrial zones. During the period of the Tenth Five-Year Plan (**十五規劃**), more than 80 percent of China's hi-tech industry was located in the Yangtze River Delta (**長江三角洲**), the Pearl River Delta (**珠江三角洲**), and the Circum-Bohai Sea Region (CBSR) (**環渤海地區**).[16] "Key cities" have been at the core of industrial development, and hi-tech industries such as biological medicine, aerospace, microelectronics, photoelectronics, and software have accelerated this development. Hi-tech industrial zones and economic technical development areas (**經濟技術開發區**) have become important centers for hi-tech industries. The Eleventh Five-Year Plan for Hi-Tech Industrial Development (**高技術產業發展十一五規劃**) expressed the development strategy as follows: "based on the optimal allocation of resources, make industrial agglomeration the strategic route for the development of hi-tech industries and speed up the concentration of industries in dominant areas and key cities, thus building

[15]Here, profit is calculated as a percentage of output value (similar to sales revenue), because there are no statistics on overall sales revenues. There are no statistics on gross industrial profits in the *Statistical Yearbook of China* before 1998.

[16]The Yangtze River Delta generally comprises the triangular-shaped territory of Wu-speaking Shanghai, southern Jiangsu Province, and northern Zhejiang Province. The Pearl River Delta (or Zhusanjiao) in southern China is the low-lying area where the Pearl River flows into the South China Sea. It comprises nine prefectures of the province of Guangdong, namely Guangzhou, Shenzhen, Zhuhai, Dongguan, Zhongshan, Foshan, Huizhou, Jiangmen, and Zhaoqing. The Circum-Bohai Sea Region in northern China is the area around the Gulf of Bohai, including parts of Beijing, Tianjin, Shandong, Hebei, and Liaoning.

characteristically hi-tech industrial bases" (**立足於資源的優化配置, 把產業集聚作為高技術產業發展的戰略途徑,加快產業向優勢區域和主要中心城市的集聚，建設特色高技術產業基地**).

Research Methods and Data

The literature on methods of measuring industrial, spatial, and geographic concentration is extensive. The measurement indexes of aggregation and geographic concentration proposed by Ellison and Glaeser[17] and by Maurel and Sedillot[18] are based on the distribution of activities (industry activities, innovation activities, and S&T activities) within a geographical unit and beyond the scope of the industry. Taking the spatial scale of industrial aggregation into consideration, Duranton and Overman[19] used continuous quantity of location and distances between factories to measure agglomeration.

According to Ratanawaraha and Polenske,[20] there are two kinds of geographic concentration indexes, with and without spillover effects, in which the concentration index of spillover effects is also used to measure the spatial distribution of industries and innovation activities. In fact, there are no certain connections between agglomeration and spillover of hi-tech industries.[21] However, the geographic concentration index with spillover effects implies that the geographic concentration of hi-tech ac-

[17]Glenn Ellison and Edward L. Glaeser, "Geographic Concentration in US Manufacturing Industries: A Dartboard Approach," *Journal of Political Economy* 105, no. 5 (October 1997): 889-927.

[18]Francoise Maurel and Beatrice Sedillot, "A Measure of the Geographic Concentration in French Manufacturing Industries," *Regional Science and Urban Economics* 29, no. 5 (September 1999): 575-604.

[19]Gilles Duranton and Henry G. Overman, "Testing for Localization Using Micro-Geographic Data," *Review of Economic Studies* 72, no. 4 (December 2005): 1077-106.

[20]Apiwat Ratanawaraha and Karen R. Polenske, "Measuring the Geography of Innovation: A Literature Review," in *The Economic Geography of Innovation*, ed. Karen R. Polenske (New York: Cambridge University Press, 2007), 30-59.

[21]Wang and Lin, "The Growth and Spatial Distribution of China's ICT Industry," 145-92; Yao, "Spatial Overlap of Regional Innovation Capability," 615-32.

tivities should have spillover effects.

This paper measures the spatial distribution of hi-tech industries using the geographic concentration index without spillover effects to measure industrial concentration and dispersion. It also employs spatial econometrics to examine spatial spillover effects.[22]

Methods for Measuring Spatial Concentration Effect

Degrees of concentration and dispersion are important indexes for judging whether an industry is concentrated. This paper adopts the locational Gini coefficient (LGC) and concentration ratio (CR) to reflect two aspects of the spatial distribution of industries: the degree of spatial difference and the degree of concentration.

Locational Gini coefficient: The first method used to measure geographic concentration is the locational Gini coefficient.[23] This is simply a modification of the Gini inequality index where individuals are replaced by regions and weights are given in terms of the regional shares in total output value. The LGC for hi-tech industry can be rewritten as:

$$G = \sum_i (s_i - x_i)^2$$

Where G is LGC, s_i is the output value of an industry within region i as a percentage of the output value of the country, and x_i is the output value of all industries in region i as a percentage of that of the whole country. This method is simple and visual. The higher the coefficient (the maximum value is 1), the bigger the aggregation value—that is, the more geographically concentrated the industry.

[22]See, for example, Luc Anselin, *Spatial Econometrics: Methods and Models* (Dordrecht: Kluwer Academic Publishers, 1988), 50-53; Luc Anselin, Raymond Florax, and Sergio J. Rey, *Advances in Spatial Econometrics, Methodology: Tools and Applications* (Berlin: Springer, 2004), 60-65.

[23]Paul Krugman, "Increasing Returns and Economic Geography," *Journal of Political Economy* 99, no. 3 (June 1991): 483-99.

Concentration ratio: Concentration radio is a simple and commonly used index to measure the spatial concentration of an industry. Taking production as an example, CR is calculated by ranking regions by their levels of production and dividing their shares in the national production of the first "*n*" regions with their share of national territory (that is, their region as a percentage of all regions in the country). The larger this ratio is, the higher the geographic concentration. The CR for hi-tech industry can be rewritten as:

$$CR_n = \sum_{i=1}^{n} S_i^k$$

Where S_i^k is the output value of industry *k* of region *i* as a percentage of the gross output value of the country's hi-tech industries. CR_n is the sum of the first "*n*" regions with their S^k in national territory. In general, $0 \leq CR_n \leq 1$. The larger the ratio, the higher the geographic concentration of the industry. In industry analysis, *n* always equals *1, 4, 8*. CR visually reflects the degree of spatial distribution of hi-tech industries.

The two methods are easy to operate but both have been the target of criticism[24] because they neglect the difference between the scale of the enterprises and the distances between enterprises. Due to differences in enterprise scale within industries and the size of geographic areas, this oversight can cause errors when the above method is used to compare the degree of concentration of different industries. Because the equation is primarily used to examine the evolution of distribution in hi-tech industries rather than the spatial organization structure of enterprises, it will not affect the interpretive accuracy of this study.

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[24]See, for example, Ellison and Glaeser, "Geographic Concentration," 889-927; Giuseppe Arbia, *Spatial Data Configuration in Statistical Analysis of Regional Economic and Related Problems* (Dordrecht: Kluwer Academic Publishers,1989), 25-30; Michael C. Wolfson, "Divergent Inequalities-Theory and Empirical Results," in *Analytical Studies Branch Research Paper Series*, ed. Statistics Canada, http://www.statcan.gc.ca/pub/11f0019m/11f0019m1997066-eng.pdf.

