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The Spatial Pattern and Influencing Factors of Urban Knowledge-Intensive Business Services: A Case Study of Wuhan Metropolitan Area, China

Zilu Ma [1,2,*] and Yaping Huang [2,3]

[1] School of Architecture & Urban Planning, Chongqing Jiaotong University, Chongqing 400074, China
[2] School of Architecture & Urban Planning, Huazhong University of Science and Technology, Wuhan 430074, China; hust_hyp@sina.com
[3] Hubei Engineering and Technology Research Center of Urbanization, Wuhan 430074, China
* Correspondence: zlmaup@163.com; Tel.: +86-13996419392

Abstract: Knowledge-intensive business services (KIBSs) are key links in leading the sustainable development of cities. Studying the spatial pattern and influencing factors of urban KIBSs can help improve the utilization of KIBS resources. Taking the Wuhan metropolitan area as a case study, based on data from industrial and commercial registration enterprises, this study uses the multi-ring buffer zone analysis and kernel density estimation method to analyze the spatial pattern of KIBS, and uses a negative binomial regression model to detect the influencing factors of the spatial pattern of KIBS. The results show that: (1) KIBSs are mainly distributed in the inner suburbs, presenting a multi-center spatial pattern, exhibiting the law of agglomeration along entrepreneurial streets, headquarter bases, science and technology parks, university clusters, business centers, and industrial bases. Obvious differences exist in the spatial patterns of KIBS sub-sectors. (2) Land price, traffic conditions, office space, commercial environment, technology factors, industry diversity, incubation environment, investment environment, manufacturing foundation, agglomeration factors, and policy factors are the main factors affecting the spatial patterns of KIBSs. There are differences in the impact of influencing factors on KIBS sub-sectors. The results can provide a decision-making basis for the rational layout and planning of urban KIBSs in the post-industrial era.

Keywords: knowledge-intensive business services (KIBSs); spatial pattern; influencing factors; negative binomial regression model; Wuhan Metropolitan Area

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1. Introduction

The new round of technological revolution is accelerating the reshaping of the global industrial system. Knowledge-intensive business services (KIBSs), as important players in the national innovation system and modern industrial system, have become key links in leading the sustainable development of cities. According to statistics, in 2020, the value added by the KIBSs in Beijing was CNY 1.79 trillion, accounting for 49.61% of the city's GDP [1]. China's 14th Five Year Plan proposes to focus on industrial innovation and vigorously develop KIBSs, such as research, design, and consulting. KIBSs comprise a sector composed of commercial enterprises or institutions that are rooted in specific expertise and technology, offering knowledge-based products and services to clients [2]. KIBSs play a significant role in enhancing innovation capabilities, driving the transformation of traditional industries, and fostering the growth of emerging sectors [3]. Therefore, characterizing the spatial pattern of urban KIBSs and analyzing the influencing factors of their location selection is of great theoretical and practical significance for revealing the law of spatial distribution of urban KIBSs and achieving the optimal allocation of KIBS resources.

Since the 1970s, study on the distribution patterns of urban KIBSs has attracted widespread academic attention. The existing research mainly focuses on the distribution characteristics, evolution of spatial patterns, and factors influencing the spatial arrangement of urban KIBSs. In terms of the distribution characteristics of urban KIBSs, these industries are mainly concentrated in urban centers and sub-centers, showing a single-center or multi-center distribution pattern, and forming hotspot clusters in suburban office parks. KIBSs tend to be distributed in a centralized multi-center pattern in European cities such as London, Paris, and Madrid, while KIBSs are distributed in a dispersed multi-center pattern in American cities such as New York, Los Angeles, and Chicago [4]. KIBSs in Dublin are anchored in the central business district, serving as the center of urban and national KIBS activities [5]. KIBSs in Toronto are close to the city center, forming KIBS clusters near the central entertainment area, University of Toronto, and highways [6]. KIBSs in Seoul are often located in traditional KIBS centers and new centers around them [7]. The advanced producer services in Brussels exhibit a centralized distribution characteristic [8]. The spatial distribution of producer services in Beijing gradually decreases from the center to the surrounding areas, and is mainly concentrated in the urban core area [9]. Producer services in Guangzhou are mainly distributed in the CBD [10]. The producer services in Lanzhou have a spatial pattern of "circle+sector" [11]. Different types of KIBSs have different spatial pattern characteristics. Professional producer services in Warsaw prefer the city center and commercial areas, while creative producer services prefer to cluster in the surrounding areas of the city center [12]. Advertising and IT firms in Prague, Brno, and Ostrava are concentrated in city centers [13]. More than half of the financial and insurance services in Brussels are located within 15 min of the center, while legal services are scattered throughout the city [8]. The number of internet firms in Yangzhou exhibits a pattern of low–high–low from the city center to the periphery, with the highest concentration observed in the suburban areas [14]. The financial services in Beijing exhibit a single-center distribution pattern with the Financial Street at its core [15].

Regarding the evolution of the spatial pattern of urban KIBSs, previous studies indicated that the urban KIBS has exhibited a trend of suburbanization, expanding towards urban sub-centers, thereby shaping a multi-center spatial configuration and manifesting a mode of dispersed concentration. Knowledge-intensive jobs in Barcelona are more concentrated in sub-centers of employment, following a multi-center pattern [16]. The KIBS clusters in Madrid are attracted by major population and employment centers, developing in a pattern of dispersed concentration [17]. The producer services in Tehran have formed a new spatial pattern, with a large number of enterprises located in newly constructed commercial and administrative complexes [18]. The producer services in Hangzhou have both a tendency for centripetal agglomeration and an inclination towards outward expansion [19]. KIBSs in Baoding tend to cluster around the city center, forming multiple agglomeration hotspots [20].

In terms of the factors influencing the distribution of urban KIBSs, the spatial pattern of KIBS involves a variety of factors such as face-to-face interaction, traffic conditions, government planning, land rents, agglomeration economies, human resources, reputation, and urban amenities. Scholars have found that face-to-face interaction creates a dynamic atmosphere that helps to transmit knowledge and exchange ideas [21]. Creative producer services prefer regions with good car accessibility, providing convenience for clients to visit [12]. The urban development policy and functional area planning promote the transformation of industrial and land spatial patterns, affecting the spatial distribution of producer services [22]. The high rent has led to the relocation of productive service companies from newly built enterprise service areas [18]. The agglomeration of productive services is aimed at seeking cooperation and exchange between enterprises [23]. The location of producer service firms in urban centers is associated with the proximity to the workforce [24]. The location of advertising and IT companies in the city center is associated with the image and reputation of central areas [13]. In the context of the knowledge economy, urban amenities are an important driving force attracting talents [25]. From the

perspective of research methods, common methods for the study of the spatial patterns of KIBSs include kernel density estimation, Herfindahl–Hirschman Index (HHI), location quotient analysis, and spatial autocorrelation analysis. Qualitative analysis methods are mainly used to study the factors that affect the distribution of KIBSs.

