

Article

Where Are Business Incubators Built? County-Level Spatial Distribution and Rationales Based on the Big Data of Chinese Yangtze River Delta Region

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Abstract: Business incubators (BIs) in China have predominantly exhibited a government-led characteristic, recently broadening their spatial and temporal scope and extending reach to the county level. Regarding the inadequacies of county-level analysis scale, this study leverages Points of Interest (POI) big data to overcome them. To comprehend the governmental rationale in the construction of BIs, we examine the evolution dynamics of BIs in conjunction with policies. An economic geography framework is developed, conceptualizing BIs as quasi-public goods and productive services, and incorporating considerations of county-level fiscal operations and industrial structures. Focusing on the Yangtze River Delta (YRD) region as a case study, our findings reveal that over 98% of County Administrative Units (CAUs) have built BIs. Using kernel density estimation and Moran's *I*, the spatial patterns of CAUs are identified. The CAUs are further classified into three categories of economic levels using the k-means algorithm, uncovering differentiated relationships between industry, finance, and their respective BI. Additionally, we analyze the density relationship between BIs and other facilities at a micro-level, showcasing various site selection rationales. The discussions highlight that while BIs tend to align with wealthier areas and advanced industries, affluent CAUs offer location advantages on BIs, whereas less wealthy CAUs prioritize quantity for political achievements. This paper concludes with recommendations about aligning BIs based on conditions and outlooks on future research.

Keywords: business incubators; dynamic evolution; distribution mechanism; spatial planning; county administrative units; government logic; fiscal operation; industry structure; POI



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1. Introduction

Entrepreneurial economies are inherently high-risk economic activities. Given this, business incubators (BIs) (also called enterprise incubators) emerged in the 1960s as the most effective institutional solution in the United States for improving startup survival rates [1]. BIs address early stage market failures in technology businesses by efficiently allocating resources [2]. BIs play a critical role in driving innovation and fostering new enterprises by offering services, such as office space, funding, entrepreneurial mentorship, shared resources, technical support, and consultancy [3,4]. Reflecting the heterogeneous nature of BIs' roles [5], various countries and regions have tailored their BIs to align with local goals, organizational frameworks, service landscapes, and predominant industries. This customization has imparted distinct regional characteristics to BIs [6].

Since the post-1980s economic reforms, China has ascended as a key player in the global BI landscape [7,8]. By 2020, China boasted over 13,000 state-sanctioned BIs (including technology BIs and mass maker spaces) [9], a testament to the government's commit-

ment to leveraging these entities as instrumental in promoting innovation and employment [10,11]. China's Ministry of Science and Technology (MOST) categorizes BI as a crucial element of the national innovation framework [12]. While predominantly state-operated, China's BI sector includes a modest proportion of market-oriented entities (e.g., 3W Coffice, Krspace) which grapple with profitability. Over half of these entities obtain more than 50% of their net profits from government grants [13], thereby underlining the government-led nature of Chinese BIs. The reason BIs have become the government's large-scale procurement and quasi-public products with weakened profit motives [14] is due to the government aligning the development goals of BIs with the national objective of overtaking major international market competitors in economics and innovation [15]. This alignment bestows a unique corporate identity upon BIs, diverging from regular enterprises. From central to local governments, legislation and policy environments are built to support and protect the high-quality development of BIs. Of particularly note is the unprecedented support for BIs focused on novel concepts and technological advancements [16].

The substantial physical footprint is a hallmark of most Chinese BIs. As per China's official guidelines, BIs should be centrally located, span at least 10,000 square meters, and allocate over 75% of this area to incubatees [12]. That is to say, in China, the priority lies in offering complimentary housing and infrastructural support for incubatees [17]. This contrasts with the Western emphasis on BIs' soft services such as entrepreneurial coaching, technical and management support [18], resource provision [19], and strategic selection [20]. The physical space preference of Chinese BIs interestingly reflects in the nomenclature of these BIs, often ending with "space", "park", or "base" [21]. In other words, in the early stage of startups as invisible firms, they are more visible in China, which allows the spatial analysis conducted for enterprises [22,23] to radiate down to smaller units. The characteristics of physical space make spatial distribution an important dimension in the study of BIs in China. BI is a micro-form of start-up entrepreneurship carrier and a quasi-public affair, which can serve as a new prism to broaden the understanding of the spatial nature [24] and development pattern [25] of the entrepreneurial economy, providing a scientific basis for optimizing resource allocation, improving efficiency and fairness.