Methods for Measuring Spatial Spillover Effect

Scholars of spatial econometrics often use the theory of spatial dependence or correlation to explain spatial aggregation. According to this theory, spatial aggregation has a cluster effect, and regions in which industry is concentrated will influence nearby regions via spillovers. Certainly, spatial similarity could be due to regions sharing similar underlying conditions, and not necessarily be due to externalities from neighboring regions, although it may also be affected by internal factors. However, spatial correlation reflects the relationship among observations in a geographic space, and geographical proximity is an important condition. The externalities of geographical proximity are not only scientific and technological knowledge spillover by means of supply chains, the flow of capital and labor, and other channels, but also the demonstration effect affecting internal factors, such as cultural concept and policy philosophy. This is an intangible and complex process, and the assumption of existing externalities is more realistic than the assumption that no externalities exist. So, spatial correlation is a better indicator than geographic concentration indexes with spillover effects for measuring spillover effect, although it does not remove other uncertainty factors.

This article introduces spatial autocorrelation to test the effects of spatial spillovers associated with China's hi-tech industries. Classic spatial autocorrelation statistics include Moran's I and Geary's C. Both require the measurement of a spatial weights matrix, which reflects the intensity of the geographic relationship between observations in a neighborhood. Spatial autocorrelation statistics such as Moran's I and Geary's C are global in the sense that they estimate the overall degree of spatial autocorrelation for a dataset. The possibility of spatial heterogeneity suggests that the estimated degree of autocorrelation may vary significantly across geographic space.[25] Moran's I is used to reflect the spatial spillover effect in this study.

[25]Anselin, *Spatial Econometrics*, 35-40.

The first step in calculating Moran's I is to build spatial weight matrix *W*. The construction principle of element w_{ij} is: $w_{ij} = 1$ if region *i* is adjacent to region *j*; $w_{ij} = 0$ if *i* is not adjacent to *j*. So *W* is a $n * n$ matrix.

Moran's I is calculated based on the following formula:

$$I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}} \times \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i - \overline{x})(x_i - \overline{x})}{\sum_{i=1}^{n}(x_i - \overline{x})^2} \qquad \text{where } \overline{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

and $\overline{x}$ is the mean of the variable *x*, w_{ij} are the elements of the weight matrix, $-1 \leqq I \leqq 1$, $I < 0$ means negative correlation, $I = 0$ means no correlation, and $I > 0$ means positive correlation.

Standardization statistic *Z* can be used to examine the significance of Moran's I, and it can also reflect whether autocorrelation exists among *n* areas. (The assumption is that autocorrelation does not exist between statistics). *Z* is defined as follows:

$$Z(I) = \frac{I - E(I)}{\sqrt{Var(I)}} \qquad \text{where } E(I) = -1/(n-1),$$

$$Var(I) = \frac{n^2 w_1 - n w_2 + 3 w_0}{w_0(n^2 - 1)} - E(I)^2$$

$$\text{Where } w_0 = \sum_{i=1}^{n}\sum_{j}^{n} w_{ij},\ w_1 = \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}(w_{ij} + w_{ji})^2,\ w_2 = \sum_{i=1}^{n}(w_i + w_j)^2,$$

w_i is the sum of row *i*, and w_j is the sum of column *j*. When *Z* is positive and significant, there is a positive correlation, and a similar trend in the observed values tends toward spatial aggregation, and vice versa. When $Z = 0$, the observed values are independent and randomly distributed.

This study takes the hi-tech industrial output value of China's provinces and regions (excluding Hong Kong, Macao, and Taiwan) from 1995 to 2007 as the development indicator of hi-tech industries. According to the Notice on the Classified Catalogue of Statistics on Hi-Tech Industries (**高技術產業統計分類目錄的通知**), issued by the National Bureau of Statistics in July 2002, China's hi-tech industries include aerospace manufacturing (ASM), electronics and telecommunications equipment manufacturing (ETEM), computers and office equipment manufacturing (COEM), medical and pharmaceutical products manufacturing (MPPM), and medical instrument and meter manufacturing (MTIMM). Unless otherwise specified, all data related to China's hi-tech industries are taken from the *China Statistics Yearbook on High Technology Industry* (**中國高技術產業統計年鑒**), issued by National Bureau of Statistics (NBS,**國家統計局**).

Evolution of Spatial Agglomeration Effects of China's Hi-tech Industries

Spatial Distribution Patterns of Hi-tech Industries based on LGC

ETEM occupies a dominant position among China's hi-tech industries, accounting for 50 percent of gross output value (around 53.24 percent in 1995 and 49.72 percent in 2007) (see table 2). The fastest-growing industry is COEM, whose percentage of hi-tech output value has increased from 8.65 percent to 29.45 percent over the same period, with an annual growth rate of 36.52 percent. MPPM and MTIMM have also grown fast, but their output values as percentages of the total for hi-tech industries, especially that of MPPM, have fallen. The output value of ASM as a percentage of the hi-tech total is lower, and has dropped from 6.56 percent to 2.03 percent, due to relatively slow growth.

The development of China's hi-tech industries has largely followed the course laid down in government plans. In the mid-1990s, China's hi-tech industries were still at their initial stage of development. The Ninth Five-Year Plan for the Scientific and Technological Development of China and the Outline for 2010 (**全國科技發展"九五"計劃和 2010 年規劃**) proposed that hi-tech industries of all kinds should be developed in parallel. With the advent of the information revolution and the internet,

Table 2
The Output of China's Hi-tech Industries, 1995-2007

(Unit: RMB100 million)

Industries	1995	1996	1997	1998	1999	2000	2001
ASM	268.97	286.41	313.17	323.27	333.07	387.58	469.31
MTIMM	331.4	386.46	427.25	446.84	474.33	584.2	652.95
MPPM	961.26	1151.1	1262.24	1372.73	1497.22	1781.37	2040.86
ETEM	2181.67	2504.21	3172.01	3847.21	4708.52	5981.38	6900.45
COEM	354.46	580.94	796.95	1120.6	1203.49	1676.95	2199.8
Industries	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**AGR**
ASM	535.18	550.8	501.6	797.23	828.01	1024.44	11.79%
MTIMM	758.85	911.44	1327.4	1785.35	2420.66	3128.21	20.57%
MPPM	2378.44	2889.9	3241.3	4250.45	5018.94	6361.90	17.06%
ETEM	7947.99	10217.16	14006.7	16867.13	21217.6	25088.04	22.57%
COEM	3478.83	5986.8	8691.5	10666.95	12510.7	14858.57	36.52%

Source: *Zhongguo gaojishu chanye tongji nianjian* (China Statistics Yearbook on High Technology Industry) (Beijing: Zhongguo tongji chubanshe, 1996-2008).

the electronic information and computer related industries have developed more rapidly.

