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Observing regional divergence of Chinese nanotechnology centers

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ABSTRACT

While China has emerged as one of the world's leading technological innovators, past studies have uncovered that technology centers have been overwhelmingly concentrated in Beijing and Shanghai. We take a step further to investigate whether this geographic concentration has persisted over time with nanotechnology-related patents. We apply the spatial analysis techniques and employ Gini's coefficient and global Moran's I. We additionally test the spatial patterns at four scales: the municipality, the county, the intra-metropolitan, and the distance-based.

We find that while Beijing and Shanghai have remained the two dominant nanotechnology clusters, the Shanghai region, together with Jiangsu and Zhejiang, surpassed the traditionally productive Beijing–Tianjin region by 2007. We did not identify spatial autocorrelation at the province level, but at the county level, and at the scale between 20 km and 75 km. The intra-metropolitan analysis in Beijing and Shanghai further confirmed that the geographic concentration of nanotechnology is small, around 20 km. These results support the regional divergence theory and a small scale of technology diffusion, as well as the possibility of continually increasing inequality in China and its technology development.

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1. Introduction

In recent years, the People's Republic of China has emerged not only as a mass manufacturer, but also as one of the world's leading technology nations. Many semiconductor products come from China, approximately one in ten professionals in Silicon Valley's high-tech workforce is from mainland China [1], and China successfully became only the second country to launch the radar-evading stealth fighter jet [2]. In addition to anecdotal evidence, various bibliometric studies have suggested that China has made a major advancement in the fields of science and technology. China has surpassed Japan and now is ranked second in the production of academic journal articles in science and engineering fields [3]. In the nanotechnology field, often considered one of the cutting-edge areas in science and engineering, China has surfaced as one of the top players [4–6]. Indeed, while the journal *Nature Nanotechnology* [7], and Lenoir and Herron [8] predicted that China would surpass the United States by 2012, according to Kostoff et al. [9], China not only achieved this in 2009, but also produced 20% more academic journal articles in science and engineering fields than the United States by 2012. Additionally, China dominates in the nanotechnology area of most-cited academic articles: the top eighteen out of the twenty scholars are of Chinese origin [10].

However, such success may come at a cost. While China boasts world-class research institutes in nanotechnology such as the Chinese Academy of Sciences, Tsinghua University, and Peking University, to name a few [11], they are overwhelmingly concentrated in two regions: Beijing and Shanghai. This concentration of technology centers could become an important issue because it can bias the geographic locations of technology, knowledge, scientific workforce, and wealth, and eventually could enlarge inequality in China [12]. Rising inequality will explicitly contradict the goal of harmonious regional growth set by the Chinese government [13] and could obstruct long-term sustainable growth, especially in this enormous and demographically diverse country.

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Examining the Chinese case could reveal significant implications for technology development and geography. In contrast with the United States, the Chinese government has most aggressively invested in and prioritized nanotechnology development using the top-down approach [14]. Such an approach may be effective to create a selected number of research institutes, but technological diffusion and long-term sustainability of the technological, as well as economic development, may be questionable. Moreover, the Chinese case exhibits a different pattern from even other East Asian nations. For example, Japan, Taiwan, and South Korea managed equitable high growth through interregional distribution of resources [15] and regionally oriented technology programs [16]. The strong central government and vast scale of the country may create an entirely different development pattern for China.

This article applies bibliometric analysis to examine the geography of nanotechnology research centers in China. While several past studies analyzed the location and heavy geographic concentration of nanotechnology centers, we consider it more important to take a step further to investigate whether such concentration has persisted over time. Based on Chinese nanotechnology patents, our analysis identifies the leading regions and shifts among them, and employs Gini coefficients and local and Global Moran's I to test spatial concentration. Moreover, we critically examine the concentration by not relying on the conventional administrative unit, such as provinces and counties, but by employing distance-based measure and intra-metropolitan analysis. Although we do not detect a spatial clustering of nanotechnology centers at the large province level, there is a significant clustering at the small county level that has been persistent over time. Furthermore, our spatial analysis indicates that such clustering is most observable at the scale of 20 km. Thus, based on the technological clustering at this small scale, we support the regional divergence hypothesis and related concerns about the potential rise in inequality in China.