Existing research on BIs primarily adopts paradigms from science and technology management and business studies, lacking analysis from the perspective of economic geography [1]. First, the financial sustainability and revenue models of BIs are analyzed [6,26], though this revenue-centric approach is less prevalent in China due to the quasi-public nature of its BIs. Second, a performance evaluation is conducted, encompassing a comprehensive assessment of BI effectiveness [27] and sector-specific analyses addressing the compatibility between BIs and their incubatees [28]. Third, the role of BIs within incubation networks is scrutinized, exploring their engagement in knowledge exchange with technology companies, service providers, and other stakeholders.

Research on regional perspective of Chinese BIs remains scant in the English-language context, despite a few existing Chinese studies examining the relationship between BI growth and regional economic development. These studies validate the hypotheses that BI development benefits from funding sources [29], educated labor [30], and university control [31] on provincial-level [32] and city-level scales [33]. Nonetheless, there is a dearth of research focusing on smaller, county-level regions. Despite the historical stability of Chinese county-level administrative units (CAUs), these regions have recently become key spatial hubs for BIs, driven by policy initiatives. What are the distribution characteristics of BIs at the county-level? What influences the construction of these BIs? These questions remain unexplored. To address this gap, our study employs Points of Interest (POI) big data to circumvent the limitations of statistical yearbook data, which often fail to capture county-level nuances. Given the reliance of POI data on digital economy levels, we select the economically vibrant Yangtze River Delta (YRD) region for a case study. The precision of POI big data is instrumental for addressing the third research question: what is the underlying rationale for the site selection of BIs within county jurisdictions?

The article is structured as follows. The next section dynamically reviews the policy background and evolution process of China's BIs, and builds an analytical framework based on the inherent attributes of BIs for spatially understanding their construction. The mixed datasets with big data and statistical data employed for the empirical research are then introduced together with a description of case study area and methods. The modeling results on spatiotemporal characteristics and mechanisms at the county and micro scales are presented. Insights based on public policy, governance, and industrial economics are discussed before the conclusion and suggestions.

2. Background Information and Theoretical Framework

2.1. "Lowering Thresholds" for Both BIs' Users and Suppliers

Prior to the 1980s, China's government classified non-state-owned economic activities as speculative, even illicit [34]. Since the mid-1980s, a reconstruction of social norms [35] regarding entrepreneurship took place in China, legalizing the private economy and laying the groundwork for the emergence of BIs. Initially, these state-led BIs targeted high-tech startups but progressively broadened their scope to overseas returnees, college students, and the general public. Geographically, the supplying places of BIs reach down from major urban centers to suburb regions and even county towns (see Figure 1).

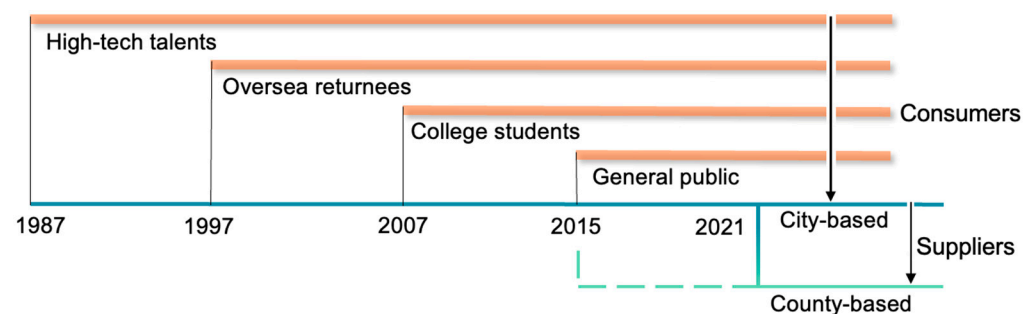


Figure 1. The downward-compatible dynamics of Chinese BIs.