In summary, although previous studies have provided valuable information, some deficiencies still exist. Firstly, in terms of research content, existing studies have suggested that KIBSs are mainly clustered in urban central areas and sub-centers. However, as cities enter the post-industrial era and new business models continue to emerge, research on the spatial pattern characteristics of KIBSs has not reflected the current new development trend, and there is a lack of exploration of the differences in spatial patterns of KIBS sub-sectors. Meanwhile, the influences of industry diversity, the incubation environment, and the investment environment on the spatial pattern of KIBSs have also been neglected in existing research. Furthermore, comparative studies on the factors influencing the location selection of KIBS sub-sectors are also rarely undertaken. Secondly, in terms of research methods, qualitative methods are mainly used to study the factors that affect the distribution of KIBS, and quantitative methods are relatively lacking.

In this article, we attempt to fill this research gap. The objective of this study is to analyze the spatial patterns of urban KIBSs and identify the main factors affecting the spatial patterns of KIBSs. Therefore, the article aims to address the following research questions: What are the spatial pattern characteristics of urban KIBSs in the context of post-industrialization, and are there any differences in the spatial patterns of KIBS sub-sectors? What factors affect the spatial patterns of urban KIBSs, and what are the differences in location factors between KIBS sub-sectors?

Wuhan, as an important growth pole in China, is representative within a heterogeneous China. In view of this, taking the Wuhan metropolitan area as the research object, based on multi-source data, this article uses multi-ring buffer zone analysis and kernel density estimation methods to study the distribution pattern of KIBSs and the location differences of KIBS sub-sectors in the Wuhan metropolitan area. Using a negative binomial regression model, this article quantitatively analyzes the factors that affect distribution patterns of KIBSs and the differences between KIBS sub-sectors (Figure 1). We aim to provide references for the healthy development and rational layout of urban KIBSs.

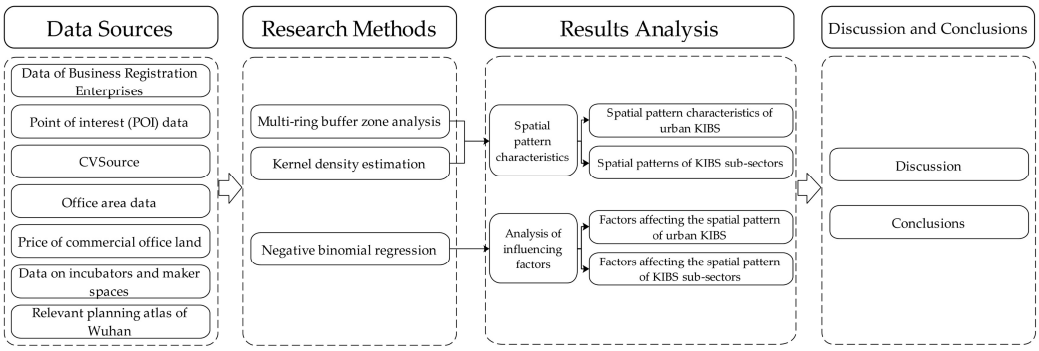

Figure 1. The research framework.

2. Materials and Methods

2.1. Study Area

Wuhan is a national central city in central China, serving as the geographical center of China that connects east and west and north and south. The unique transportation location, scientific and educational resources, and policy advantages of Wuhan provide favorable conditions for the rapid growth of KIBS. The study area is the Wuhan metropolitan area, defined in the Wuhan Urban Master Plan (2010–2020) (Figure 2), including the main urban area and some towns in the suburbs, with a total area of 3261 km^2, which is the key area for the agglomeration of urban functions and spatial expansion.

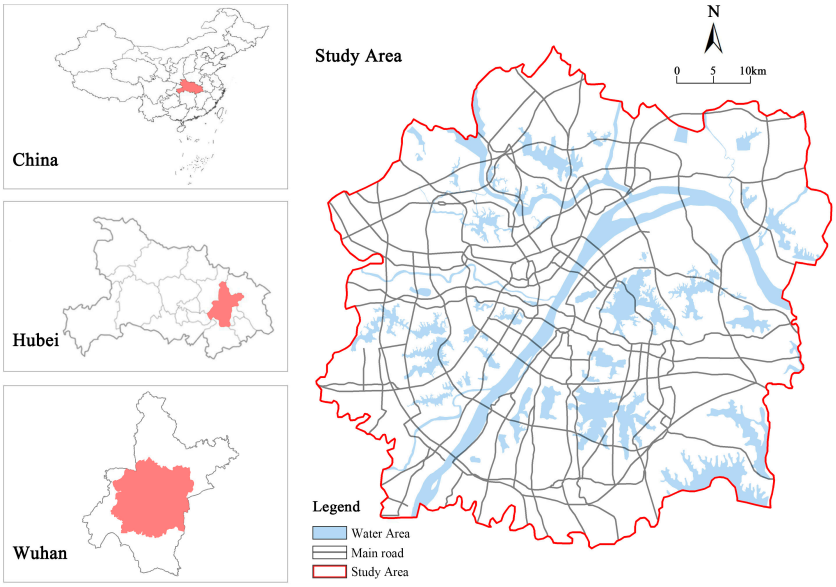

Figure 2. Location of the study area.