The Special Plan for Hi-tech Industrial Development (**高技術產業發展重點專項規劃**) in the Tenth Five-Year Plan for S&T and Education Development (**十五科技教育發展專項規劃**), issued in 2000, proposed the development of new industries such as software, communication equipment, digital products, biomedical products, and biological chips. In the Eleventh Five-Year Plan for Hi-tech Industrial Development, the electronic information, biological, and aerospace industries were named as focuses for development. The electronic information technology industry is more mature and on a larger scale than the others, and the biological and aerospace industries have potential for future development.

Applying the LGC to the data, we obtain the following results (see table 3). In 1995, ASM exhibited the highest degree of spatial concentration, followed by COEM, MPPM, MTIMM, and finally ETEM. The industry with the largest output values, ETEM, has the lowest degree of

Table 3
Locational Gini Coefficient of China's Hi-tech Industries

Industries	1995	1996	1997	1998	1999	2000	2001
ASM	0.1052	0.1141	0.1182	0.1421	0.1412	0.1521	0.1606
MTIMM	0.0449	0.0460	0.0507	0.0365	0.0496	0.0470	0.0599
MPPM	0.0253	0.0274	0.0299	0.0351	0.0421	0.0399	0.0475
ETEM	0.0085	0.0078	0.0064	0.0064	0.0060	0.0042	0.0029
COEM	0.0721	0.0550	0.0447	0.0376	0.0241	0.0255	0.0471
Industries	2002	2003	2004	2005	2006	2007	AGR
ASM	0.1836	0.2187	0.2297	0.2272	0.1886	0.1767	4.41%
MTIMM	0.0595	0.0647	0.0323	0.0339	0.0396	0.0302	-3.24%
MPPM	0.0586	0.0723	0.0786	0.0858	0.0808	0.0797	10.02%
ETEM	0.0028	0.0019	0.0039	0.0036	0.0044	0.0047	-4.71%
COEM	0.0369	0.0270	0.0159	0.0210	0.0242	0.0245	-8.59%

spatial concentration, while ASM, the industry with the lowest output values, has the highest degree of spatial concentration.

From the growth rate of LGC from 1995 to 2007, we can see that MPPM is the fastest growing industry, with an annual growth rate of 10.02 percent. ASM had a lower growth rate, while other industries were declining. The spatial distribution of hi-tech industry changed greatly between 1995 and 2007, but ASM still had the highest degree of spatial concentration.

Spatial Distribution Patterns of Hi-tech Industries Based on CR

This study uses the CR formula and the data to measure CR_1, CR_4, and CR_8—that is, the CR of China's hi-tech industries in the top region in terms of production value, the top four regions, and the top eight regions (see table 4). From 1995 to 2007, the industry with the highest CR_1 is COEM, and the one with the second highest is ETEM. The CR_1 of MPPM and MTIMM are not significant, and MPPM has the lowest CR_1 of all five industries. The situations of CR_4 and CR_8 are similar to that of CR_1, the difference being that the CR_4 and CR_8 of MTIMM are higher than those of ASM.

Table 4
Concentration Ratio of China's Hi-tech Industries (%)

Industries	CR_n	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
ASM	CR_1	15.88	17.10	17.03	16.69	16.34	17.19	18.88	18.82	23.80	24.73	20.28	21.66	21.19
	CR_4	50.45	52.29	48.95	54.77	52.56	54.76	54.15	58.65	63.24	42.92	65.38	54.00	53.15
	CR_8	82.76	85.65	80.81	81.93	81.17	81.13	79.16	82.90	83.81	82.01	83.30	77.82	76.80
MTIMM	CR_1	18.01	17.89	17.66	17.12	18.38	18.29	18.21	16.29	15.71	17.45	17.33	17.53	18.94
	CR_4	50.75	50.84	50.36	55.89	54.26	55.89	55.84	54.85	54.32	56.75	57.67	56.80	58.15
	CR_8	72.10	72.99	71.59	77.07	76.15	76.44	76.87	76.82	77.84	78.91	80.67	80.97	81.40
MPPM	CR_1	10.36	10.61	10.82	10.59	9.56	10.32	10.18	10.03	10.63	11.47	12.58	12.60	13.72
	CR_4	36.19	37.20	35.74	35.40	33.37	34.89	34.86	34.92	36.58	38.50	40.22	40.14	39.67
	CR_8	59.36	59.54	57.54	58.14	55.82	56.33	56.84	57.40	57.30	58.34	58.94	58.97	59.46
ETEM	CR_1	31.25	30.44	30.92	32.30	33.27	31.09	30.95	33.04	34.52	36.13	34.66	34.31	32.91
	CR_4	63.05	62.54	60.98	62.18	63.61	64.16	65.13	64.77	67.30	71.21	69.93	69.33	69.07
	CR_8	82.90	83.57	82.98	84.38	84.87	85.45	86.41	86.56	88.73	91.18	91.76	91.87	90.84
COEM	CR_1	45.78	43.43	41.14	35.68	35.31	36.36	47.04	46.45	45.28	37.67	39.86	39.53	36.99
	CR_4	75.20	76.02	77.51	79.69	76.12	77.24	81.36	81.19	87.33	87.53	88.42	88.29	87.70
	CR_8	92.49	93.38	93.69	94.43	94.30	95.35	96.09	97.00	98.04	97.25	97.68	97.50	97.37

From the point of view of the evolution of CR, with the exception of the CR8 of ASM and the CR_1 of MTEM, all industries tend toward spatial and geographic aggregation. The top region for ASM is Shaanxi, for MTIMM it is Jiangsu, while the top region for MPPM has shifted from Guangdong to Shandong (**山東**). The top region for both COEM and ETEM is Guangdong (see table 5). On the whole, the top eight regions in terms of hi-tech industrial output value remain relatively stable, with a little internal adjustment, between 1995 and 2007. There is only one region that drops out of the top eight in MTIMM and one drop-out and one new entry in ETEM, while three regions drop out of the top eight for COEM by 2007, and there are three new entries. China's hi-tech industry is mainly concentrated in the eight coastal provinces of Guangdong, Jiangsu, Shanghai, Zhejiang (**浙江**), Fujian (**福建**), Shandong, Beijing, and Liaoning (**遼寧**). Additionally, several central provinces such as Henan (**河南**), Hubei (**湖北**), Sichuan (**四川**), Shaanxi, and Heilongjiang (**黑龍江**) also have significant concentrations of hi-tech industries.