Stage 1 (1987–1996): BIs targeting high-tech talent

BIs in China originated during the initial surge of the “entrepreneurship boom”, following the state’s formal acknowledgment of private economic sectors [35]. The government’s early directive that “economic construction must rely on science and technology” [36] laid the foundation for the high-tech focus of BIs. In the meantime, the state maintained an “permissive” attitude towards entrepreneurship in essential societal services, while adopting a “supportive” stance towards technology-based entrepreneurship, reflecting the goal of harnessing civilian wisdom to drive technological innovation and its commercialization.

China’s first BI, the Wuhan Donghu Pioneer Center (WDPC), was established in 1987 through government investment. WDPC rapidly gained recognition locally and nationally, initially providing basic services such as space (650 sqm), typing, telecommunication, business registration, and tax registration to just six small enterprises. Locally, WDPC operated as a non-profit, vice-county-level government-affiliated institution, with its regular staff expenses covered by the state. Nationally, WDPC was integrated into China’s Torch Program [37], aimed at fostering high-tech industrialization via market mechanisms and participated in drafting the “Outline of the Development Strategy of Enterprise Incubators in China”. This pioneering effort was soon emulated by major urban centers like Shanghai (1988) and Beijing (1989) [38], leading to the establishment of their own BIs.

China’s high-tech-oriented BIs flourished during the country’s second entrepreneurship wave, driven by post-1992 policy shifts. The “Southern Tour” speeches marked a pivot towards supporting the private sector [39], leading to the establishment of entrepreneurial financing mechanisms, notably state-owned bank loans to private entities [40]. This period

saw BIs, funded by government science and technology departments and managed locally, emerge as key elements in the national innovation strategy, aligning with the National Entrepreneurial Service Center Work Conference (1994) and the “Ninth Five-Year Plan” for Entrepreneurial Centers.

Stage 2 (1997–2006): BIs focusing on overseas returnees

The integration of overseas-educated elites into BIs marked the second phase, aligning with China’s assimilation of its market economy with global standards. Although such BIs initiated in Nanjing in 1994, this trend took three years to permeate nationally [38,41]. This period marked a subtle shift in the government’s strategy, balancing the internationalization of BIs and talent recruitment, thereby relaxing the strict technological prerequisites for BIs. Concurrently, the previously exclusive government funding and management of BIs began transitioning towards a model incorporating diverse funding channels.

In the realm of international enterprise incubation, the first series of pilot projects, a collaborative venture between the National Science and Technology Commission Torch Center and the United Nations Development Programme, set the stage for China’s first international BI network meeting in 1997 [42]. Subsequently, international training and seminar centers were established in each of China’s five geographical regions—East, South, West, North, and Central—with the Western hub targeting APEC opportunities.

Regarding international talent introduction, the 15th National Congress of the CPC in 1997 catalyzed the focus on BIs tailored for overseas-educated Chinese returnees. This was exemplified by the Beijing Overseas-Educated Scholars Service Center’s partnerships with various districts, facilitating a structured proliferation of BIs across multiple CAUs within a single city [43]. The 4th Plenary Session of the 15th Central Committee of the CPC in 1999 further endorsed this approach, propelling the formalization of “space-administration-finance” service model for BIs.

Stage 3 (2007–2014): BIs catering to College Students

During this stage, BIs catering to college students were established, almost a decade after the initial policy promoting student entrepreneurship. The initial policy aimed to alleviate the combined impacts of two developments: the widespread cessation of job assignments for university graduates in 1998 [44] and the nearly 50% expansion in university admissions in 1999 (Ministry of Education, Action Plan for Education Revitalization for the 21st Century) [45]. However, the underrealized encouragement policies did not directly address the employment gap that affected nearly a quarter of China’s university graduates in the early 21st century.

By 2007, the employment rate for university graduates dropped from 77% to 70%. The same year’s “Notice on the Employment of College Graduates in 2007” [46] emphasized the implementation of policies for fee reductions and secured loans for graduates initiating individual businesses. Within the same year, the 17th National Congress of the CPC promoted entrepreneurship as a means to boost employment. Then, the ensuing “Employment Promotion Law of the People’s Republic of China” solidified county-level government roles in job creation and entrepreneurship, thereby setting the preconditions for county-level BIs [47].