2.2. Data Sources

The data on KIBSs (company name, industry attributes, company address, business scope, etc.) were collected from the commercial big data platform Tianyancha's website (https://www.tianyancha.com/, accessed on 30 April 2021). Tianyancha Platform is an official registered enterprise credit reporting agency [26]. We define KIBSs based on China's Industrial Classification Standard for National Economic Activities (GB/T4754-2017) and relevant studies [27]. KIBS, in this article, refers to information services, financial services, business services, and technology services [28]. Based on the registered address of the enterprise, this article obtains the longitude and latitude coordinates of the enterprise through geocoding technology. There are a total of 226,156 pieces of KIBS enterprise data in the Wuhan metropolitan area. In order to analyze the factors that affect distribution pattern of the urban KIBSs, multiple spatial datasets were also obtained. The point of interest (POI) data of universities, research institutions, subway stations, bus stops, and shopping malls were obtained from the Gaode Map platform. The data on venture capital institutions came from the CVSource database [29]. The office area data came from the Anjuke website, a commonly used online real estate information platform in China. The price of commercial office land came from the Wuhan Natural Resources and Planning Bureau. The data on incubators and maker spaces were sourced from the Wuhan Science and Technology Bureau and the Gaode Map platform. The data of the development zone came from the relevant planning atlas of Wuhan City.

2.3. Research Methods

2.3.1. Analysis of Multi-Ring Buffer Zones

The distribution characteristics of urban KIBSs in different ring buffer zones were revealed using the multi-ring buffer zone analysis method. This article takes the intersection of the Yangtze River and the Han River as the center, constructs a circular buffer zone at 3 km intervals, and calculates the number and proportion of KIBS firms in each circular buffer zone. The formula is defined as follows:

$$P_i = \frac{A_i}{A} \times 100\% \quad (1)$$

where P_i represents the proportion of knowledge-intensive enterprises in the i-th buffer zone; A_i represents the number of KIBS firms in the i-th buffer zone; and A represents the number of KIBS firms in the research area.

2.3.2. Kernel Density Estimation

Kernel density estimation takes a certain area around a point as the density calculation range. The closer it is to the point, the higher the density, while the farther it is from the point, the lower the density. Utilizing this approach, the density of each feature point within the region is calculated. The densities at identical locations are subsequently aggregated, resulting in the establishment of the overall distribution density of feature points throughout the entire region [30]. The formula is as follows:

$$f_n(x) = \frac{1}{nh}\sum_{i=1}^{n} k\left(\frac{x - x_i}{h}\right) \quad (2)$$

where $f_n(x)$ is the density value at point x; n represents the number of sample points within the search radius; h is the search radius; $K(\ )$ is a kernel function; and $(x - x_i)$ is the distance between the kernel density estimation point x and the sample point x_i. This article calculates the distribution density of KIBSs using ArcGIS 10.2.

2.3.3. Negative Binomial Regression

This study divides the Wuhan metropolitan area into 1 km × 1 km grids, with the density of KIBS firms within each grid as the dependent variable. Due to the fact that the density of KIBS firms within each grid is count data, ordinary least squares analysis is not applicable. Research can be conducted using count models such as Poisson regression or negative binomial regression [31]. The Poisson regression model is based on the assumption that the mean and variance of the dependent variable are equal. However, the density of KIBS firms within the grid varies significantly, manifested as the variance being greater than the mean and exhibiting overdispersion. Therefore, this article uses the negative binomial regression model to analyze the factors that affect the distribution pattern of KIBSs. The negative binomial regression model has found extensive application in examining the location determinants of the manufacturing industry [32]. The model is as follows:

$$Y_i = a + \sum_{j=1}^{k} \beta_j x_{ij} + \varepsilon_i \quad (3)$$

where Y_i is the density of KIBS firms in grid i; β_j is the coefficient of the explanatory variable; α is a constant term; and ε_i is a random error term.

3. Results

3.1. Spatial Pattern Characteristics of KIBS

3.1.1. Overall Spatial Pattern Characteristics of KIBS

In order to understand the distribution characteristics of KIBSs in the Wuhan metropolitan area, a multi-level buffer zone is established every 3 km outward, with the intersection of the Yangtze and Han Rivers being the center, and the proportion of KIBS firms in each buffer zone is calculated. The KIBSs in the Wuhan metropolitan area are mainly distributed in the inner suburbs (Figure 3). The enterprises in the inner suburbs (9–24 km) account for 51.39% of the total; the enterprises in the central urban area (0–9 km) account for 42.92%; and the enterprises in the outer suburbs (24–42 km) only account for 5.69% of the total. The distribution of KIBSs in the Wuhan metropolitan area exhibits two peaks, located within the ranges of 3–6 km and 12–15 km, accounting for 18.70% and 16.49% of the total. The area within the 18 km range is the main area for the distribution of KIBSs, accounting for 85.38% of the total. The distribution of KIBSs has reaches a small peak within the range of 24–27 km, indicating that hot spots have formed in the peripheral areas of the city. There are few KIBS firms in areas beyond 30 km from the center.

The kernel density estimation method is employed to analyze the distribution characteristics of KIBSs (Figure 4). The spatial distributions of KIBSs in the Wuhan metropolitan area were "dense in the east and sparse in the west", presenting a multi-center spatial pattern, including two main centers (Optics Valley Entrepreneurial Street and Optics Valley

Technology Harbor) and six sub-centers (Guangdong Science and Technology Park, Optics Valley Software Park, Wuhan University Science and Technology Park, Zhongnan Road Business District, Jiedaokou Business District, and Optics Valley Square Business District). The innovation and entrepreneurship environment in these areas is relatively superior, with a large number of transportation facilities, commercial facilities, and incubators, providing not only diverse innovation resources but also superior support policies, which is convenient for the development of KIBSs. Overall, the KIBSs exhibit the law of agglomeration along entrepreneurial streets, headquarters bases, science and technology parks, university clusters, business centers, and industrial bases.

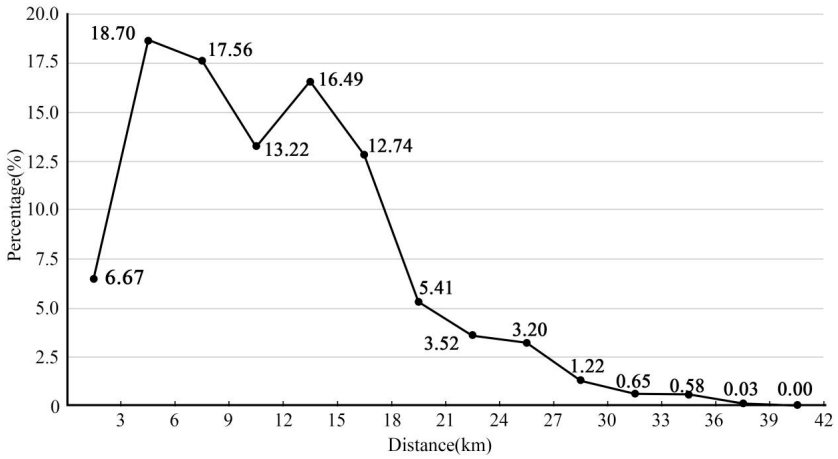

Figure 3. The percentage of knowledge-intensive business services (KIBSs) in each buffer.

