FROM CLOSURE TO GRADUAL RELEASE OF EGS INDUSTRY: EMPIRICAL EVIDENCE FROM THE SPATIAL EVOLUTION AND CAUSAL MECHANISM IN THE MAIN TOWN AREA OF WUHAN, CHINA

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ABSTRACT

With the economic impact and increasing popularity of the electronic gaming industry, EGS (Electronic Gaming Sports) had become an important topic of debate in sports academia regarding its conceptual delineation and attribute characteristics. This paper jumped out of the hotspot academic perspective of the concept, characteristics, and impacts of EGS. In response to the gaps in the spatial development of the EGS industry and the lack of empirical research findings, an interpretive empirical research method was adopted, focusing on Wuhan as the study area to gain insight into the situation where the spatial development of the EGS industry was unclear. The spatial evolution of the EGS industry in the main town area of Wuhan was interpreted through a quantitative approach and based on the spatial data of EGS companies from 2006 to 2022 using Average Nearest Neighbor (ANN), Kernel Density Estimation (KDE), and Ordinary Kriging (OK) of geospatial analysis. The results indicated closure to the gradual release of the EGS industry, with specific findings as follows. (1) The EGS industry in the main town area of Wuhan from 2006 to 2022 developed rapidly, and the overall spatial distribution showed a process from discrete to cluster, accompanied by an apparent deepening of aggregation in recent years. The local aggregation of the EGS industry transformed from dual to multiple cores, and the multiple cores formed stronger groups of aggregation as the cluster spread and merged. (2) The spatial interpolation of the registered capital of companies predicted the hot spot of high-capital distribution of EGS companies in the Optics Valley vice town area of Hongshan to the southeast, indicating that more competitive EGS companies and larger EGS industry groups might emerge in Optics Valley in the future. (3) The spatial evolution of the EGS industry in the main town area of Wuhan could be divided into an early start phase from 2006-2010, a rapid development phase from 2010-2014, an aggregate explosion phase from 2014-2018, and a cluster integration phase from 2018-2022. (4) The spatial evolution of the EGS industry was influenced not only by the main factors of industrial economic agglomeration, industrial chain derivation, and industrial policy environment but also by the other factors of land and talent market, adjacent infrastructure support, city industrial promotion, and globalization dissemination. The future development of the EGS industry could be guided by the government's industrial policies, supported by high-quality talent teams, and driven by local promotion and international communication to provide an essential impetus for the optimal EGS industry.

KEYWORDS

Electronic Gaming Sports (EGS); Spatial Evolution Pattern; Capital Weighted Forecast; Causal Mechanism; Wuhan, China.

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1. INTRODUCTION

With the economic impact and increasing popularity of electronic gaming industries, EGS (Electronic Gaming Sports) had become an important topic of debate in the academic debate on sport, and how the future direction of EGS would evolve was the issue's main focus [1]. In recent years, EGS had been one of the fastest-growing and most convenient forms of entertainment, driven by new media technologies to become mainstream [2]. EGS was a sport in which electronic gaming competitions reached the organized competition level. A sports model combined athleticism, technology, spectacle, and entertainment by using modern technology to organically integrate electronic games with the rules of traditional sports competitions. EGS connected the Internet, traditional media, and new mass-consumption industries with low pollution, strong driving effects, and sustainable development, and was conducive to promoting the city's image. However, due to the younger demographic of the EGS industry, there was a general perception that the development of the EGS industry had a negative impact on young people [3]. The negative effects include health, psychological, consumer, social, and ethical issues for young people [4, 5, 6, 7].

As an emerging topic of interest to scholars from various disciplines, there was a debate among academics as to whether EGS qualifies as a sport. Some scholars suggested that EGS was different from other traditional sports because it could be considered both recreational and physical, and as a cultural industry practice was bound to accelerate the development of society [8]. Conversely, some scholars claimed that EGS was not a sport, regardless of its similarity to sports [9, 10]. Some scholars proposed that EGS as a form of sportification, whether it fell within the definition of sport or not, needed to be examed for its positive or negative impact on the industry through sports management [11]. Furthermore, EGS was not just about playing electronic games but also being used to satisfy team relationships and a sense of social belonging [12]. After EGS players face social isolation due to excessive gaming, social capital was fostered by constructing communication mechanisms between online gaming and offline social interaction, transforming EGS into real-life social support with positive potential [6,13]. Some scholars studied the potential of EGS as a sporting category from the perspective of professional recognition in the school, suggesting a relationship between EGS and education in academia [14]. The findings showed that EGS penetrated the daily life of Chinese college students, so it was crucial for students to plan a rational schedule and consumption of EGS to promote a better life and mental health [15]. This paper found that some scholars believed that EGS was similar to playing computer games in the traditional sense, which was a misunderstanding between the concepts of computer games and EGS. As an emerging industry evolved after the development of computer games and internet technology, the organization and standardization of EGS were essential features that distinguished it from traditional computer games. Compared with traditional computer games, EGS events with organizational management could exercise and improve participants' thinking and reaction, limb coordination, willpower, and team cohesion. As the commercial value and social influence of EGS increased, a

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mainstream EGS cultural complex was formed based on the core elements of EGS events and EGS communities. Some scholars found that for EGS players, a small proportion of players experienced gaming addiction, with a larger proportion exhibiting issues of self-esteem, performance, family conflict, sleep, and physical health [16].

In summary, a comprehensive literature review of EGS found that existing research on EGS was distributed in the fields of sport, business, health, technology, and media, but the disciplinary results showed a certain fragmentation [17]. Most scholars only focused on the traditional related fields of EGS, lacking consideration for combining EGS with other disciplines [18]. There was a considerable research gap in the direction of the spatial development of the EGS industry. The only existing studies were the progression of EGS diffusion in the center to the surrounding urban network, the factors that need to be considered in urban EGS organization, and the business opportunities created by EGS facilities organization, indicating that there were almost no studies on the spatial development of EGS industry [19,20]. Therefore, this paper discerned the unclear status of the spatial development of EGS industries through an interpretive empirical research approach. The main town area of Wuhan in Hubei Province, China, was used as the case study area. The period from 2006 to 2022 was used as the time interval for this study. The study focused on the regional development of the EGS industry and explored the spatial evolution, causation, and suggestion of the EGS industry. The study results were important for grasping the spatial pattern and evolutionary trend of the EGS industry in the main town area of Wuhan, which was conducive to optimizing the future spatial development of Wuhan's EGS industry as a representative city in central China.