2. Literature review

There has been a long debate about regional convergence and divergence in technology, even before the emergence of information technology [17]. Studies about the convergence theory often were based on the neoclassical growth theory in which capital and labor were mobile and could relocate over space without friction [18]. Furthermore, imitation was conventionally less expensive than discovery [19], and thus poor regions could catch up with technologically advanced nations. This catch-up convergence could occur if government provided the infrastructure and legal framework to foster labor and capital productivity growth. It further assumed that technology was a public good and was available to every economic player.

Several empirical studies involving patent analysis supported this convergence thesis. Co [20] found that states whose patents per capita were higher than the U.S. average in 1963–69 experienced either slower or negative growth in the later years compared to lagging states. Johnson and Brown [21] echoed these findings by adding that formerly wealthy states were the slowest to convert from stagnating sectors because they tended to remain with traditional and even stagnating industries. Thus, the initial state of a region was important, but its overall innovativeness could change over time. Ó hUallicháin and Leslie [22] gave a nuanced conclusion, but still supported the convergence theory. Their study found spatial convergence among U.S. states between 1963 and 1993, while a modest level of divergence took place between 1993 and 2003.

Another set of studies indicated a regional and structural shift of innovation in the past few decades in the United States. The Sunbelt states, such as Florida, Texas, and California, were growing faster technologically than the traditional manufacturing region of the Northwest and Midwest [23–27]. However, these studies about the emergence of the "newcomers" did not necessarily support the convergence theory because the studies did not provide an analytical criterion about the most lagged regions, which often continued to be most lagging. Furthermore, it will be more important to consider the continuous trajectory between the new risers, the Sunbelt states, and the traditional Northeast and Midwest. If the Sunbelt states continue to grow faster than the traditional centers, that would bring divergence.

In contrast, we would expect the divergence of regions by incorporating theories of evolutionary economics, such as the increasing returns to scale and endogeneity of growth and technological development [28,29]. In other words, regions with certain economic and geographic endowments would bring positive feedbacks of agglomeration and concentration, while the initial location of firms and industries might happen by historical accident [30]. A handful of empirical regional studies supported such theory. Ó hUallicháin [31] discovered that the largest U.S. metropolitan areas predominated the patent activities, and such advantages arose from the concentrations of technologically intensive manufacturing and well-educated workforce. Bettencourt and others [32] found a super-linear effect with U.S. metropolitan areas between 1980 and 2001, indicating that larger metropolitan areas were becoming even more productive. Sonn and Park [17] dissected the analysis between cities with similar size (horizontal convergence) and between larger and smaller cities (vertical divergence). They concluded that horizontal convergence dominated over vertical divergence, leading to a net effect of overall convergence.

We identify four major limitations of the past studies. First, these apparently mixed results indicate that variations may come from differences over time, by geographic regions, by industry or technology types. Thus, it will be critical to test the phenomenon of convergence and divergence in a specific context. As mentioned before, Ó hUallicháin and Leslie found convergence before 1993 but divergence after 1993. Moreover, the difference potentially coming from industry or technology can be critical, and we have to consider two related empirical studies. Varga [25,27] disaggregated patent technology types by IT, drugs, chemicals, high-tech machinery, defense and aerospace, and professional and scientific instruments, and found substantially different patterns of specialization and emergence/decline of U.S. metropolitan regions between 1970 and 1992. Johnson et al. [33] found that different technology types showed significant differences in the distance of patent citation, though the pattern of patent citation was different from the geographic clustering of patents. More specifically, in computers and biotech, particularly affecting California and Texas, the citation distance has shortened, while in other industries citation distance has increased over time.

Second, the past patent studies overwhelmingly were concentrated on the U.S. case. There have been few studies examining the non-U.S. context. So far, only one European case has been identified: Carrincazeaux and others [34] demonstrated a

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