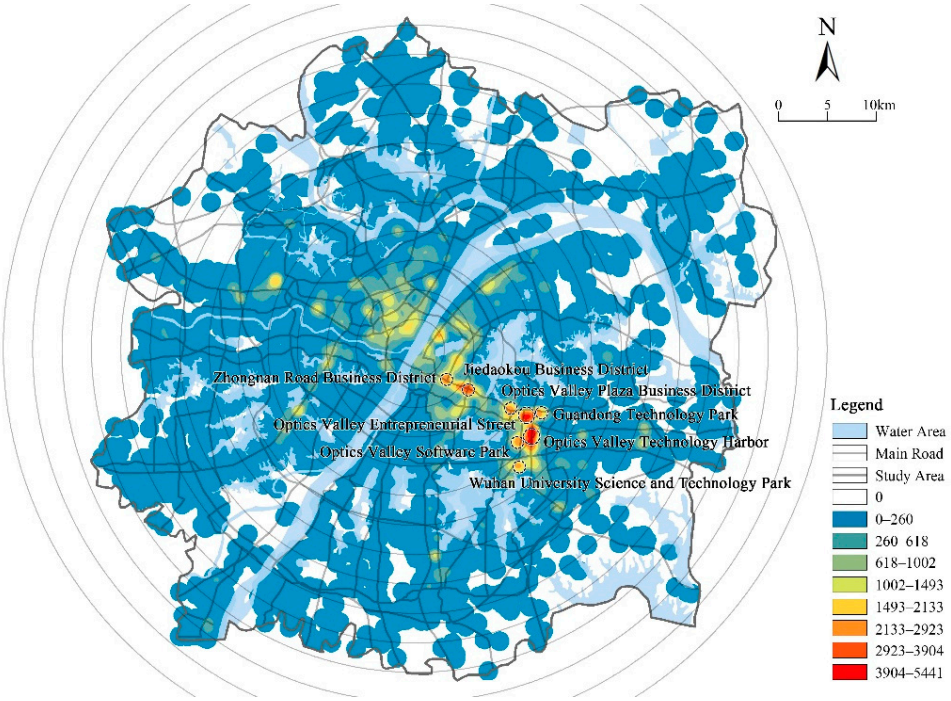

Figure 4. Kernel density map of KIBSs in the Wuhan metropolitan area.

3.1.2. Spatial Pattern Characteristics of KIBS Sub-Sectors

From the perspective of the density distribution of KIBS sub-sectors, obvious differences exist in the spatial pattern of KIBS sub-sectors. The information services present a pattern of "three main centers and four sub-centers" (Figure 5a), exhibiting the law of agglomeration along entrepreneurship streets, headquarters bases, university clusters, software parks, and

technology parks. The main centers are located in Optics Valley Entrepreneurial Street, Optics Valley Technology Harbor, and Jiedaokou Business District. The sub-centers are distributed in the Optics Valley Software Park, Optics Valley Plaza Business District, Guandong Science and Technology Park, and Wuhan University Science and Technology Park. The financial services present a pattern of "one main center, five sub-centers" (Figure 5b), exhibiting the law of distribution along commercial and financial centers, and partially along financial service backends and technology finance clusters. The main center is located in the Chuhehanjie Business District. The sub-centers are distributed in Jianshe Avenue Financial Street, Wangjiadun Business District, Jianghan Road Business District, Yuejiazui Business District, and Zhongnan Road Business District. In addition, a financial backend service cluster has been formed in the Optics Valley Financial Harbor, and a technology finance cluster has been formed in the Optics Valley Entrepreneurship Street. The business services present a pattern of "five main centers and seven sub-centers" (Figure 5c), exhibiting the law of agglomeration along the entrepreneurial street, headquarters base, university cluster area, and commercial center. The main centers are located in Optics Valley Entrepreneurship Street, Optics Valley Technology Harbor, Jiedaokou Business District, Chuhehanjie Business District, and Zhongnan Road Business District. The sub-centers are distributed in the Wuhan Square Business District, Wujiashan Business District, Lingjiao Lake Wanda Plaza, Jianshe Avenue Financial Street, Jianghan Road Business District, Shuian Business Street, and Optics Valley Square Business District. The technology services present a pattern of "two main centers and four sub-centers" (Figure 5d), exhibiting the law of agglomeration along entrepreneurship streets, headquarters bases, science parks, and university clusters, and partially along industrial bases. The main centers are located in Optics Valley Entrepreneurship Street and Optics Valley Technology Harbor. The sub-centers are distributed in the Jiedaokou Business District, Guandong Science and Technology Park, Optics Valley Software Park, and Wuhan University Science and Technology Park.