2. METHODOLOGY

2.1. DESCRIPTION OF THE STUDY AREA

Wuhan, Hubei Province, China, had 13 administrative districts, with a permanent resident population of 12,326,500 at the end of 2020, according to the 7th National Census of China. The main town area of Wuhan included the seven administrative districts of Jianghan, Jiangan, Qiaokou, Qingshan, Hanyang, Wuchang, and Hongshan (Figure 1). As a mega-city in China, a central city in the central region of China, and the center of the EGS industry in central China, Wuhan had a particular influence on the world.

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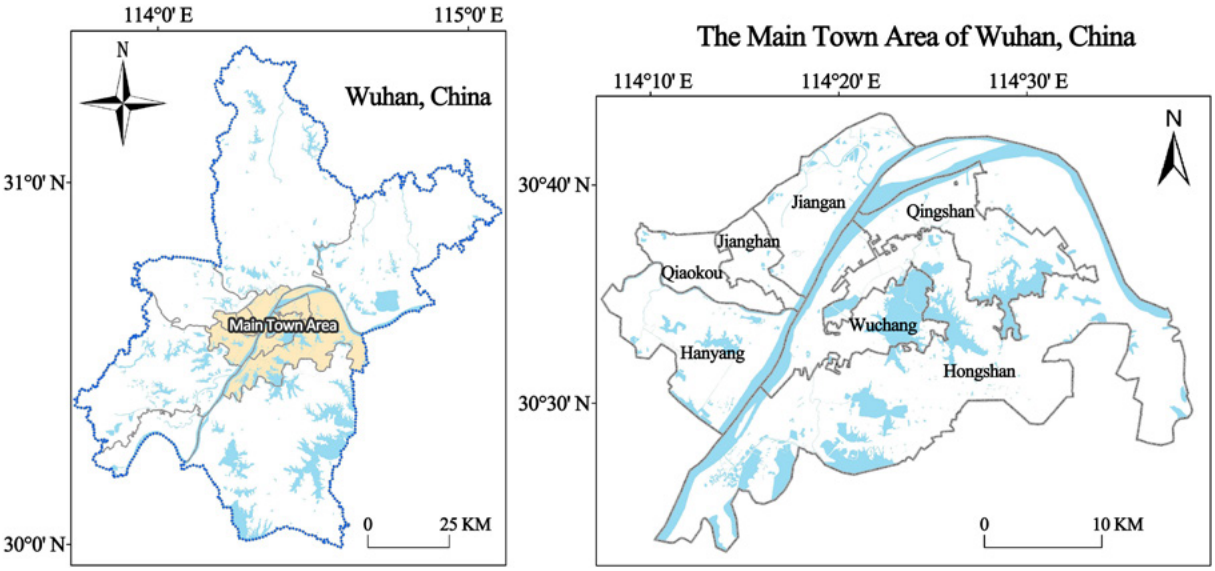

Figure 1. Wuhan Main Town Area Location Map, China

To a certain extent, spatial clustering of industry tended to occur in regions where the division of labor and specialization was more sophisticated. The EGS industry relied on the foundations of the cultural, sports, digital information, and technology industries. By linking its production factors and demand conditions, new industrial chains could be formed to promote the region's economic development. As the core city in central China, Wuhan was a cluster of EGS developing companies upstream, EGS operation companies midstream, and EGS organization companies downstream of the industry chain. Examples included Wuhan eStar Gaming and Wuhan Douyu Network Technology Co. Ltd. (listed on the NASDAQ exchange under the ticker symbol "DOUYU"). Due to the urban development structure of Wuhan, the main town area of Wuhan was much smaller than the other distant town areas, but it was more representative of Wuhan's main characteristics in terms of population density, economic activity, infrastructure, and so on. Therefore, as a city in central China with the most comprehensive industry chain, using the main town area of Wuhan as the case study area to discuss the spatial development of the EGS industry was representative and typical for exploring the trend of the EGS industry in China.

2.2. DATA COLLECTION

As the Chinese officially recorded a company credit agency, the Tianyancha system was one of China's leading business inquiry platforms (www.tianyancha.com). On 10 May 2019, Tianyancha was awarded Enterprise Credit Business Operation Qualification License by the People's Bank of China (PBC). Tianyancha system included information on hundreds of millions in social entity companies (including companies, institutions, foundations, schools, law firms, etc.) in China, with more than 300 dimensions of information automatically updated, such as listing information, corporate background, corporate development, judicial risk, operational risk, business status, intellectual property rights, etc. This paper used the data of EGS business companies as representative data of the development of the EGS industry and carried

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out a query based on the Tianyancha system to quantify and classify the collation of EGS companies. The specific search procedure was as follows.

The search engine based on the Tianyancha query platform was searched for all aspects of the following keywords relating to the business of EGS companies. As of 2022, these included eSports, electronic games, eSports tournaments, eSports clubs, eSports media, eSports news, eSports production, eSports host, eSports community, eSports live stream, eSports training, eSports broker, eSports internet cafes, eSports startup, eSports matchmaking, eSports platform, eSports equipment, eSports player, eSports service and other related Keywords.

Tianyancha's data search engine was comprehensive, but some of the information included may be inaccurate, which resulted in some screened companies not belonging to the EGS industry. Therefore, the selected EGS companies were reviewed through manual screening. Through the National Enterprise Credit Information Publicity System (https://www.gsxt.gov.cn/), data on the registered address, date of registration, registered capital, type of company, scope of business, and registration status of the above-mentioned EGS companies were collected. For the authenticity and validity of the data source, anomalous companies with unclear registered addresses, current business status showing cancellation, and revoked business licenses were removed. The resulting EGS industry data for the main town area of Wuhan showed that there were 4 EGS companies as of 2006, 12 EGS companies as of 2010, 27 EGS companies as of 2014, 63 EGS companies as of 2018, and 114 EGS companies as of 2022.