Leveraging BIs to foster college student entrepreneurship became a strategic response to employment challenges and the global financial crisis of the late 2000s. A sequence of national policies was released to support BIs for university students. Among these, the “Notice on Strengthening Employment Work for Graduates of Regular Higher Education Institutions” called for regional constructions of small-investment, quick-return BIs for college students. This led to the nationwide emergence of BIs for college students, further promoted by various national administrative policies in the early 2010s [47,48].

Stage 4 (2015–2020): BIs for all

The year 2014 signaled China’s economic growth from high-speed to high-quality. In this year, Premier Li Keqiang advocated for “mass entrepreneurship and innovation”,

heralding the advent of the era of popular entrepreneurship. In addition to continuing encouragement of entrepreneurship among technical talents, overseas returnees, and university students, Chinese BIs also targeted migrant workers with the issuance of the “Opinions on Supporting Entrepreneurial Activities of Migrant Workers and Other Personnel Returning to Their Hometowns”. This initiative sparked enormous enthusiasm among the Chinese public for mass entrepreneurship, shifting the trend from a focus on “elite few” to the “general public”, marking a significant era. To date, the number of BIs for the general public has surpassed the total of all other BIs, reaching over 9000.

During this period, multiple policies mentioned BIs, typically the “Guiding Opinions on Developing Makerspaces and Promoting Mass Innovation and Entrepreneurship”, forming a top-level design for national assistance in BI construction. Correspondingly, ministries and local governments enacted policies to create affordable, accessible, multi-faceted BIs, blending innovation and entrepreneurship, online–offline integration, and the combination of incubation and investment. In early 2016, the guiding opinions about “Accelerating the Development of Makerspaces to Serve the Transformation and Upgrading of the Real Economy” were released [49], followed by the announcement of 17 specialized BIs, reflecting the ongoing dominant role of the state in BI evolution.

Stage 5 (2021–present): BIs are being built at the county level

Since 2021, the advancement of mass entrepreneurship has led to a shift in BI contributions to lower administrative levels, positioning counties as focal suppliers for their establishment. This shift aligns closely with China’s county-level urbanization strategy. The State Council’s “14th Five-Year Plan for Employment Promotion” issued in 2021, underscores a guideline to amalgamate and expand diverse types of parks at the county level, including development zones, industrial parks, industrial clusters, and entrepreneurial platforms [50]. A notable innovation is the legal repurposing of underutilized factories, public spaces, idle properties, and vacant lands for BIs, marrying the efficient use of spatial resources with the establishment of county-level BIs. This approach is particularly pertinent given the resource constraints in these regions.

The policy on constructing county-level BIs has become the final component in forming China’s four-tier national BI structure (spanning national, provincial, city, and county levels) as delineated in the “Opinions on Strengthening the Construction of Entrepreneurship Parks for Returnees and Newcomers in Existing Parks (2021)” [51]. Beyond transforming existing parks into BIs, China plans to build 1500 entrepreneurship parks in county areas by 2025, aiming to attract 3 million people in counties for entrepreneurial endeavors and innovation, thereby potentially generating employment opportunities for 20 million workers.

2.2. Theoretical Framework Based on BI’s Natures

To understand why BIs in different CAUs exhibit varying degrees of prosperity, we factor in the government-led nature of Chinese BIs. A theoretical framework (Figure 2) is developed for understanding the distribution mechanism of Chinese BIs, acknowledging their dual roles as both “quasi-public goods” and components of “(productive) service industry [52]”.

Based on the quasi-public good aspect of BIs, fiscal expenditure is considered a key factor influencing the spatial distribution. This perspective overcomes the dilution of government-led characteristics in economic-centered analyses. From the perspective of the second-generation fiscal federalism theory, local governments function as “economic agents” [53], aiming to maximize their own interests driven by self-interest maximization. This implies that the local governments’ provision of public services might not always be aligned with the preferences of local residents. The misalignment could stem from goals diverging from social welfare maximization and the informational advantage inherent within their jurisdictions [54]. This rationale plays out in China’s structure of administrative centralization and fiscal decentralization [55], where government officials balance directives from higher

authorities while maximizing their own interests, resulting in diverse fiscal expenditures on BIs across regions.