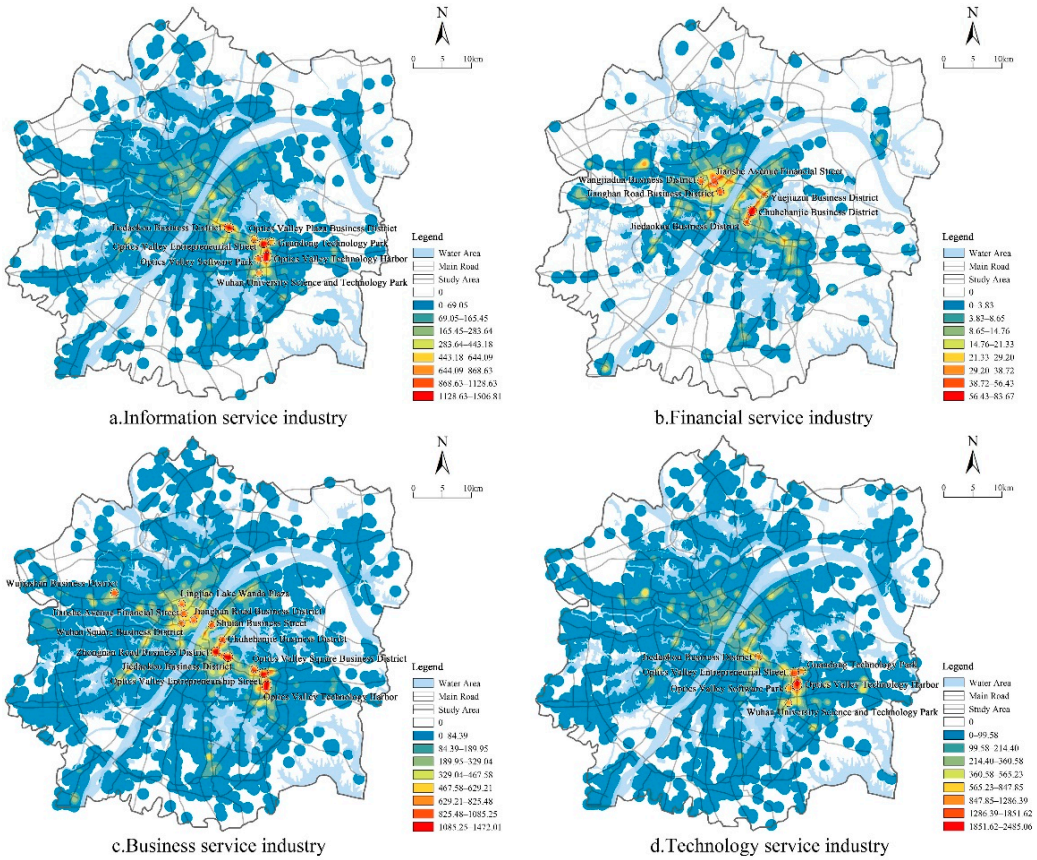

Figure 5. Kernel density map of KIBS sub-sectors in the Wuhan metropolitan area.

3.2. Influencing Factors of the Spatial Pattern of KIBS

3.2.1. Variable Selection

The spatial pattern of urban KIBSs is the joint result of many elements. Referring to existing research and considering the inherent characteristics of KIBSs, this article summarizes the factors that affect the spatial patterns of KIBSs as follows: land price, traffic conditions, office space, commercial environment, technology factors, industry diversity, incubation environment, investment environment, manufacturing foundation, agglomeration factors, and policy factors. The variables and definitions are shown in Table 1.

Table 1. Definition and interpretation of variables.

Variables	Code	Definition	Reference
Land price	X1	Benchmark land price for business and office within the research unit/(CNY 100 million/km^2).	Mohammadi [18]
Distance to subway stations	X2	The distance from the research unit to subway stations/(km).	Smtkowski et al. [12]
Bus station density	X3	The density of bus stops within the research unit/(piece/km^2).	Smtkowski et al. [12]
Office space	X4	Office area of office buildings within the research unit (10,000 m^2/km^2).	Zhang et al. [11]
Business environment	X5	Whether the shopping mall is within the research unit—Yes, 1; No, 0.	Wang et al. [33]
Technology factors	X6	Whether the university or research institution is within the research unit—Yes, 1; No, 0.	Zhan et al. [34]
Industry diversity	X7	The degree of diversification of KIBSs within the research unit.	Frenken et al. [35]
Incubation environment	X8	Whether the incubator or maker space is within the research unit—Yes, 1; No, 0.	Zhou et al. [36]
Investment environment	X9	Whether the venture capital institution is within the research unit—Yes, 1; No, 0.	Lin et al. [37]
Manufacturing foundation	X10	The density of factories within the research unit/(piece/km^2).	Tang et al. [38]
Agglomeration factors	X11	The density of KIBS firms within a 1 km buffer zone outside the research unit/(piece/km^2).	Jiang et al. [39]
Policy factors	X12	Whether the research unit is within the development zone—Yes, 1; No, 0.	Li [22]

Land is an important element and cost in enterprise operations. The land price (X1) reflects the competitive leasing ability of the enterprise, which was measured by the commercial office land price in the research unit. The business connections and employee commuting of KIBSs rely on a convenient transportation environment. This study selects the shortest straight-line distance from the grid to subway stations to measure the distance to subway stations (X2) and selects the bus station density within the grid to measure the bus station density (X3). Office space is an important carrier of a KIBS, related to sharing infrastructure and services, creating a comfortable and innovative environment, and providing sufficient development space. This study selects the office area of office buildings in the grid to measure the office space (X4). The KIBSs provide abstract analyses and customized services for activities such as finance, commerce, and technology promotion. Enterprises located in areas with high commercial vitality could receive multi-source market information and business channels. This study introduces the variable business environment (X5). A value of 1 is assigned to the research unit with shopping malls; otherwise, a value of 0 is assigned. Universities and research institutions provide necessary professional technology and intellectual resources for KIBSs. This study

introduces the variable technology factors (X6). A value of 1 is assigned to research units with universities or research institutions; otherwise, a value of 0 is assigned. Industry diversity is conducive to promoting knowledge spillover among different enterprises [33], promoting integrated innovation of new knowledge and technologies, and enhancing the technological innovation capability of the industry. This study introduced the variable of industry diversity (X7), which is measured by the diversity of KIBS within the research unit. The entropy index is employed to assess industrial diversification. The calculation formula is: $H = \sum_i S_i \times \ln(1/S_i)$, where H is the industrial diversification index; i is the type of KIBS; and S_i is the proportion of i-type enterprises in the total quantity within the research unit. Incubators and maker spaces play an important role in establishing financing channels, promoting collaboration between industry, academia, and research institutions, expanding markets for new startups, and promoting the efficient operation of enterprises [34]. This study introduces the variable of incubation environment (X8). A value of 1 is assigned to research units with incubators or maker spaces; otherwise, a value of 0 is assigned. Technological innovation has the characteristics of high investment and high uncertainty, making it difficult to obtain financing. However, venture capital can promote technological innovation and industry change by providing technology enterprises with the necessary funds and management consulting, and participating in enterprise management [35]. This study introduces the variable of investment environment (X9). A value of 1 is assigned to research units with venture capital institutions; otherwise, a value of 0 is assigned. The KIBS and manufacturing industry are interdependent. The potential demand for KIBS is constantly increasing due to the transformation of the manufacturing industry. This study introduces the variable of manufacturing foundations (X10). A value of 1 is assigned to research units with factories; otherwise, a value of 0 is assigned. The agglomeration economy is conducive to knowledge spillover, promotes information and resource sharing, and reduces investment risks and production costs [36]. The agglomeration factor (X11) is measured by the density of KIBS firms within a 1 km buffer zone outside the research unit. Local governments attract businesses by establishing development zones, formulating preferential policies on land use and taxation, and providing comprehensive infrastructure and a conducive business environment. This study introduces the variable of policy factors (X12). A value of 1 is assigned to research units located in the development zone; otherwise, a value of 0 is assigned.