2.3. DESIGN OF THE STUDY

Through an overview of important historical events in the development of EGS, this paper sorted out the important historical progressions affecting the development of EGS in China (Table 1). It concluded that EGS as a controversial emerging industry was developing in a positive direction through continuous regulation and refinement by various sectors [21]. Based on a comprehensive analysis of EGS events, this paper considered that the longitudinal period from 2006 to 2022 was an essential guideline and reference value for evaluating the development status of the Chinese EGS industry. Therefore, this paper took the year 2006 as the beginning of the study ("General Administration of Sports of China first issued series of normative documents for the EGS industry") and established the period from 2006 to 2022 as the study's time interval. Based on the key historical events affecting EGS in China during the period, four-time intervals were delineated: 2006-2010, 2010-2014, 2014-2018, and 2018-2022. The spatial distribution characteristic, spatial evolution trends, and spatial forecasts of the high-capital areas in Wuhan's main town area were analyzed according to the four historical development stages of the Chinese EGS industry. The research objective was to explore the causation of spatial evolution and make recommendations for the development of the EGS industry in the main town area of Wuhan.

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Table 1. Key Events Affecting the Development of EGS in China (2003-2022)

Year	Key Events on the Development of EGS in China
2003	For the first time, EGS officially became the 99th sport recognised by the General Administration of Sports of China (GASC).
2004	The National Radio and Television Administration of China (NRTAC) issued notices prohibiting the broadcasting of EGS programs.
2006	The General Administration of Sports of China (GASC) issued a series of policies for the first time, such as "National E-Sports Competition Management Measures", to gradually establish an effective EGS management regulation system.
2008	The General Administration of Sports of China (GASC) redefined EGS as the 78th sport for the first time.
2009	The World Cyber Games (WCG) Final was held in Chengdu, China.
2011	China Central Television (CCTV) sports channel broadcasted the EGS specials program for the first time, and the World Cyber Games (WCG) had officially held in Kunshan, China.
2012	EGS had been nominated for the Tokyo 2020 Olympic Games.
2013	For the first time, the General Administration of Sports of China (GASC) set up a 17-member national team of EGS to compete in the 4th Asian Indoor and Budo Games.
2014	The "Sports on Earth" program of China Central Television (CCTV) broadcasted a documentary on the League of Legends project of EGS.
2016	For the first time, the Ministry of Education of China (MEC) added "E-Sports and Management" to the "Catalogue of Specialisation in Higher Vocational Education of General Higher Education Schools".
2017	The Olympic Council of Asia announced the inclusion of EGS as an official competition. In addition, the International Olympic Committee announced at its sixth summit in Switzerland that the EGS competition would be considered a sporting event.
2018	The 2018 Asian Games in Jakarta included EGS as a performance event. The same year, the Chinese government issued the "Measures for the Registration of E-Sports Athletes in Sichuan Province" to officially implement the EGS athletes' registration system.
2019	For the first time, the Ministry of Human Resources and Social Security of China (MHRSSC) issued a public notice for new occupations, including EGS athletes and EGS operators. In the same year, EGS was officially listed as a sporting competition after the fourth executive meeting of the National Bureau of Statistics of China (NBSC).
2020	For the first time, the Olympic Council of Asia announced the EGS program as an official event of the Asian Games.
2022	For the first time, EGS was an official event at the 19th Asian Games in Hangzhou, China, and was recorded in the national medal table.

Note: Compiled by the author from a variety of open-source information.

The spatial distribution characteristic was used to determine EGS companies based on temporal cross-sectional data for the main town area of Wuhan in 2006, 2010, 2014, 2018, and 2022. The study used Average Nearest Neighbour (ANN) analysis, which emphasized closer spatial connectivity of near objects than distant objects. The spatial distribution of point elements of EGS companies in the main town area of Wuhan was used to measure the mutual proximity and distribution characteristics in geographic areas. The Average Nearest Neighbour (ANN) ratio was calculated as the observed average distance divided by the expected average distance, which was used to measure the distribution of point elements in geographic

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areas. The ratio of ANN less than 1 indicated that the distribution was a cluster, greater than 1 indicated that the distribution was discrete, and equal to 1 indicated that the distribution was random [22].

The spatial evolution trend was simulated using Kernel Density Estimation (KDE) analysis based on data from four-time intervals, 2006-2010, 2010-2014, 2014-2018, and 2018-2022. Kernel Density Estimation (KDE) assumed that within a certain spatial range, a certain object could occur at any geographical location, but the probability of occurrence differed at each spatial location [23]. The object was considered to happen more frequently if it occurred more often in the spatial range and less frequently if not. The simulation results provided a graph that showed the spatial density change of the EGS company number. Based on the crest and trough in the spatial density graph of EGS companies, the spatial degree of clustering and the evolution trend of EGS companies were recognized from 2006 to 2022.

The spatial forecast was based on the location and number of spatially distributed EGS companies in 2022 and discriminated the high-capital areas of EGS using the registered capital of EGS companies as a weighted variable. The method used to discriminate high-capital areas of EGS companies was the Ordinary Kriging (OK) with spatial interpolation, which was an approach to optimally estimate unknown points based on variable data related to known point elements within the study area by the semivariogram model [24]. The aim was to forecast the high-capital distribution in the main town area of Wuhan and to make recommendations for the future spatial development of the EGS industry.

3. RESULTS AND DISCUSSIONS

3.1. SPATIAL EVOLUTION OF THE EGS INDUSTRY

3.1.1. SPATIAL DISTRIBUTION CHARACTERISTICS OF THE EGS INDUSTRY

The geographical location of EGS companies was abstracted as spatial point element data, and the results of its spatial distribution characteristics were discriminated by the Average Nearest Neighbor Ratio (R). R was calculated through the observed average distance (the actual EGS company distribution) divided by the expected average distance (the assumed random EGS company distribution) [25]. The calculation formulas were as follows.

$$R = \frac{\bar{D}_o}{\bar{D}_e} \quad (1)$$

$$\bar{D}_o = \frac{\sum_{i=1}^{n} d_i}{n} \quad (2)$$

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$$\bar{D}_e = \frac{1}{2\sqrt{\frac{n}{s}}} \quad (3)$$

In the above formula (1), the observed average distance was the average distance between the EGS company's point and the centroid of its nearest neighbor point, defined as $\bar{D}_o$. The expected average distance was the average distance in the random distribution of each EGS company's point, defined as $\bar{D}_e$. Average Nearest Neighbor Ratio was defined as R. In the above formula (2), d_i was the distance between EGS company's point i and each other EGS company's point. n was the number of EGS company's points i within the study area (the main town area of Wuhan in China). $\bar{D}_o$ was the observed average distance of the EGS company's point. In the above formula (3), n was the number of EGS company's point i within the study area (the main town area of Wuhan in China). S was the size of the study area (the main town area of Wuhan in China). $\bar{D}_e$ was the expected average distance of EGS company's point.