BIs in China, as a unique productive service, exhibit characteristics of both government leadership and market orientation. Therefore, in constructing BIs, governments must weigh fiscal considerations alongside the supply–demand dynamics of local BIs [56]. The inclusion of industrial structure in this context is informed by its resource concentration effects [57], which not only creates market demand [58] for new members entering local value chains [59] but also drives innovation spillover, supplying knowledge for entrepreneurship [60]. This establishes the local demand conditions necessary for the development of BIs. However, the entrepreneurial environment largely provided by the industrial structure imparts locational stickiness to the potential incubatees [61], which in turn constrains market-oriented decisions in the local government construction of BIs. Therefore, the governments often undertake the optimization of industrial structure [62], despite the associated high costs and external shocks [63]. In addition to endogenous structural optimization, industry transfer based on regional comparative advantages for industrial realignment is a prevalent approach [64]. The restructuring of opportunity space inherent in this process can impact BI construction.

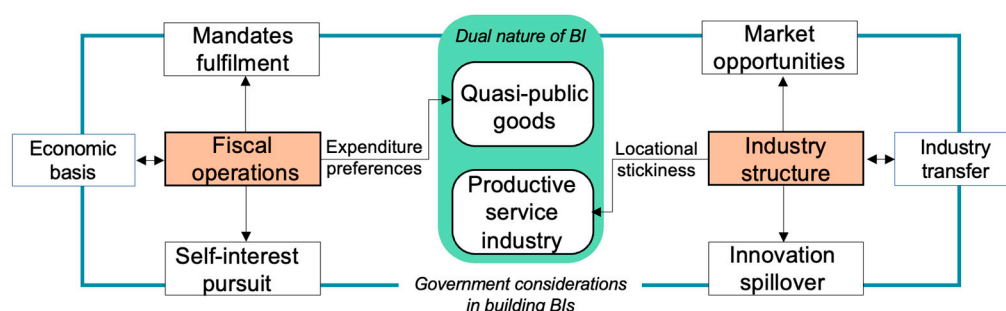


Figure 2. Theoretical framework regarding government actions based on BI's natures.

3. Materials and Methods

3.1. Study Area

The YRD (Figure 3), positioned between latitudes 27°02' N and 35°08' N and longitudes 114°52' E and 122°57' E, is not only a globally recognized urban cluster but also a key economic zone endorsed by the Chinese government [61,63]. This region, covering 4% of China's land (358,000 km²) but housing 10% of its population (235 million), remarkably contributes about one-quarter of the nation's total economic output.

Administratively, the YRD comprises 306 county-level units, spanning 40 prefecture-level cities within the provinces of Jiangsu, Zhejiang, and Anhui and Shanghai's municipality [64]. These CAUs, leading nationally in development, are models of regional economic synergy, integrating natural resources, market flows, cultural heritage, and social development. Outstandingly, CAUs of Shanghai includes districts like Pudong New Area and Huangpu District, renowned for their highest GDP and GDP per capita figures in China, respectively.

County economies from rural Jiangsu, Zhejiang, and Anhui balance 50% of the GDP primacy in municipal districts. While the Yangtze River Delta (YRD) is a showcase of regional cohesion, it presents a stark dichotomy of progress and underdevelopment. Despite the pronounced regional integration in the YRD, it encompasses a contrast of both development and disparity: it is home to 34 of China's 100 premier districts and 50 of the highest-ranked counties [65], contrasting sharply with its underprivileged mountainous counties. This heterogeneity exemplifies the inequalities shaped by variations in local resource allocations, industrial heterogeneity, and regional policy frameworks.