3.2.2. Analysis of Results

In this article, 1 km × 1 km grids are selected as the basic unit of study, with the density of KIBS firms within the research unit selected as the dependent variable. The factors in Table 1 are selected as independent variables. This study has a total of 3261 effective samples. Due to the fact that the density of KIBS firms in the research unit is discontinuous and has the characteristic of overdispersion, this article uses Stata15.0 software for negative binomial regression analysis. The regression results for both the overall and sub-sectors of KIBS are obtained (Table 2), and the parameters of alpha are significantly greater than zero, which proves the rationality of using the negative binomial regression models.

The regression results of all KIBSs show that each indicator has a high level of significance, indicating that the above factors have a strong impact on the spatial patterns of KIBSs. The regression coefficient of land price (X1) is significantly positive, indicating that regions with higher land prices are more likely to attract KIBSs. This may not seem to be in line with the principle of enterprises pursuing the lowest cost, but it reflects the high ability of KIBSs to compete for rent, as well as the important role of traffic conditions and infrastructure in the location of KIBSs. Typically, areas with better traffic conditions and infrastructure have higher land prices. The traffic conditions play an important role in the distribution of KIBSs. The impacts of the distance to subway stations (X2) and the density of bus stops (X3) are consistent with expectations and have passed the significance level tests, indicating that KIBSs are mostly distributed in areas with convenient transportation. Convenient traffic conditions provide more opportunities for enterprises to establish business connections with other regions.

Table 2. Negative binomial regression results.

Variables	KIBS	Information Services	Financial Services	Business Services	Technology Services
Land price (X1)	0.013 *** (0.003)	0.018 *** (0.004)	0.021 *** (0.005)	0.014 *** (0.004)	0.010 *** (0.003)
Distance to subway station (X2)	−0.049 *** (0.012)	−0.045 ** (0.019)	−0.056 * (0.030)	−0.063 *** (0.014)	−0.022 (0.014)
Bus station density (X3)	0.162 *** (0.011)	0.118 *** (0.012)	0.136 *** (0.012)	0.172 *** (0.013)	0.136 *** (0.012)
Office space (X4)	0.011 *** (0.003)	0.014 *** (0.003)	0.009 *** (0.002)	0.009 *** (0.003)	0.012 *** (0.003)
Business environment (X5)	0.302 *** (0.075)	0.371 *** (0.077)	0.572 *** (0.079)	0.384 *** (0.081)	0.184 ** (0.082)
Technology factor (X6)	0.299 *** (0.065)	0.225 *** (0.069)	0.178 ** (0.077)	0.256 *** (0.070)	0.282 *** (0.072)
Industry diversity (X7)	4.356 *** (0.070)	5.889 *** (0.163)	5.939 *** (0.337)	4.083 *** (0.082)	4.219 *** (0.089)
Incubation environment (X8)	0.577 *** (0.080)	0.730 *** (0.082)	0.094 (0.086)	0.354 *** (0.085)	0.752 *** (0.086)
Investment environment (X9)	0.546 *** (0.097)	0.537 *** (0.098)	0.480 *** (0.096)	0.494 *** (0.104)	0.562 *** (0.103)
Manufacturing foundation (X10)	0.166 *** (0.056)	−0.054 (0.063)	0.026 (0.077)	0.074 (0.062)	0.275 *** (0.062)
Agglomeration factor (X11)	0.001 *** (0.000)	0.004 *** (0.000)	0.052 *** (0.010)	0.003 *** (0.000)	0.003 *** (0.000)
Policy factors (X12)	0.154 *** (0.051)	0.180 *** (0.067)	−0.238 *** (0.086)	0.094 * (0.056)	0.326 *** (0.060)
Constant	−1.284 *** (0.079)	−4.468 *** (0.174)	−7.044 *** (0.374)	−1.740 *** (0.092)	−2.286 *** (0.101)
N	3261	3261	3261	3261	3261
alpha	0.885	0.846	0.493	1.009	0.986
Log-likelihood	−7821.918	−4435.272	−1702.179	−6473.684	−5905.824

Values in parentheses are standard errors. Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

The coefficient of office space (X4) is significantly positive, indicating that the supply of office space is conducive to the location selection of KIBSs. The larger the office area of an office building, the more enterprises it can accommodate. The positive and significant coefficient of business environment (X5) suggests that the KIBSs attached great importance to good market access and a convenient business environment. The coefficient of technology factors (X6) is significantly positive, indicating that KIBSs tend to be distributed near universities and research institutions. Knowledge spillover and technological cooperation are beneficial for enhancing the innovation capability of KIBS firms. At the same time, universities and research institutions could meet the needs of KIBS firms n terms of specialized talents.

The regression coefficient of industry diversity (X7) is the highest and has passed the significance test, indicating that KIBSs are highly dependent on knowledge and technology spillovers between related industries. Diversified related industries are a key factor affecting the location of KIBS. The coefficient of the incubation environment (X8) is significantly positive, suggesting that the entrepreneurial resources and incubation services brought by incubators and maker spaces provide very favorable conditions for the agglomeration of KIBSs. The coefficient of venture capital (X9) is significantly positive, indicating that the KIBSs are very sensitive to the convenience of obtaining venture capital.

The regression analysis reveals a notably positive coefficient for the manufacturing foundation (X10), implying that the manufacturing foundation has a significant promoting effect on the location selection of KIBSs. The transformation of the manufacturing industry has increased intermediate demands such as research, testing, and marketing, which is conducive to enhancing the scale and specialization of KIBSs. The coefficient of agglomeration factors (X11) is significantly positive, indicating that the agglomeration economic effect has a significant impact on the location of KIBSs. The existing development conditions provide a good foundation for new enterprises, and the scale effect and externalities caused by enterprise agglomeration are conducive to attracting similar enterprises. The significantly positive regression coefficient for policy factors (X12) suggests that the sound facilities and preferential policies in the development zone are highly attractive to KIBS firms.