The distribution of EGS companies for five-time sections in 2006, 2010, 2014, 2018, and 2022 were measured by performing Average Nearest Neighbor (ANN) analysis in the ArcGIS software platform's Spatial Statistics tool (Table 2). The distribution of EGS companies in 2006 showed a very significant discrete trend, with R=2.440>1. The large R might be because the number of EGS companies was too less and caused the difference between the observed average distance and the expected average distance being too strong. The distribution of EGS companies in 2010 had observed an average distance of 2464.319m and an expected average distance of 2286.432m with R=1.078. However, P=0.606>0.05 indicated that the null hypothesis was rejected and the distribution pattern lacked evidence of statistical significance (the null hypothesis specified that the spatial elements were randomly distributed states). The number of EGS companies increased to twenty-seven in 2014, with R=0.789<1, indicating that the distribution of EGS companies in the main town area of Wuhan had gradually varied from discrete to cluster distribution. Until 2018 and 2022, R kept decreasing to 0.666 and 0.661, indicating a more obvious clustering of EGS companies. Moreover, the expected average distance of 114 EGS companies in 2022 was 1174.579m, and the actual observed average distance was only 776.757m. This indicated that the distance between the closest elements had been relatively small, and the aggregation dynamic of EGS industries was high. Therefore, the results indicated that the EGS industry distribution in the main town area of Wuhan as a whole exhibited a process from discrete to cluster distribution between 2006 to 2022, and the degree of aggregation continued to deepen in recent years.

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Table 2. Average Nearest Neighbor (ANN) Results for the Main Town Area of Wuhan (2006-2022)

Year	Number of companies /individual	Z-Score	P-Value	Observed Average Distance/m	Expected Average Distance/m	Average Nearest Neighbor Ratio (R)	Distribution Characteristic
2006	4	5,508	0,000	7814,481	3203,248	2,440	Discrete Distribution
2010	12	0,516	0,606	2464,319	2286,432	1,078	Insignificant Distribution
2014	27	-2,097	0,036	1761,916	2232,881	0,789	Cluster Distribution
2018	63	-5,069	0,000	1028,692	1544,212	0,666	Cluster Distribution
2022	114	-6,918	0,000	776,757	1174,579	0,661	Cluster Distribution

3.1.2. SPATIAL EVOLUTION TRENDS OF THE EGS INDUSTRY

Kernel Density Estimation (KDE) estimated probability density values based on the distance between the element to be estimated and the sample element. Using the spatial property of the data sample to explore its spatial evolution trend, helped reveal the spatial concentration of the EGS industry [26]. The calculation formulas were as follows.

$$F(x) = \frac{1}{Nh}\sum_{i=1}^{n} K_n\left(\frac{x - x_i}{h}\right) \quad (4)$$

In the above formula (4), $F(x)$ was the estimated density function at spatial location x. N was the number of EGS companies in the main town area of Wuhan. h was the bandwidth that controlled the degree of smoothing and the range of effect for the kernel function. K was the kernel function for the spatial weights. $x - x_i$ was the distance between data sites x and x_i.

Kernel Density Estimation (KDE) analysis was performed in the ArcGIS software platform's Spatial Analyst tool to reveal the spatial concentration and trend among EGS companies within the main town area of Wuhan for 2006, 2010, 2014, 2018, and 2022. In addition, based on the variation of the EGS company numbers from 2006 to 2022, this paper found that the number of EGS industries in the main town area of Wuhan had been growing in a developmental trend, but there were discrepancies in the growth rate of the number in different periods. There was a 200% increase from 2006 to 2010 (8 additional EGS companies), a 125% increase from 2010 to 2014 (15 additional EGS companies), a 133% increase from 2014 to 2018 (36 additional EGS companies) and an 81% increase from 2018 to 2022 (51 additional EGS companies).

In terms of the spatial evolution of the EGS industry from 2006 to 2010, the number of EGS companies in the main town area of Wuhan was not significantly increased

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but initially formed a spatial distribution kernel (Figure 2). The maximum kernel density value increased from 449.99 to 1545.92. This indicated that the double core density areas of Hongshan and Jiangan had already taken shape and showed a certain aggregation trend phenomenon.

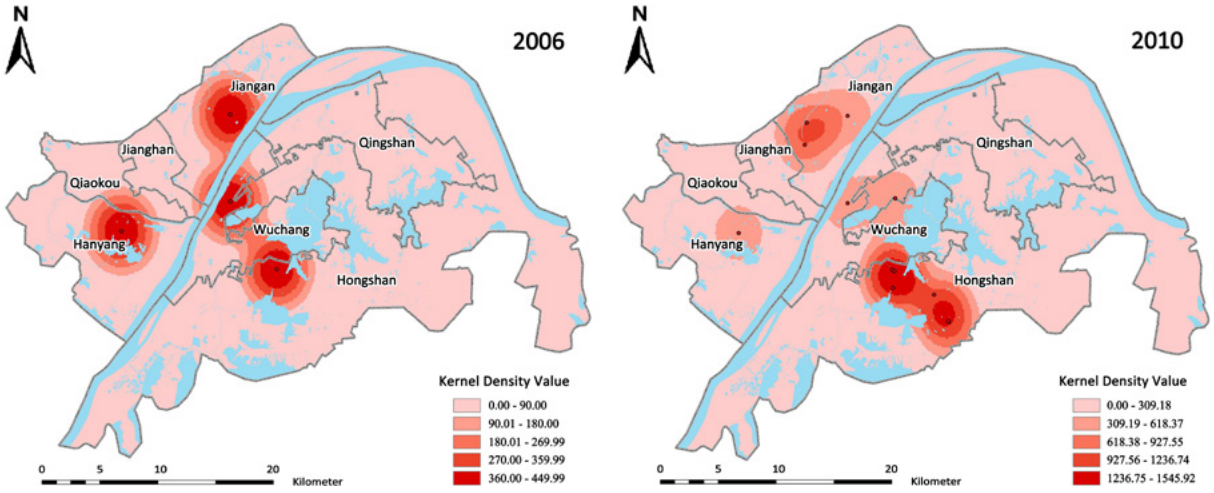

Figure 2. Kernel Density Estimation (KDE) Results for the Main Town Area of Wuhan (2006-2010)