Table 5
The Top Eight Regions in Terms of the Output of China's Hi-tech Industries

Ranking	ASM		MTIMM		MPPM		ETEM		COEM	
	1995	2007	1995	2007	1995	2007	1995	2007	1995	2007
1	Shaanxi	Shaanxi	Jiangsu	Jiangsu	Guangdong	Shandong	Guangdong	Guangdong	Guangdong	Guangdong
2	Jiangsu	Sichuan	Shanghai	Guangdong	Jiangsu	Jiangsu	Jiangsu	Jiangsu	Beijing	Jiangsu
3	Heilongjiang	Liaoning	Zhejiang	Zhejiang	Shanghai	Zhejiang	Shanghai	Beijing	Fujian	Shanghai
4	Guizhou	Heilongjiang	Beijing	Shandong	Shandong	Guangdong	Tianjin	Shanghai	Liaoning	Fujian
5	Liaoning	Jiangxi	Guangdong	Shanghai	Zhejiang	Henan	Sichuan	Tianjin	Jiangsu	Zhejiang
6	Sichuan	Guizhou	Sichuan	Beijing	Sichuan	Sichuan	Zhejiang	Shandong	Shanghai	Beijing
7	Jiangxi	Beijing	Liaoning	Liaoning	Hebei	Hebei	Beijing	Zhejiang	Heilongjiang	Shandong
8	Beijing	Jiangsu	Shandong	Henan	Henan	Shanghai	Shandong	Fujian	Tianjin	Hubei

ASM has the smallest scale of all the hi-tech industries. Given its high market access threshold, large initial investment, and close links to national security, it is hardly surprising that ASM has retained its position. The CR_1 of ASM ranked third in 2007, and Shaanxi was the number one province for ASM in both 1995 and 2007. While the CR_1 and CR_4 of ASM have shown slight increases between 1995 and 2007, the CR_8 hovered near 80 percent before dropping a little in 2006 and 2007. At present, the top cities for ASM are Xi'an (**西安**) in Shaanxi, Chengdu (**成都**) in Sichuan, Shenyang (**瀋陽**) in Liaoning, and Haerbin (**哈爾濱**) in Heilongjiang. The Xi'an Yanliang (**閻良**) National Aviation Hi-Tech Industrial Base in Shaanxi is the only state-level aviation industry base in China.

The CR_1 of MTIMM is not significant, and dropped in 2002 and 2003. The CR_4 and CR_8 of MTIMM have shown steady growth. In 1995, the top three regions for MTIMM were Jiangsu, Shanghai, and Zhejiang, and the Yangtze River Delta had an absolute advantage in this industry. In 2007, the top four regions were Jiangsu, Guangdong, Zhejiang, and Shandong, and the Pearl River Delta and the CBSR have grown in strength. MPPM has low spatial concentration. Its CR_4 hovers around 40 percent and its CR_8 is below 60 percent, which indicates that MPPM is relatively dispersed. It also indicates that MPPM has yet to form a division of labor or to undergo industrial agglomeration. On the whole, the Yangtze Delta (Jiangsu, Shanghai, Zhejiang), the Pearl River Delta (Guangdong), and the CBSR (Shandong, Hebei) still dominate where this industry is concerned.

In terms of both CR_4 and CR_8, ETEM ranked second, with 2007 values of 69.07 percent and 90.84 percent, respectively. COEM was top in terms of CR_4 and CR_8, increasing from 75.20 percent and 92.49 percent in 1995 to 87.74 percent and 97.37 percent in 2007. The aggregation effects for ETEM and COEM have obviously tended to increase over time.

From the perspective of regional distribution, Guangdong remains the consistent leader and Fujian was among the top eight regions in 2007.

All of the top eight regions for ETEM are located in the coastal provinces, and the situation is similar for COEM (with the exception of Hubei). The Yangtze Delta provinces of Jiangsu, Shanghai, and Zhejiang;

the southern coastal provinces of Guangdong and Fujian; and Beijing, Shandong, and Tianjin in the CBSR have become the major areas for ETEM and COEM. MTEM and COEM account for nearly 90 percent of the total output value of China's hi-tech industries, so these three regions dominate in terms of the hi-tech sector as a whole.

Geographical factors that speed up the circulation of information and commodities mean that the eastern coastal areas of China are intellect-intensive. These areas thus dominate the electronic information and computer industries. On the whole, this distribution pattern mirrors the distribution of innovation ability.[26] While some provinces in the interior (including Hubei, Henan, Shaanxi, Sichuan, and Heilongjiang) also have a certain comparative advantage in some industries, the distribution is spotty and the industries have failed to form clusters.

The Evolution of the Spatial Spillover Effects of China's Hi-tech Industries

We now calculate Moran's I to indicate the spillover effects of spatial distribution within China's hi-tech industries (see table 6).

All hi-tech industries reject the null hypothesis with the exception of ASM, which means that there is spatial autocorrelation on the distribution of hi-tech industries among provinces and regions. This shows that the distributions of hi-tech industries are not random, and they have significantly positive spatial dependence. Provinces in which hi-tech industries have a high (or low) level of development tend to aggregate, and the performance of hi-tech industries in a province is strongly influenced by its adjacent provinces. Several factors, such as knowledge spillovers, capital flows, and transportation or transaction costs, may influence the spatial similarity

[26]Fengchao Liu and Yutao Sun, "A Comparison of the Spatial Distribution of Innovative Activities in China and the U.S," *Technological Forecasting & Social Change* 76, no. 6 (July 2009): 797-805.

Table 6
Spatial Moran's I of China's Hi-tech Industries

Types	Index	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
ASM	Moran I	-0.219	-0.196	-0.197	-0.173	-0.191	-0.191	-0.187	-0.194	-0.169	-0.135	-0.157	-0.152	-0.159
	Z Test	-1.861	-1.601	-1.621	-1.255	-1.615	-1.361	-0.161	-1.538	-1.266	-1.172	-1.115	-1.252	-1.195
	P Value	0.015	0.025	0.030	0.035	0.030	0.015	0.025	0.025	0.020	0.090	0.060	0.070	0.071
MTIMM	Moran I	0.466	0.482	0.539	0.444	0.456	0.439	0.475	0.442	0.409	0.295	0.283	0.338	0.322
	Z Test	4.470	4.651	5.368	4.749	4.850	4.378	4.612	4.291	4.122	3.055	2.980	3.369	3.300
	P Value	0.005	0.005	0.005	0.005	0.005	0.002	0.002	0.001	0.002	0.004	0.010	0.005	0.010
MPPM	Moran I	0.303	0.280	0.266	0.236	0.237	0.209	0.207	0.241	0.300	0.341	0.310	0.290	0.275
	Z Test	3.028	2.791	2.715	2.455	2.421	2.211	2.123	2.433	3.001	3.378	3.202	2.930	3.019
	P Value	0.005	0.009	0.010	0.017	0.018	0.027	0.024	0.018	0.006	0.002	0.003	0.008	0.006
ETEM	Moran I	0.051	0.029	0.044	0.049	0.065	0.087	0.091	0.076	0.086	0.070	0.083	0.072	0.072
	Z Test	1.037	0.873	0.996	1.059	1.425	1.412	1.636	1.487	1.562	1.713	1.500	1.447	1.213
	P Value	0.114	0.120	0.120	0.080	0.060	0.076	0.050	0.055	0.065	0.070	0.065	0.075	0.075
COEM	Moran I	0.031	0.038	0.044	0.035	0.057	0.070	0.050	0.063	0.076	0.143	0.123	0.134	0.169
	Z Test	1.162	1.189	1.202	0.811	1.105	1.310	1.443	1.448	1.458	0.220	1.991	2.058	2.267
	P Value	0.070	0.085	0.090	0.140	0.095	0.085	0.070	0.065	0.060	0.030	0.035	0.035	0.028

between adjacent provinces and regions.