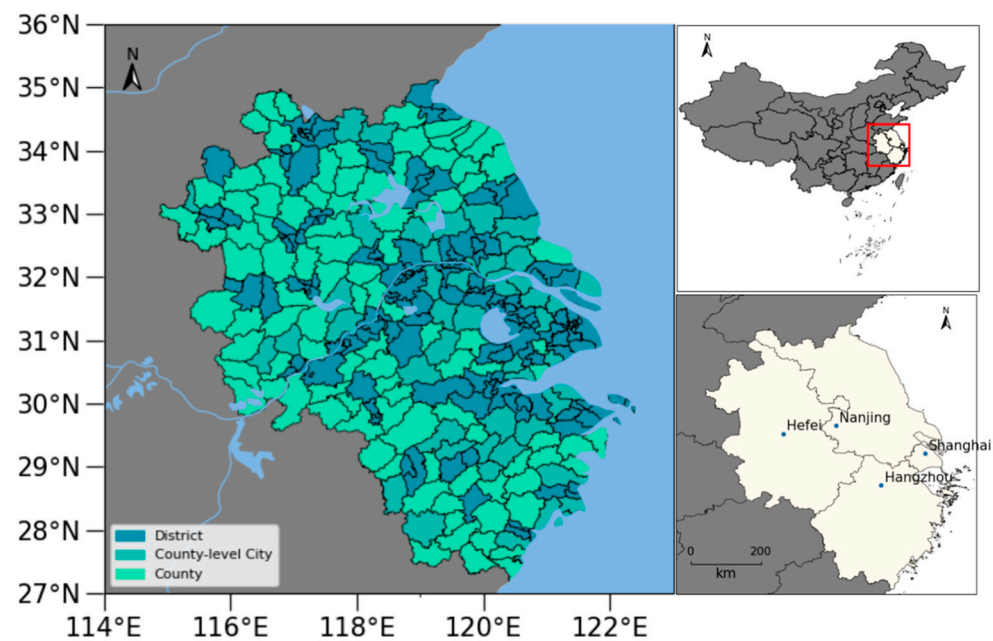


Figure 3. Profile of the CAUs in Yangtze River Delta (YRD).

3.2. Data Collection

This study scrutinizes the evolution of the BI paradigm within the milieu of China's development. Notably, it blurs the lines between “physical incubators” and those “virtual incubators” offering remote enterprise support. This research, for precision, narrows its focus to physical BIs characterized by dedicated spaces and park-like features. The methods for obtaining relevant data are as follows (Table 1).

Table 1. Data sources.

Data	Sources
POI data	Amap search POI 2.0 API
County-level industrial and fiscal data	China County Statistical Yearbook County-level statistical yearbooks County-level statistical bulletins
County Development Level Rating	2022 China County Economy Top 100 Research 2022 Report on High-quality Economic Development of Chinese Urban Areas 2022 CCID Top 100 Districts

Data collection leveraged web-scraping techniques and the API of Amap (高德 in Chinese, likewise with subsequent words), a leading navigation service in China boasting 760 million monthly active users [65]. The methodology involved isolating POIs categorized as “Business Residence” and further, “Industrial Park”. These were then screened using POI names. Following Hu et al.'s framework [1] and pertinent official definitions, a set of keywords—including “entrepreneurship (创业)”, and “incubation (孵化)”, and 8 other synonyms or hyponyms (创客, 大创, 留创, 农创, 众创, 青创, 双创, 加速器)—facilitated the identification of BI POIs within the YRD for 2022, culminating in a dataset of 3137 entities.

We also considered other relevant POIs for mechanism analysis. These included factories, essential living facilities (e.g., dining and shopping establishments) and educational institutions encompassing both colleges and vocational–technical institutes. In 2022, the data comprised 74,417 factories, 1,318,367 living facilities, and 7747 educational institutions, providing a comprehensive view of the region's infrastructural landscape.

For county-level industrial and fiscal data in 2022, this study primarily relied on the latest editions of regional statistical yearbooks, including those from Jiangsu, Zhejiang, Anhui, and Shanghai, as well as the China County Statistical Yearbook. Additionally, statistical bulletins issued by each county for 2022 were consulted. Furthermore, the research incorporated findings from the “2022 China County Economy Top 100 Research” and the “2022 Report on High-quality Economic Development of Chinese Urban Areas and the 2022 CCID Top 100 Districts”, both published by CCID Consulting [66], a key institute under the Ministry of Industry and Information Technology.

3.3. Methods

This study utilizes kernel density estimation (KDE) [63] to elucidate the spatial distribution patterns of BIs. The procedure begins by representing BIs as point features on a map. These points are then processed through the kernel density function (1, 2). The kernel function K_{1D} and K_{2D} distribute each data point's contribution over a range, rather than representing each point as a discrete spike, resulting in a continuous spatial density distribution map. K_{1D} and K_{2D} are Gaussian kernel functions, where $K_{1D}(x) = \frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}x^2}$ and $K_{2D}(x_1, x_2) = -\frac{1}{2\pi}e^{-\frac{1}{2}(x_1^2+x_2^2)}$. This approach visualizes the BIs' spatial distribution, highlighting areas of high agglomeration and identifying clustered regions. The kernel density values serve as direct indicators of the spatial clustering intensity of BIs.