In terms of the spatial evolution of the EGS industry from 2010 to 2014, the growing number of EGS companies led to an increasing spatial aggregation phenomenon, with EGS companies covering the main town area of Wuhan's seven administrative districts (Figure 3). The maximum kernel density value increased from 1545.92 to 1910.94, a small increase compared to 2006-2010, reflecting the growing core concentration in the cluster area but with a slower development rate. The initial dual-core aggregation of Hongshan and Jiangan gradually evolved into the multi-core aggregation of Jiangan, Jianghan, Hanyang, and Hongshan.

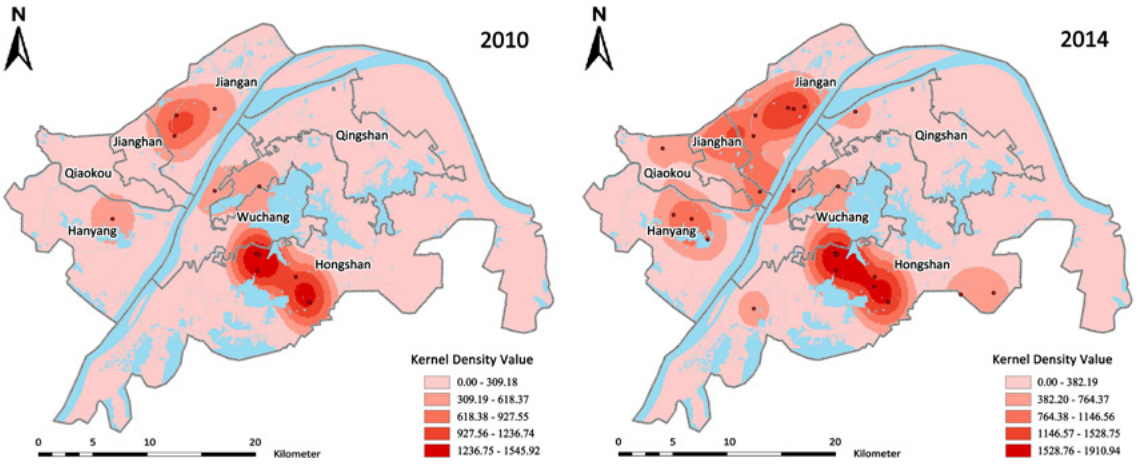

Figure 3. Kernel Density Estimation (KDE) Results for the Main Town Area of Wuhan (2010-2014)

In terms of the spatial evolution of the EGS industry from 2014 to 2018, the number of EGS companies in the main town area of Wuhan showed a faster growth and the distribution of EGS companies increased, especially the number of EGS companies in

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the southwestern region of Hongshan which grew very significantly (Figure 4). The maximum kernel density value increased from 1910.94 to 9175.94, which in turn led to a sharp strengthening of the core clustering trend for the EGS industry in southwestern Hongshan, with the degree of concentration already surpassing the cluster area in Jiangan. The trend of EGS industry evolution broke with the multi-core aggregation of the EGS industry in 2014 and emerged the trend of unipolar grouping in the Hongshan region.

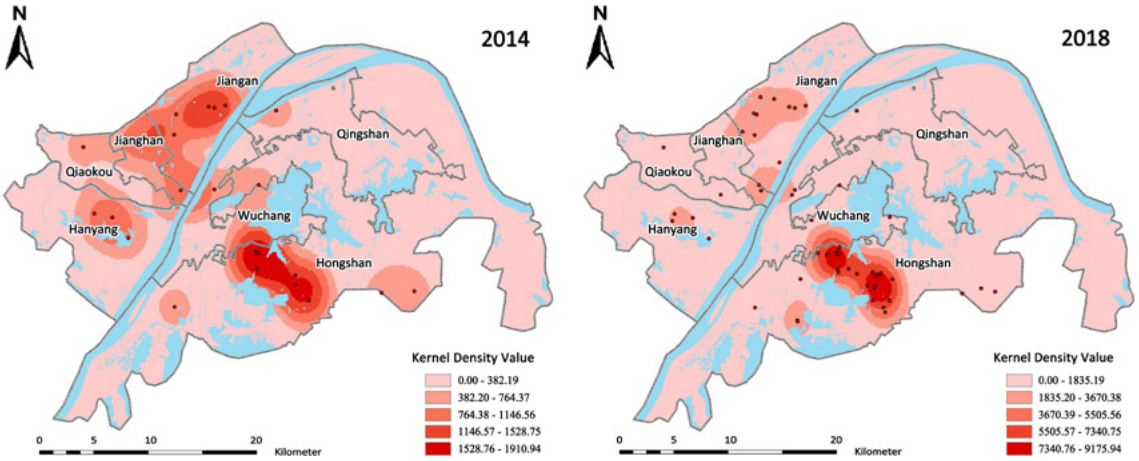

Figure 4. Kernel Density Estimation (KDE) Results for the Main Town Area of Wuhan (2014-2018)

In terms of the spatial evolution trend of EGS industries from 2018 to 2022, the aggregation trend of EGS companies in the main town area of Wuhan spread further, and not only the trend of unipolar grouping in the Hongshan area continued to strengthen, but also the trend of group consolidation in Jianghan (Figure 5). The maximum kernel density value increased from 9175.94 in 2018 to 15921.97, and the spatial aggregation trend of EGS industries steadily increased. The spatial pattern of the EGS industry presented the core grouping of Hongshan and the ribbon grouping of Jiangan and Jianghan.