ASM has a negative spatial autocorrelation, in line with Moran's I in table 6. ASM is a military industry in China, and its layout is almost the same as it was during the planned economy period. Centers such as Xi'an, Chengdu, and Shenyang have failed to form industrial linkages or promote the flow of knowledge, information, and talent to surrounding areas. This, in turn, leads to stronger spatial independence. Therefore, the spatial distribution of ASM has an individual spot pattern, as opposed to a network, facets, or a belt.

However, with the deepening of reform and opening-up, as well as the expansion of the civil aerospace market in China, ASM has tended to transfer to the coastal regions. Examples include the plant for the final assembly of the Airbus-A320 aircraft and the National Aerospace Industrialization Base which are now located in the Tianjin Binhai New Area (天津濱海新區), and the Commercial Aircraft Corporation of China, Ltd. (CACC,中國商用飛機有限公司) which is located in Shanghai. The latest data issued by the National Bureau of Statistics (NBS) show that the output value of Tianjin's ASM was RMB11.225 billion in 2009, and the city's ranking in terms of the output value of its ASM industry rose dramatically from thirteenth in 2008 to fourth in 2009. The top three provinces for this industry in 2009 were Shaanxi (RMB26.525 billion), Liaoning (RMB16.18 billion), and Sichuan (RMB15.699 billion).[27]

Moran's I for both MTIMM and MPPM has decreased slightly, but both industries maintain a high spatial autocorrelation. The Yangtze and Pearl River deltas and the CBSR are where MTIMM and MPPM are mainly concentrated. Additionally, Henan Province in the central region, as a major contributor to the medicinal and pharmaceutical industry, has demonstrated rapid development in recent years. Pharmaceutical manufacturing, especially traditional Chinese medicine manufacturing and biomedicine manufacturing, is an important force in the development of

[27]http://www.frponline.com.cn/news/detail_25657.html.

hi-tech industries, of which MPPM accounts for 57.6 percent. MTIMM and MPPM have developed rapidly within this group of central cities, while Jilin Province (**吉林省**) in the northeast region has a similar advantage in MPPM, though its growth remains slow.

The Moran's I for ETEM and COEM is smaller than it is for MTIMM and MPPM, but in increase to a certain degree from 1995 to 2007 which indicates a trend toward aggregation in these industries. The aggregation regions for ETEM, COEM, MTIMM, and MPPM are the Yangtze and Pearl River deltas and the CBSR. Hubei province is a major contributor to the development of S&T in China, and it has demonstrated rapid development in COEM, optoelectronic information and other fields based on the Wuhan East Lake (**武漢東湖**) High-Tech Development Zone and the Xiangfan (**襄樊**) National High-tech Zone.

Jiangsu, Shanghai, and Zhejiang in the Yangtze River Delta; Fujian and Guangdong in the southern coastal region; Beijing, Tianjin, Hebei, and Shandong in the CBSR; and Henan and Hubei in the central region are all high-high aggregation regions for hi-tech industries, and they have significant spatial autocorrelation. Liaoning, Shaanxi, Sichuan, and Guizhou (**貴州**) have some comparative advantages, but development in surrounding provinces lags behind, making it difficult to identify agglomerative advantages. The rest of the vast western region consists of low-low aggregation areas.

The geographic distribution of China's hi-tech industries is not random. The growth pattern of these industries presents strong spatial aggregation features with significant local autocorrelation. The growth of hi-tech industries in each province is influenced by its adjacent provinces, and the diffusion of knowledge plays an important role in the development of these adjacent provinces. The eastern regions, especially the eastern coastal provinces, are in the lead, not only in terms of absolute output value, but also in the growth rate of hi-tech industries. The most easterly parts of the central regions are expected to be gradually influenced by the radiation effects and leading power of the eastern regions, due to the positive effects of spatial correlation. The rapid development of Henan and Hubei in the central region is a good example of this.

An Explanation of Spatial Evolution in China's Hi-tech Industries

LGC is a measure of the spatial agglomeration and dispersion of specific industries against the background of national industrial development, and CR is calculated by comparing a single industry across multiple regions. Combining LGC and CR will compensate for the shortcomings of each in measuring spatial aggregation and divergence.

From LGC, we can see that hi-tech industries do not present any significant tendency toward agglomeration but are actually more obviously dispersed than other, non-high-tech industries in China. From their CRs, we can see that hi-tech industries have exhibited a consistent tendency to concentrate in the Yangtze River Delta (Jiangsu, Shanghai, Zhejiang), the southern coastal region (Guangdong, Fujian), and the CBSR (Beijing, Shandong, Tianjin) (see figure 2). This is most evident in the case of electronic information and computer-related industries (ETEM and COEM).

The spatial autocorrelation results indicate that in most hi-tech industries (with the exception of ASM) knowledge-intensive features determine the extent of spatial dependence autocorrelation. Knowledge spillover, flow of talent, and the sharing of infrastructure among adjacent areas all have a positive influence on the spatial concentration of industries. Meanwhile, the development of hi-tech industries in the coastal region has tended to diffuse to the central region. Below, we will attempt to explain why spatial distribution patterns in China's hi-tech industries changed between 1995 and 2007.

First, throughout the 1990s, China's reform and opening-up underwent dramatic developments, but the economy remained in transition from a planned economy to a market economy (also known as the "mixed economy period"). During this time, the development of hi-tech industries was the result of a combination of market forces and government power.

Industrial aggregation is an important development strategy for hi-tech industries (it was proposed by the Chinese government in its Eleventh Five-Year Plan for Hi-tech Industrial Development) which serves the interests of the industries themselves and complies with the rules of the market

Figure 2
The Spatial Distribution Evolution of Hi-tech Industries in China (Mainland)