Overall, the KIBSs are greatly influenced by industry diversity, incubation environment, and investment environment, indicating that the KIBSs place more emphasis on diversified related industries, innovation incubation, and venture capital.

The analysis results of the sub-sectors indicate that differences are present in the impact of influencing factors on KIBS sub-sectors.

For information services, the impacts of land prices, transportation accessibility, and commercial environment are significant, indicating their strong rent-paying ability and preference to be located in commercial centers with convenient transportation. Compared with other enterprises, the information services attach greater importance to office space; a sufficient and suitable working environment provides the essential conditions for its spatial layout. Technology factors, industry diversity, incubation environment, investment environment, and policy factors are important factors that affect the distribution of information services, leading to their cluster characteristics. The agglomeration factor is significantly positive, indicating that the information services are beneficiaries of the agglomeration economy. The impact of manufacturing infrastructure is not significant, indicating that factories have little attraction to information services.

The financial services tend to exhibit a concentrated distribution under the influence of land prices, transportation accessibility, and office space. The impact of industry diversity, business environment, and agglomeration factors is greater than that of the other three industries, indicating that the financial services prefer to lay themselves out in areas with high industry diversification, a strong business atmosphere, and a concentration of similar enterprises. The investment environment and technology factors are important factors of its spatial distribution, leading to a preference for locating around venture capital institutions and universities. The coefficient between the incubation environment and manufacturing foundation is not significant, indicating that incubators and manufacturing bases have little attraction to financial services. The coefficient of policy factors is significantly negative, indicating that the financial services are more inclined to be distributed in the central urban area to obtain a larger market.

For the business services, the higher regression coefficients for the distance to subway stations and the density of bus stations, compared to the coefficients for the other three industries, suggest a preference for the business service industry to be located in areas with convenient subway and bus services. Land prices, office space, and agglomeration factors are significantly positive and represent a significant attraction for the location of the business services. The business environment, industry diversity, incubation environment, and investment environment are important factors influencing the location selection of the business services, indicating a preference for clustering in areas near commercial centers, business incubators, venture capital firms, and regions with high industry diversity. The coefficient of manufacturing foundation is not significant, indicating that the level of manufacturing development has little effect on the location selection of the business services. The business services have strong dependences on technology factors and policy factors, leading to their preference for layout around universities, research institutions, and development zones.

The technology services are significantly positively influenced by land prices, bus station density, agglomeration factors, and office space, which represent a significant attraction in the location selection of the technology services. The coefficient of distance to subway stations is not significant, indicating that subway transportation poses little attraction to the technology services. Industry diversity and business environment are important factors in the location selection of technology services, leading to their preference for clustering in areas with high industry diversity and close to commercial centers. Compared with the other three types of enterprises, the technology services attach greater importance to the incubation environment, investment environment, technology factors, manufacturing foundation, and policy factors. The superior incubation investment environment, favorable technological conditions, urgent transformation needs, and diverse preferential policies provide conditions essential to the layout of the technology services.

4. Discussion

Based on the above results, we further discuss the spatial patterns of KIBSs and their influencing factors. In terms of the spatial pattern, the KIBSs in the Wuhan metropolitan area have formed a cluster area around business centers and universities, which is consistent with previous research results from Dublin [5], Toronto [6], and Beijing [9]. At the same time, this article also discovered something unique about the distribution pattern of KIBSs in the Wuhan metropolitan area. This article found that the KIBSs in the Wuhan metropolitan area are mainly distributed in the inner suburbs, with clustering characteristics along the entrepreneurial street, headquarters base, science and technology park, and industrial base. In the post-industrial era, emerging business models are developing rapidly, and the spatial distribution of KIBSs is becoming more flexible. KIBSs tend to adopt a diversified agglomeration model. Due to the implementation of incentive policies and the improvement of the innovation environment, KIBSs are showing a trend of spreading to the inner suburbs of cities. Obvious differences exist in the spatial patterns of KIBS sub-sectors. The information services in Wuhan metropolitan area have formed a cluster area around science and technology parks, software parks, and university clusters, which is consistent with previous research [14]. However, the information services in the Wuhan metropolitan area still exhibit clusters along the entrepreneurship street and headquarters base. Due to the intensive innovation factors, strong policy support, and diverse outsourcing services in these regions, favorable conditions have been provided for the development of the information services. The financial services in Wuhan metropolitan area are highly clustered around commercial and financial centers, which is consistent with previous research results [15]. In addition, the financial services in Wuhan metropolitan area also show a law of clustering around the financial service backends and technology finance clusters, mainly due to the rapid development of e-commerce and technology finance. The business services exhibit a law of clustering around entrepreneurial streets, headquarters bases, university clusters, and commercial centers. Due to the high-tech nature of business services, it is necessary to constantly engage and communicate with customers in order to achieve specialized value-added services. Therefore, the spatial layout of business services is closely related to the innovation environment, incentive policies, and intellectual resources. At the same time, in order to approach customers, business services are concentrated in densely populated commercial centers. The technology services exhibit a clustering pattern around entrepreneurial streets, headquarters bases, science and technology parks, university clusters, and industrial bases. Due to the fact that the technology services are based on scientific knowledge and professional technology, and heavily rely on professional and technical talents, innovation sources, technology parks, incubation platforms, and high-tech industry bases represent a great attraction to technology services.

In terms of the influencing factors, previous studies have shown that the distribution pattern of KIBSs is influenced by various factors, such as face-to-face interaction [21], traffic conditions [12], government planning [22], land rent [18], agglomeration economies [23], human resources [24], reputation [13], and convenience facilities [25]. These results are similar to the research findings of this article. On the basis of existing research, this article further verifies the impact of the industry diversity, incubation environment, and investment environment on the location selection of KIBSs. This is primarily attributed to the escalating influence of innovation elements such as incubators, venture capital, and industry diversity on the distribution of KIBSs, as urban areas progress into the post-industrial era and a phase characterized by innovation-driven development. In addition, the differences in KIBS sub-sectors may lead to different factors affecting the spatial patterns. The customer characteristics, business composition, and resource elements of KIBS sub-sectors are different. The information services and technology services place high demands on technological innovation, and pay more attention to industry diversity, incubation environment, investment environment, technological factors, and policy factors. The financial services have the characteristic of being close to the customer source market, and are mainly influenced by the business environment, industry diversity, and investment environment. Business services combine the characteristics of the three mentioned above, placing greater emphasis on investment environment and industry diversity. At the same time, incubation environment, business environment, and technological factors are also important factors in location selection. This article systematically analyzes the spatial pattern and influencing factors of KIBS sub-sectors, which contributes to a more profound comprehension of the laws and mechanisms underlying the distribution patterns of urban KIBSs.