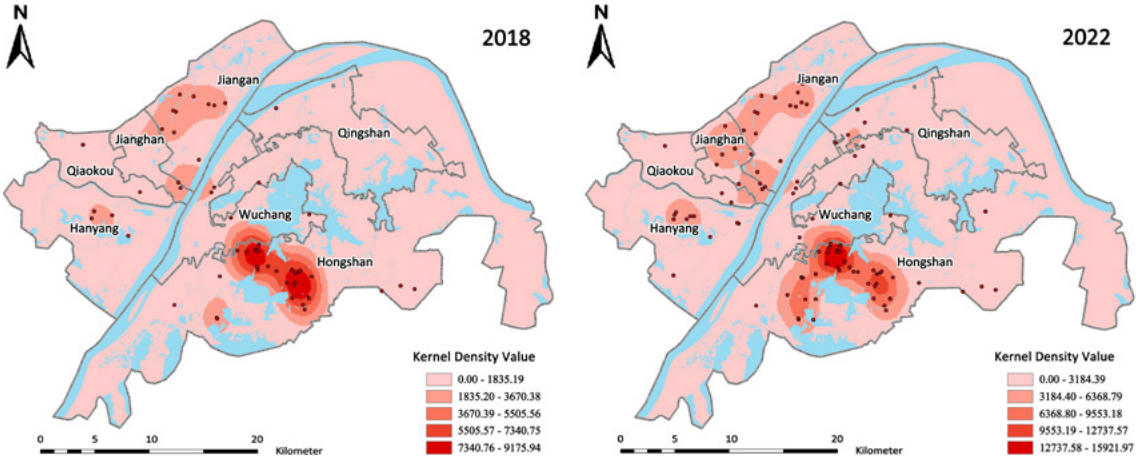

Figure 5. Kernel Density Estimation (KDE) Results for the Main Town Area of Wuhan (2014-2018)

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Therefore, as the number of EGS companies in the main town area of Wuhan continued to increase, the degree of spatial core aggregation of the EGS industry grew year by year, and the core aggregation areas transformed from the dual-core cluster to the multi-core cluster. The multi-core cluster of the EGS industry kept spreading to the surrounding areas based on the aggregation of each center, which in turn led to the formation of larger-scale monopole grouping and ribbon grouping in the adjacent core aggregation areas as the cluster spread. By exploring the growth and spatial evolution of EGS companies in each period, this paper suggested that the main town area of Wuhan's EGS industry experienced the early start phase (2006-2010), the rapid development phase (2010-2014), the aggregate explosion phase (2014-2018) and the cluster integration phase (2018-2022) between 2006 to 2022.

3.1.3. SPATIAL FORECAST OF THE HIGH-CAPITAL EGS INDUSTRY

Kriging interpolation was known as the spatially local interpolation technique, which enabled linear optimal unbiased estimation of data at unknown sampling sites in the area [27]. Ordinary Kriging (OK) was a univariate model with relatively simple operation compared to Regression Kriging (RK) and Universal Kriging (UK), as well as low error and good spatial prediction results [28]. Therefore, this paper adopted the Ordinary Kriging (OK) for spatial interpolation in predicting the spatial dynamic of the high-capital EGS industry. The calculation formulas were as follows.

$$Z'\left(x_0\right) = \sum_{i=1}^{n} \lambda_i \cdot Z\left(x_i\right) \tag{5}$$

In the above formula (5), $Z'\left(x_0\right)$ was the estimated value of the attribute at the unknown EGS company's location x_0. λ_i was the weight, which was used to weight the attribute value of the known EGS company's points. $Z(x_i)$ was the attribute value of the x_i point in the set Z of known EGS company points.

The main town area of Wuhan's EGS industry had been improving recently in terms of the supporting chain of industries, which to a certain extent demonstrated the unique development opportunities of the EGS industry in the future. Therefore, this paper predicted the capital hotspots for the main town area of Wuhan's EGS industry in the future by weighing the capital elements of companies. Ordinary Kriging (OK) analysis was performed in the ArcGIS software platform's Spatial Analyst tool based on the point data of EGS companies in 2022, the spatial forecast for the high-capital areas of the EGS industry in the main town area of Wuhan was carried out by weighting the registered capital of companies (Figure 6). Parent companies within the spatial distribution hotspots might spin off its industries chain to continuously increase their competitiveness and asset value [29]. Therefore, the aggregation of high-capital EGS companies in the hotspots signified the opportunity for more competitive EGS companies to emerge in the future. The spatial prediction results showed that high-

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capital EGS companies in the main town area of Wuhan were distributed around the Optics Valley vice town area in the southeast of Hongshan. This indicated that the Optics Valley vice town area in the southeast of Hongshan had the opportunity for more competitive EGS companies to emerge in the future and formed a larger EGS industry group with other EGS companies clustering in the region.