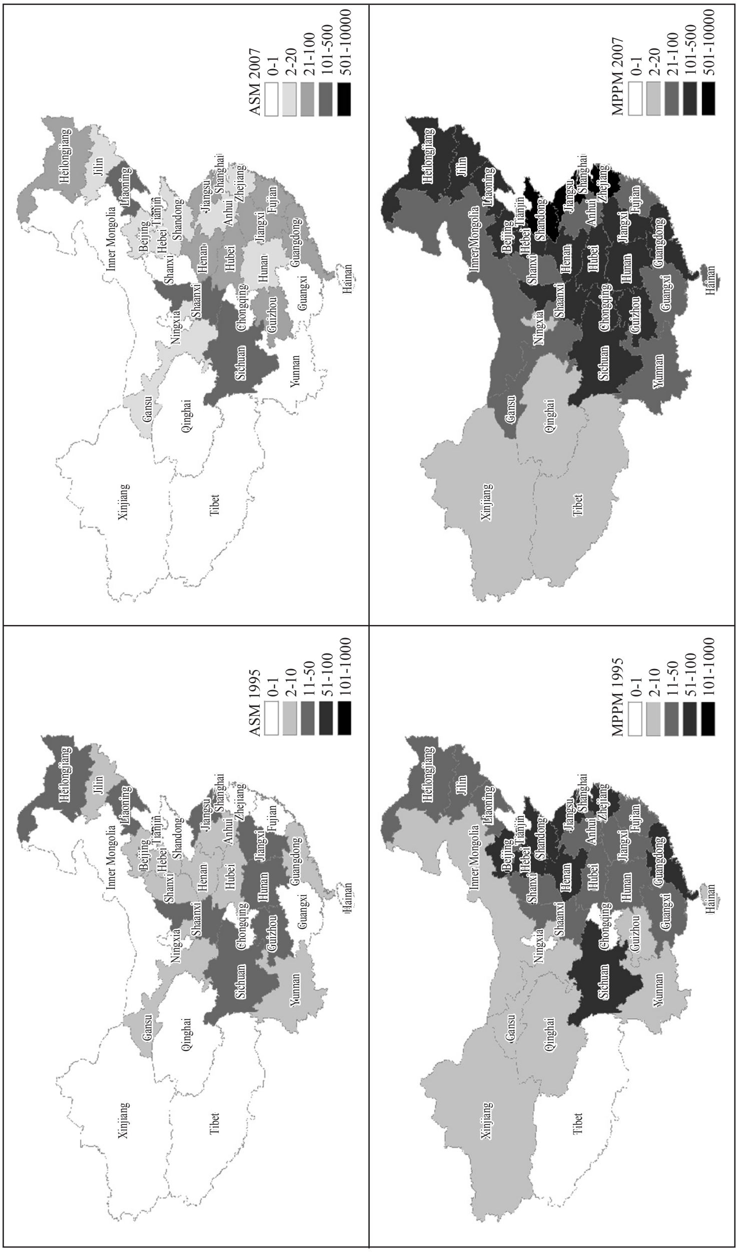


Figure 2 (Continued)

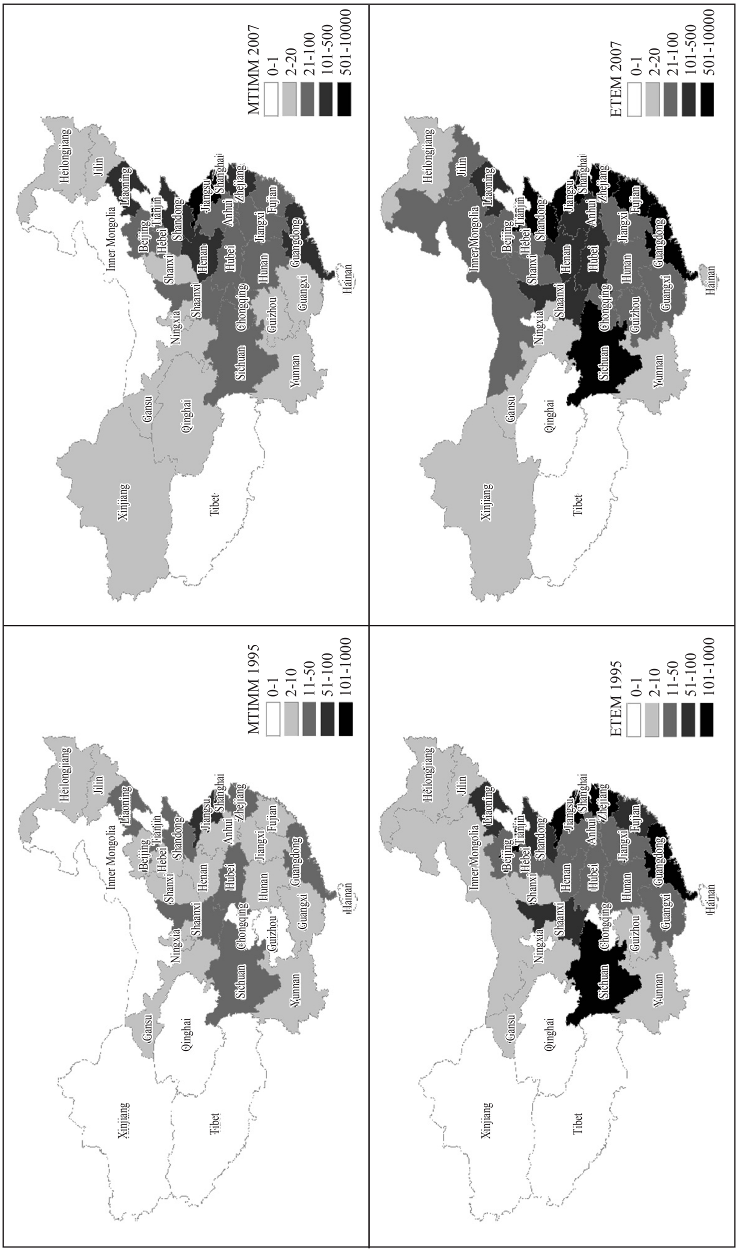
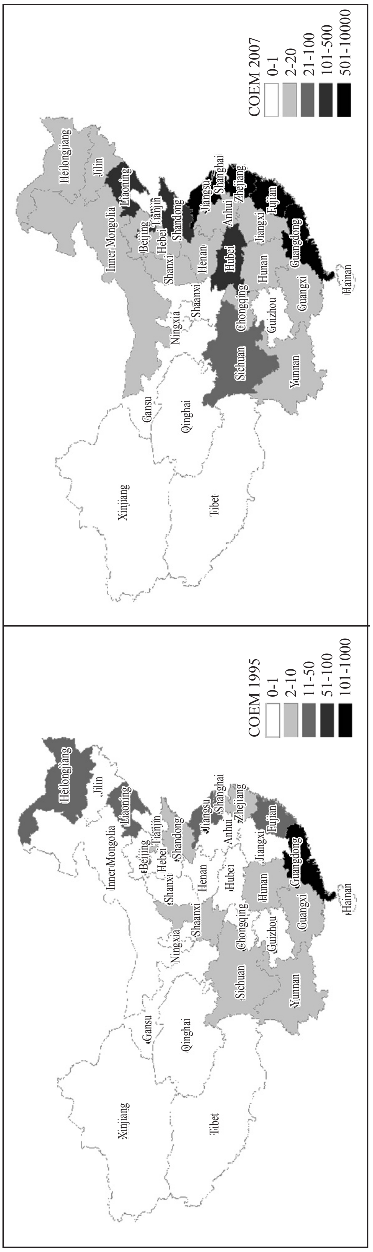


Figure 2 (Continued)



Source: See figure 1.

Table 7
The Percentage of SOEs in China's Hi-tech Industries (by Industry)

Index	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total	36.81%	33.63%	30.84%	22.75%	46.66%	41.34%	36.59%	30.26%	25.62%	18.09%	16.38%	10.98%	9.93%
ASM	95.62%	97.69%	93.30%	68.17%	98.03%	97.99%	94.31%	98.26%	97.73%	93.68%	93.21%	88.47%	86.43%
MTIMM	36.09%	33.03%	30.35%	25.75%	36.21%	32.35%	28.22%	24.40%	21.00%	19.26%	16.39%	13.66%	13.28%
MPPM	51.24%	46.69%	41.39%	32.79%	54.78%	49.62%	44.76%	40.61%	36.80%	27.49%	23.94%	19.85%	17.97%
ETEM	27.09%	24.27%	23.35%	14.94%	46.31%	40.88%	39.06%	31.96%	30.21%	18.32%	16.18%	10.16%	8.74%
COEM	13.60%	16.88%	19.64%	22.94%	27.84%	24.24%	11.41%	10.12%	6.46%	9.67%	7.94%	3.18%	2.52%

Source: *Zhongguo gaojishu chanye tongji nianjian* (China Statistics Yearbook on High Technology Industry) (Beijing: Zhongguo tongji chubanshe, 1996-2008).