Based on the above findings, this article proposes the following suggestions for the spatial layout of urban KIBSs from the perspective of sustainable development. Firstly, urban KIBSs should form a multi-center spatial pattern. The growth pole is the engine for the growth of urban KIBS clusters. Therefore, in order to enhance the strength of urban KIBSs, it is necessary to prioritize the development of regions with high development potential and strong driving forces, construct KIBS clusters, and form multiple growth poles around innovation platforms, headquarters bases, science and technology parks, university clusters, business centers, and industrial bases, thereby driving the development of industries in surrounding areas. Secondly, urban KIBSs should form a differentiated hierarchical spatial arrangement. The above research indicates that the distribution of urban KIBSs exhibits a law of hierarchical differentiation, shaping the locations of KIBSs in central urban areas, inner suburbs, and outer suburbs. Therefore, the spatial layout of KIBSs in urban areas should follow the objective laws of hierarchical differentiation, forming a differentiated hierarchical spatial arrangement. The central urban area should promote KIBSs to cluster around business centers and universities, in order to enhance the high-level service functions of the central urban area. The inner suburbs should promote the clustering of KIBSs around technology parks, headquarters bases, innovation platforms, university clusters, and high-tech industry bases, attracting talents and industries to gather in the inner suburbs. The outer suburbs should rely on important manufacturing bases and urban new areas, encourage KIBS agglomeration areas to establish themselves in the outer suburbs, promote the transformation and upgrading of the manufacturing industry, and enhance population attractiveness. Finally, urban KIBSs should implement differentiated spatial layout strategies based on the different needs of KIBS sub-sectors. Different location requirements create different spatial patterns. Therefore, differentiated layout strategies should be implemented based on the characteristics of the urban KIBS sub-sectors. Information services and technology services have a high level of innovation and should mainly be laid out around innovation platforms, science and technology parks, headquarters bases, and university clusters. Financial services tend to be close to their clients and should mainly be laid out in the urban centers, while strengthening the construction of financial backends and technology finance clusters. Business services

integrate the characteristics of the three sub-sectors mentioned above, and their spatial layout should mainly be around commercial centers, headquarter bases, entrepreneurial streets, and academic institutions.

Compared with previous studies, the innovations of this article are as follows: Firstly, in terms of spatial pattern, this article reveals the unique laws of inner suburbanization and location diversification exhibited by the KIBSs, which are significantly different from the agglomeration of KIBSs in urban centers in the industrial era. This contributes to a more profound comprehension of the characteristics and laws of the distribution pattern of urban KIBSs in the post-industrial era. Secondly, in terms of the influencing factors, this article further verifies the impacts of the industry diversity, incubation environment, and investment environment on the location selection of KIBSs, based on previous studies, which improves the theoretical explanation of the mechanism of the distribution pattern of urban KIBSs. Thirdly, this article systematically analyzes the spatial patterns and influencing factors of KIBS sub-sectors, which is relatively uncommon in previous studies.

The results of this article have certain limitations. Firstly, this article only uses cross-section data to analyze the spatial patterns of urban KIBSs, without dynamically presenting the evolution process of the distribution of KIBSs. Future research could utilize continuous time series data to analyze the spatial evolution laws of urban KIBSs, determine their spatial development trends, and provide effective references for the rational spatial layout of KIBSs. Secondly, this article focuses on the spatial patterns and influencing factors of KIBSs in the Wuhan metropolitan area, without comparing it with cities of different development levels. Future research also requires a comparative analysis of the spatial patterns of KIBSs in cities at different scales and stages, so as to systematically summarize the laws in the spatial patterns of urban KIBSs. Finally, this article mainly adopts quantitative analysis methods to analyze the influencing factors. Qualitative methods have not been sufficiently applied. In future research, interview methods will be used to deeply reveal the formation mechanism of the spatial patterns of urban KIBSs.

5. Conclusions

Taking the Wuhan metropolitan area as a case study, based on multi-source data, this study uses the multi-ring buffer zone analysis and kernel density estimation method to analyze the distribution pattern of KIBSs, and uses the negative binomial regression model to detect the factors that affect the spatial pattern of KIBSs. The main conclusions are as follows.

Firstly, in terms of the spatial pattern, the KIBSs in the Wuhan metropolitan area are mainly distributed in the inner suburbs. The KIBSs in the inner suburbs (9–24 km) account for 51.39% of the total. The spatial distribution of KIBSs presents a multi-center spatial pattern, including two main centers (Optics Valley Entrepreneurial Street and Optics Valley Technology Harbor) and six sub-centers (Guangdong Science and Technology Park, Optics Valley Software Park, Wuhan University Science and Technology Park, Zhongnan Road Business District, Jiedaokou Business District, and Optics Valley Square Business District). The KIBSs exhibit the law of agglomeration along entrepreneurial streets, headquarters bases, science and technology parks, university clusters, business centers, and industrial bases. Obvious differences exist in the spatial pattern of KIBS sub-sectors. The information services present a pattern of "three main centers and four sub-centers", exhibiting the law of agglomeration along entrepreneurship streets, headquarters bases, university clusters, software parks, and technology parks. The financial services present a pattern of "one main center, five sub-centers", exhibiting the law of agglomeration along commercial and financial centers, and partially along financial service backends and technology finance clusters. The business services present a pattern of "five main centers and seven sub-centers", exhibiting the law of agglomeration around the entrepreneurial street, headquarters base, university cluster area, and commercial center. The technology services present a pattern of "two main centers

and four sub-centers", exhibiting the law of agglomeration around entrepreneurship streets, headquarters bases, science parks, and university clusters, and partially around industrial bases.

Secondly, in terms of the influencing factors, the negative binomial regression analysis shows that land price, traffic conditions, office space, commercial environment, technology factors, industry diversity, incubation environment, investment environment, manufacturing foundation, agglomeration factors, and policy factors are the main factors affecting the spatial patterns of KIBSs in Wuhan metropolitan area. Among them, industry diversity, incubation environment, and investment environment have a greater impact. There are differences in the impacts of different influencing factors on KIBS sub-sectors.

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