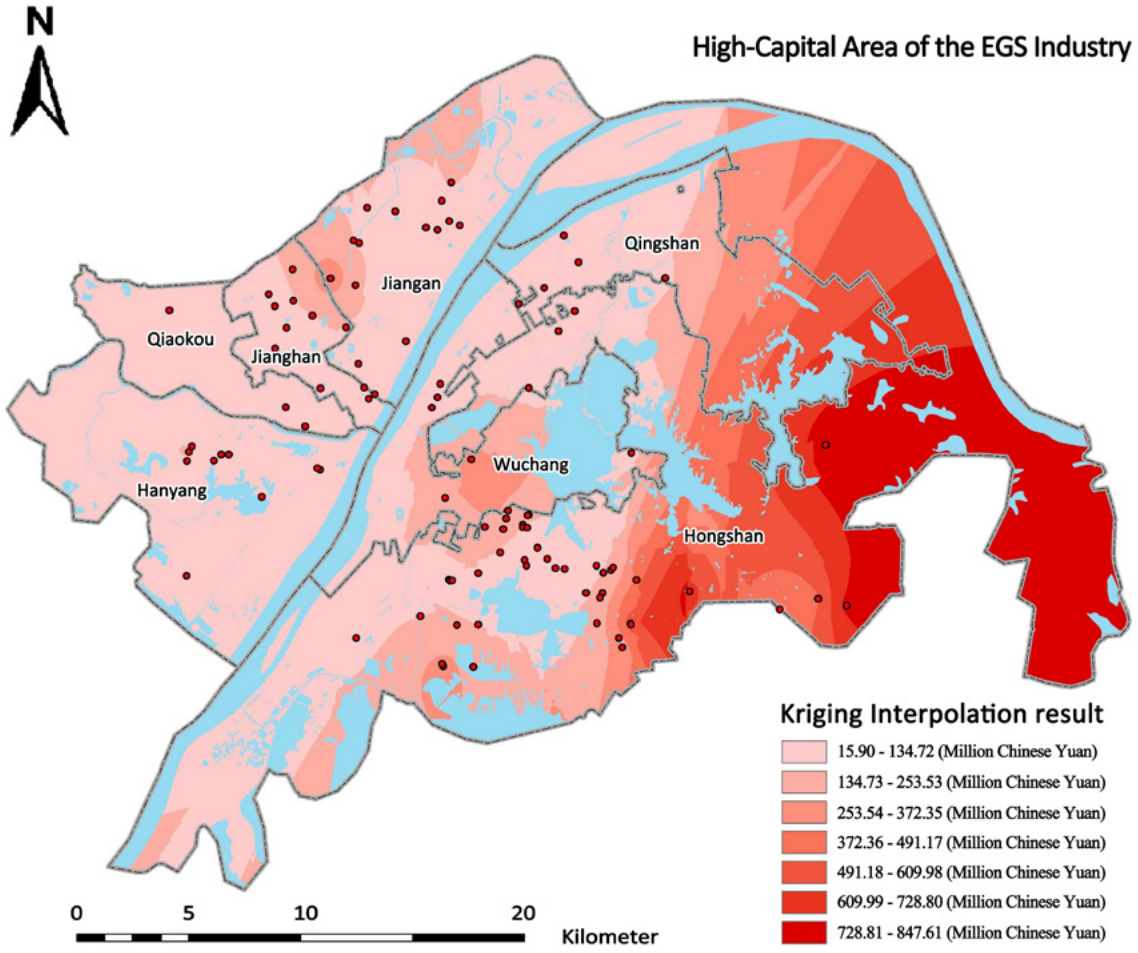

Figure 6. Capital-Weighted Kriging Interpolation Results for the Main Town Area of Wuhan in 2022

3.2. CAUSATION AND SUGGESTIONS FOR THE EGS INDUSTRY

3.2.1. CAUSATION FOR SPATIAL EVOLUTION OF THE EGS INDUSTRY

Based on the analysis of the spatial evolution trend of EGS companies in the main town area of Wuhan, this paper found that the aggregation characteristics of the EGS industry were significantly strengthened over time from 2006 to 2022. Moreover, there was the possibility of further polarisation in the Optics Valley vice town area in the southern part of Wuhan Hongshan in the future. The spatial evolution of the EGS industry in the main town area of Wuhan was considered to be influenced by three

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main factors: industrial economic agglomeration, industrial chain derivation, and industrial policy environment.

As a concentration of economic activities in geographical and spatial distribution, industrial economic agglomeration was mainly manifested by the agglomeration of similar or complementary industries in adjacent geographical locations. Further, it formed industrial economic groups and interdependent regional networks. Agglomeration economies played a guiding and centripetal role in the formation of the EGS industry group. As new companies were attracted to the city's existing industrial resources, they might congregate in industrial economic agglomerations nearby potential customers or potential suppliers, and draw resources from neighboring companies [30]. In addition, excellent agglomerations could better incubate and nurture synergies between each EGS company. The Average Nearest Neighbour (ANN) ratio of EGS companies decreased from 2.440 to 0.661, and the maximum kernel density value of EGS companies increased from 449.99 to 15921.97 between 2006 to 2022. Therefore, whether as a whole or locally, the trend of aggregation in the distribution of EGS companies in Wuhan strengthened over time, contributing to the development of the EGS industry in the direction of agglomeration and cooperation.

Inherited spin-offs in industry chain derivation arose from the spillover of new companies from the parent company’s business. In the process of inherited spin-offs, the parent company facilitated the transfer of its resources to the new company in a tolerant manner for the transfer of assets, which was more competitive and had a higher survival rate than other inexperienced start-ups [31]. Cooperative spin-offs in the industry chain derivation were achieved through cooperation between companies in the upstream, midstream, and downstream of the industries chain, bringing into play the absolute capabilities of each company in its respective strengths and achieving win-win cooperation in the industries chain further. The main town area of Wuhan's EGS companies might already have a well-established chain of industries in the Optics Valley vice town area of southern Hongshan. Compared to other EGS industry aggregations in Wuhan, the hierarchy of the EGS industry in Hongshan was much stronger than in other regions with polarising effects. In addition, the Optics Valley vice town area had hosted numerous international EGS events, and its "EGS city card" confirmed the perfection of the industry chain and supporting facilities. For example, it hosted the China Youth E-sports Competition (CYEC), the Global Optoelectronic Information Engineer Contest, and so on, which were major electronic information competitions.

The industrial policy environment was one of the factors directly influencing the aggregation of EGS industry, political, commercial, and social advantages had become a focus of attention for those EGS inside and outside sectors with active use of media tools to drive investment [32]. The industrial policy environment consisted of direct government policies contributing to forming and developing industries, which were effective and quick to implement. The positive business philosophy of companies and inclusive city culture values would more easily create a business environment conducive to the development of companies. Furthermore, the

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government proposed establishing cultural confidence in industrial development and innovating the business promotion mode of EGS industries through the combination of government policy promotion and EGS competitions [33]. This paper argued that the greater role of government industrial policy in the aggregation of the EGS industry was due to the tax breaks for micro & small companies and the technology incubation incentives enacted in the Optics Valley vice town area, which greatly supported the survival of emerging EGS companies.

3.2.2. SUGGESTION FOR FUTURE DEVELOPMENT OF THE EGS INDUSTRY

From the results of the spatial evolution of EGS, the spatial evolution trend of the EGS industry was not only influenced by the main factors of industrial economic agglomeration, industrial chain derivation, and industrial policy environment but also related to other factors such as land and talent market, adjacent infrastructure support, city industrial promotion, and globalization dissemination. Compared with the traditional sports industry, the EGS industry combined sports competition, digital information technology, and audio-visual arts into a whole, with strong information technological characteristics [34]. Therefore, by referring to the characteristics of EGS companies, which were more inclined towards emerging technology companies, this paper focused on the following three aspects to recommend the future development of the EGS industry.