Note: The percentage of SOEs and state holding enterprises is represented by their percentage of the total output value of hi-tech industries.

economy. The establishment of national hi-tech industrial zones was an important step in implementing this strategy.

The influences of the market and the government on hi-tech industries are reflected not only in policy and regulation but also in how the enterprises are owned. The influence of the market and the government differs between industries, as can be seen from data on the percentage of state-owned enterprises (SOEs) in China's hi-tech industries (see table 7), and this could explain the different evolutionary paths of the various industries.

ASM has the highest percentage of SOEs (95.62 percent in 1995, although there is a slight reduction between 1995 and 2007), which indicates that the spatial distribution of this industry (mainly in Shaanxi, Sichuan, Liaoning, and Heilongjiang) is the result of central planning. Since 1995, all of these industries, with the exception of ASM, have been concentrated in the eastern coastal regions. However, with the expansion of the civil aviation market the role of the market has begun to increase in ASM, and it has taken advantage of the mature capital market of Shanghai and the location advantage of Tianjin. From an analysis of spatial correlation, it is clear that under the planned economy, ASM was concentrated in relatively isolated locations. There was no forward or backward link to surrounding areas, so there were neither spatial spillover nor cluster effects (the Moran's I is negative).

Table 8
The Percentage of SOEs in Hi-tech Industries of Top Eight Regions, 2009

Regions	Province	Share	Province	Share	ASM	ETIMM	MPPM	ETEM	COEM
CBSR	Beijing	12.12%	Shaanxi	65.14%	☆				
	Tianjin	11.09%	Sichuan	41.03%	☆	☆	☆		
	Shandong	12.38%	Liaoning	33.17%	☆	☆			
Yangtze Delta	Shanghai	7.49%	Heilongjiang	33.62%	☆				
	Jiangsu	2.95%	Jiangxi	22.96%	☆				
	Zhejiang	5.52%	Guizhou	47.45%	☆				
Southern Coastal Region	Guangdong	8.68%	Henan	12.32%		☆			
	Fujian	2.23%	Hebei	16.25%			☆		
State		11.17%	Hubei	28.96%					☆

Source: *Zhongguo gaojishu chanye tongji nianjian, 2010* (China Statistics Yearbook on High Technology Industry, 2010) (Beijing: Zhongguo tongji chubanshe, 2010).

Note: The sharepercentage of SOEs and state holding enterprises is represented by their percentage of the total output value of hi-tech industries.The share of SOEs is the state-owned and state-holding enterprises output value account for total industries output value in hi-tech industries. There isare no corresponding statistics for the period of the state-owned and state-holding enterprises output value in hi-tech industries by regions before 2009, so we provide the share of SOEs at 2009.

In 2007, SOEs accounted for 13.28 percent of MTIMM, 17.97 percent of MPPM, 8.74 percent of ETEM, and 2.52 percent of COEM, and in all of these industries the percentage of SOEs had reduced significantly since 1995. Most of these hi-tech industries, especially ETEM and COEM, are concentrated in the eastern coastal regions, which contain the three main hi-tech industrial clusters of the Yangtze River Delta, the southern coastal region, and the CBSR (see figure 2). Within these three main clusters, market forces have produced a certain agglomeration effect.

When we look at the prominence of SOEs in hi-tech industries in different regions, we see that SOEs are less prominent in provinces in three clusters (see table 8). In the CBSR the proportion of SOEs is near the national average, while in the Yangtze River Delta and the southern coastal provinces it is under 10 percent. Other provinces which entered the top eight regions for hi-tech industry in 2007 are more dominated by SOEs than the three clusters, and the highest percentage is 65.14 percent. This indicates that the advantages possessed by Sichuan, Shaanxi, and Guizhou stem from the industrial layout of the planned economy period, as the percentage of SOEs in hi-tech industries in these provinces are still more than 40 percent. The spillover effects from the eastern coastal regions to the central regions were thus enhanced, and the hi-tech industrial clusters in the central regions based on Hubei and Henan emerged gradually.

Second, the division of labor based on specialization is lower and the spillover effects are less significant in regions with concentrations of hi-tech industry. This is because these industries are still at the stage of expanding their scale.

Spatial agglomeration can be seen as a process that deepens the division of labor and speeds up innovation for information networks of flexible production; only industrial clusters based on specialization, division of labor, and efficient information networks can highlight the spillover effects of industrial aggregation.[28]

From the LGCs and CRs calculated from 1995 and 2007 data, the degree of concentration has increased. LGC to some extent includes the idea of specialization, which could show the regional advantage of hi-tech industries compared to industry as a whole in the country. The relative advantage of hi-tech industries over other industries has weakened in the eastern region (the area in which ETEM and COEM are concentrated). Among locations such as Beijing, Shanghai, Guangdong, Fujian, and Shenzhen (深圳), only Shenzhen has a relatively high specialization coefficient.[29]

[28]Allen J. Scott, *The New Industrial Spaces: Flexible Production Organization and Regional Development in North America and Western Europe* (London: Pion, 1988), 15-20; Allen J. Scott, *Metropolis: From the Division of Labor to Urban Form*, (Berkeley, Calif.: University of California Press, 1988), 17-23; AnnaLee Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128* (Cambridge, Mass.: Harvard University Press, 1994), 25-32; Ash Amin and Patrick Cohendet, "Learning and Adaptation in Decentralized Business Networks," *Environment and Planning D: Society and Space* 17, no. 1 (March 1999): 87-104.

[29]Chien-Hsun Chen and Hui-Tzu Shih, *High-Tech Industries in China* (Cheltenham and Northampton: Edward Elgar, 2005), 101.

China's hi-tech industries lack the industrial division of labor indicated by specialization within spatial agglomeration, making it difficult to generate spillover effects among regions. The case of Guangdong[30] also shows that although ICT industry clusters have frequent contacts with local production, they tend not to share information or cooperate in research and development. This indicates that frequent contact has not eliminated distrust between enterprises within industrial clusters. This is the reason why the industry with the largest output value has the lowest degree of spatial concentration and the industry with the lowest output value has the highest degree of spatial concentration.

In order to speed up the transformation of the economic development model and to promote industrial upgrading, local governments also introduce measures to attract foreign capital. The extent to which China's hi-tech industries have expanded is largely the result of foreign direct investment (FDI) by multinational corporations in conjunction with the pulling power of exports. FDI has had a major impact on the spatial distribution patterns of hi-tech industries and it promotes the rapid development of hi-tech products for export.

China's hi-tech industries are primarily driven by external technologies (as opposed to internal knowledge), and the import or imitation of foreign technology has been more important than domestic innovation in these industries.[31] The development pattern of the hi-tech sector has meant that these industries are not technology intensive and they have low industrial efficiency. The scale of expansion in combination with the driving force of the government have made it difficult for a regional division of labor, which is based on specialization and knowledge spillover, to emerge (within the market).

Third, regional innovation capacity is still an important factor behind the rapid development of hi-tech industries within spatially concentrated regions.

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[30]Wang and Lin, "The Growth and Spatial Distribution of China's ICT Industry," 145-92.
[31]Yao, "Spatial Overlap of Regional Innovation Capability," 615-32.

FDI and international technology transfer do not easily produce technology spillover effects, and local R&D and innovation capacity still play an important role in absorbing technology from multinational corporations and developing hi-tech industries. The learning capability of local enterprises can be improved via the existing research infrastructure of enterprises and market-oriented spatial clusters.[32]

This is why regions which have a high concentration of hi-tech industries are also well-endowed with national hi-tech zones which tend to be located in regions with plentiful intellectual resources. There are fifty-six of these zones—eight of which are in the Yangtze River Delta (Jiangsu, Shanghai, Zhejiang), eight in the southern coastal region (Guangdong, Fujian), and seven in the CBSR (Beijing, Shandong, Tianjin) (see figure 3). The fact that 41 percent of China's hi-tech zones are located in these three regions demonstrates that the zones are the foundation of hi-tech industrial development.

There is no complete overlap of spatial distribution between China's innovation capacity and its hi-tech industries,[33] but they are closely connected. Liu and Sun[34] find that innovation activities in both China and the United States are concentrated in the coastal areas. In China this means the eastern coastal areas and in the United States it is the east, west, and south coasts. Our findings reveal that spatial distribution and evolution patterns are similar for both innovation capacity and hi-tech industries.

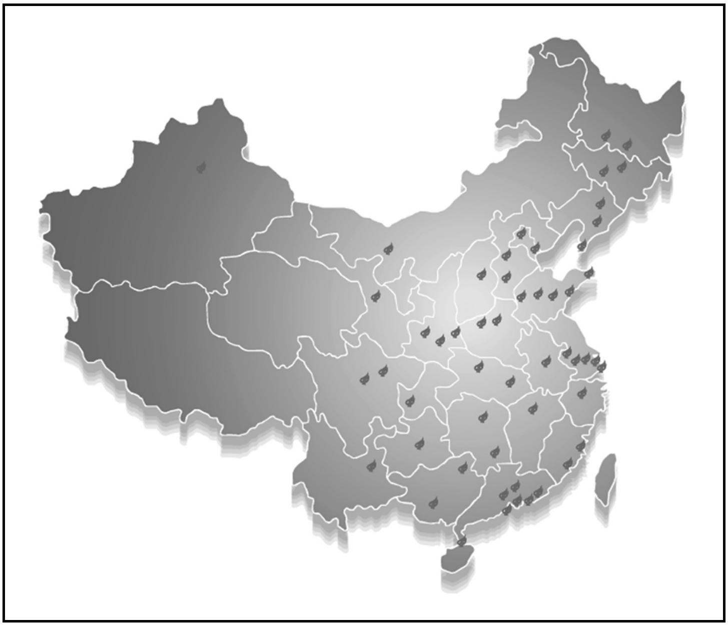
Spatial distribution is similar for China's innovation capacity, hi-tech zones, and hi-tech industries. The interactive relationship is good for innovation and hi-tech development, and regional innovation capacity is the foundation of hi-tech zones and hi-tech industries. For example, Shaanxi is a western province with few of the advantages traditionally required for hi-tech industrial development, such as a favorable geographical position, good transport infrastructure, and proximity to international markets.

[32]Zhou and Tong, "An Innovative Region in China," 129-52.

[33]Yao, "Spatial Overlap of Regional Innovation Capability," 615-32.

[34]Liu and Sun, "A Comparison of the Spatial Distribution of Innovative Activities," 797-805.

Figure 3
The Spatial Distribution of Hi-tech Industrial Zones in China



Source: Torch High Technology Industry Development Center (Torch Center), under the Ministry of Science and Technology (MOST) (**科技部火炬高技術開發中心**), http://www.chinatorch.gov.cn/.

Note: The Ningbo (2007), Xiangtan (2009), and Taizhou (2009) national hi-tech industrial zones are not included.

However, it does benefit from favorable innovation resources and a good research base. ASM in Shaanxi is based on Xi'an's national hi-tech industrial zones which focus on electronic information and advanced manufacturing industry. These zones draw their resources from Xidian University (**西安電子科技大學**), Xi'an Jiaotong University (**西安交通大學**), the Northwestern Polytechnical University (**西北工業大學**), Lishan Co., Ltd. (**驪山微電子公司**[771 **所**]), AVIC Shaanxi AERO Electric Co., Ltd. (**中航工業陝航**), AVIC Xi'an Aircraft Industry (Group) Co., Ltd, (**中航工業西飛**), and Datang Telecom (**大唐電信**). So it is hardly surprising that Shaanxi has a strong ASM industry.

Conclusions

According to the analysis and discussion above, the conclusions of this paper are as follows:

The existing literature[35] measures the spatial distribution of hi-tech industries by calculating geographic concentration or spillover effects. But geographic concentration does not necessarily imply spatial spillover, whereas geographic concentration indexes with spillover effects imply that geographic concentration does have spillover effects. This study uses spatial econometrics to measure the agglomeration and spillover effects of industrial spatial distribution, and it expands the traditional assumption that spatial aggregation should have spillover effects.

Most of China's hi-tech sub-industries tend to be concentrated in the eastern coastal regions, causing a significant spillover effect to the central regions. Five primary areas with a high concentration of hi-tech industries have emerged throughout the country: the CBSR centered on Beijing, the Yangtze River Delta centered on Shanghai, the Pearl River Delta centered on Shenzhen and Guangzhou, the central regions centered on Hubei and Henan, and the western region centered on Sichuan and Shaanxi.

The spatial distribution of hi-tech industries is the result of a combination of government push and market pull. National hi-tech industrial zones and FDI are important factors in industrial aggregation in China.

On the macro-level, hi-tech industries are concentrated in three main urban agglomerations in the eastern region. However, specific hi-tech industries with local features have emerged in the central and western regions, such as ASM in Shaanxi, MPPM and MTIMM in Henan, and ETEM in Hubei, although these are smaller in scale. On the micro-level, the spatial concentration of hi-tech industries does not result from a division of labor based on specialization, but is caused by the FDI push, local policies, and also the export pull. So although the degree of industrial concentration is increasing, the spillover effect and economic efficiency are relatively low.

[35] Ratanawaraha and Polenske, "Measuring the Geography of Innovation," 30-59.

According to the existing literature, there is only partial overlap between the spatial distribution of innovation capacity and that of hi-tech industries in China.[36] Based on a wider examination, the evolution of spatial distribution patterns in China's hi-tech industries has a similar tendency to that of innovation capacities. The R&D activities and innovation capacity of local corporations combine with technological learning and knowledge spillover from multinational corporations which then promote the development of regional hi-tech industries and influence their spatial distribution.

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[36]Yao, "Spatial Overlap of Regional Innovation Capability," 615-32.

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