1. The government's industrial policy had an important guiding role in establishing industrial chains, forming industrial aggregations, and improving cooperation in spatial groups for companies. Regional support policies, industrial cultural integration, and inter-country differences led to significant regional imbalances in the contribution of EGS industries to economic development, but economic connections between regional EGS companies had strengthened slightly in recent years [35]. Especially after the COVID-19 pandemic, government strategic plans and investments could be considered for the strategic development of EGS because of the important impact on the economy of the destination [36]. By guiding the formation of a conglomerate of EGS companies, government industrial policies could easily create a good brand appeal to attract consumers and develop high technology [37]. In addition, reasonable and favorable tax breaks for companies and a positive business environment would attract new EGS companies to locate. The location of new companies was not only influenced by the source market but also by whether the costs and benefits of operating space could be maximized under the support policies of industries.

2. High-quality talent teams played a vital role in the development of the EGS industry as carriers with corporate knowledge and skills. Typically, talent teams performed better in collaborative management than in self-management, reflecting that high-quality talent teams were better for the development of

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companies and demonstrated team pride and cohesiveness [38]. The EGS industry involved in new Internet businesses such as sports, digital information technology, and new media communications required a more versatile mix of technology professionals than traditional industries. Moreover, due to various technological and commercial dependencies, EGS was in a precarious state compared to earlier traditional sports, as the EGS industry lacked a large number of human resources to formalize and institutionalize its industrial environment [39]. In addition, whether it was upstream, midstream, or downstream of the EGS industry chain, talented teams of professionals could reduce operational costs for companies, integrate core resources, and facilitate cooperation between companies to form excellent city EGS industry cards.

3. Local promotion and international communication were critical drivers in stimulating the development of the EGS industry. As a type of sporting event, initiatives such as audience group attraction, obtaining sponsorship endorsements [40], and added value of derivative products had been important thrusts for the development of the EGS industry. In the past, the promotion and publicity of the EGS industry relied heavily on the unique enthusiasm for EGS among the youth population and the spread of various EGS events. In addition, the level of professional players in the EGS industry and the attractiveness of event broadcasts greatly impacted the promotion and dissemination of the EGS industry [41]. Many companies' brands used EGS as a medium for communication and interaction with the customer base to consolidate the space for dialogue and communication between its respective brand and the public [42]. Because the EGS industry was more commercial than other sports industries, its promotion and audience feedback were more efficient and quicker with the aid of technological communication media.

4. CONCLUSIONS

4.1. CONCLUSION

In terms of the spatial evolution trend of the EGS industry, the main town area of Wuhan had a strengthening trend of EGS industry aggregation from 2006 to 2022. The overall spatial distribution of the EGS industry showed a process from discrete to cluster distribution, and the degree of aggregation tended to deepen in recent years. The local kernel density value of the EGS industry increased year by year, and the aggregation pattern transformed from dual-core to multi-core aggregation. Moreover, as the aggregation cores spread around based on central clusters, the adjacent aggregation cores in Wuhan Hongshan formed a larger EGS industrial group as it spread and merged. The spatial interpolation results based on the weighted number of companies' registered capital predicted the future distribution of high-capital EGS companies in the main town area of Wuhan to be in the Optics Valley vice town area of southeastern Hongshan. This indicated that the Optics Valley vice town area might

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have the opportunity to emerge more competitive high-capital EGS companies in the future, which could lead to a larger scale EGS industry group.

In terms of the spatial development stages of the EGS industry, the spatial evolution of the EGS industry in the main town area of Wuhan could be divided into four phases. (1) In the early start phase from 2006 to 2010, the number of EGS companies in the main town area of Wuhan increased insignificantly, but a core concentration area was initially formed around higher education institutions and business districts. (2) In the rapid development phase from 2010 to 2014, the EGS industry aggregation core gradually developed from the dual-core aggregation of Hongshan and Jiangan to the multi-core aggregation of Jiangan, Jianghan, Hanyang, and Hongshan. (3) In the aggregate explosion phase from 2014 to 2018, along with the growth in the number of EGS companies in the southern region of Hongshan, the kernel density value of EGS companies in the main town area of Wuhan experienced explosive growth. This led to a dramatic increase in the aggregation trend of the EGS industry in Hongshan, and the intensity of aggregation surpassed that of the Jiangan agglomeration. (4) In the cluster integration phase from 2018 to 2022, the EGS industry aggregation in the main town area of Wuhan further strengthened and spread, showing the trend of the aggregation group of Hongshan, the belt group of Jiangan and Jianghan.

In terms of the causal factors of the spatial evolution for the EGS industry, the spatial distribution trend of the EGS industry in the main town area of Wuhan was not only influenced by the main factors of industrial economic agglomeration, industrial chain derivation, and industrial policy environment but also by the other factors of land and talent market, adjacent infrastructure support, city industrial promotion, and globalization dissemination. Compared to traditional industries, the EGS industry combined sports, information technology, and audio-visual arts and had the needs and characteristics of emerging technology companies. Therefore, the following three recommendations were suggested for the future spatial development of EGS companies. (1) The government's industrial policy played an important role in guiding companies to establish industrial chains, form industrial agglomeration, and improve spatial group cooperation. Reasonable and favorable tax breaks for companies and a positive business environment would be more attractive to new EGS companies. (2) High-quality talent teams, as carriers of corporate knowledge and technology, could reduce operating costs for companies, integrate core resources and promote inter-company cooperation to form excellent city cards for EGS industries. (3) Local promotion and international communication were critical drivers for the development of the EGS industry, providing an important impetus to the EGS industry development through audience attraction, sponsorship endorsement, and added value of derivative products.

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4.2. LIMITATION AND PROSPECT

This paper focused on Wuhan, the center city of Hubei Province in China. Although Wuhan was a crucial city in central China regarding study scope, there needed to be more consideration of other central Chinese cities beyond Wuhan, such as Changsha and Zhengzhou. In addition, Tianyecha, as China's largest commercial search platform, although it had the widest business coverage of commercial information, might be a little data missing covered by its search engine. It could be multi-party verification in the future by combining with other commercial search platforms such as the Aiqicha platform and the Enterprise Inspection platform. Therefore, this paper hopefully triggered more other researchers on the spatial development of the EGS industry.

5. DATA AVAILABILITY

All the data for this study is available upon request to the author.

6. CONFLICT OF INTEREST

The authors declare that the research has no financial or personal relationships with other people or organizations that can interfere with it.

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