To further investigate spatial patterns in the CAUs, this study calculates both global and local Moran's I values for the BI numbers [67]. Moran's I , a measure of spatial autocorrelation, assesses the extent of clustering at both regional and county scales, providing a nuanced understanding of spatial agglomeration dynamics in the area. We count BIs within each CAU with POI coordinates and the boundary data of the CAUs. Global and local Moran's I are defined as follows:

$$I = \frac{N}{\sum_i (X_i - \bar{X})^2} \frac{\sum_i \sum_j w_{ij} (X_i - \bar{X})(X_j - \bar{X})}{\sum_i \sum_j w_{ij}} \quad (1)$$

$$I_i = \frac{(X_i - \bar{X})}{\sum_k (X_k - \bar{X})^2 / (n - 1)} \sum_j w_{ij} (X_j - \bar{X}) \quad (2)$$

where N is the total number of BIs, n is the number of CAUs X_i is the number of BIs within a CAU, $\bar{X}$ is the mean number of BIs, and w_{ij} is the adjustable spatial weights between two CAUs to measure the spatial relationship. We adopt binary weights and give a weight of 1 if two CAUs are neighbors and 0 if otherwise.

To analyze the distribution and driving mechanisms of BIs in CAUs with different economic levels, this study employs the k-means algorithm to categorize CAUs into certain groups based on the per capita GDP [68]. The number of categories is determined through the elbow method. This method identifies the optimal number of categories by evaluating the relationship between the sum of square errors (SSE) and the number of clusters, thereby assessing the overall clustering effectiveness.

For the intra-CAU analysis, we meticulously chose corresponding POIs of various BI-relevant industries (factories, living facilities, and higher education institutions), each pinpointed with precise latitude and longitude coordinates. A 2-D kernel density function (3) is applied to calculate the POI density at any given point within the region, such as the factory density at any given latitude and longitude point. Given a set of points, we can further utilize a 1-D kernel density function to estimate the density of points at any given POI density value with Equation (4).

$$D_{POI}(\vec{x}) = \frac{1}{n_{POI}h} \sum_{i=1}^{n_{POI}} K_{2D}\left(\frac{\vec{x} - \vec{x}_i}{h}\right) \quad (3)$$

$$p(d_{POI}) = \frac{1}{n_{\text{sample}}h} \sum_{i=1}^{n_{\text{sample}}} K_{1D} \left(\frac{d_{POI} - D_{POI}(\vec{x}_i)}{h} \right) \quad (4)$$

In this research, a uniform sampling was applied to procure a set of coordinates. For each of these points, we determined the corresponding POI density values with Equation (3). This enabled us to estimate the density of the sample at assorted POI density values with Equation (4), the distribution $p_U(d_{POI})$ is used to approach the prior distribution $p(d_{POI})$. Concurrently, coordinate data for 3137 BIs were collected. We employed the kernel density estimation function (1) to assess the density of POIs at each BI's location. This analysis led to the conditional distribution $p(d_{POI}|x \in \text{Bis})$, or $P_{BI}(d_{POI})$ of BI densities with Equation (4), categorizing the BIs according to various POI density levels.

The comparative analysis of $p(d_{POI}|x \in \text{Bis})$ and $p(d_{POI})$ across different areas in YRD extends beyond mere spatial analysis to delve into the interconnections between BI locales and the density of BI-relevant industries, offering insights for urban development and policymaking.

4. Results

4.1. Geospatial Distribution and Correlation of BIs at County Level

In the YRD region, a distinct spatial distribution pattern of BIs is observed (Figure 4). Within this region, Jiangsu leads with 37.2% of the BIs, followed closely by Zhejiang with 34.0%, Anhui at 17.3%, and Shanghai at 11.3%. Specifically, the majority of Anhui's BIs are concentrated in its capital and the eastern areas. Jiangsu BIs are predominantly situated along a southern corridor, with a gradual decrease and wider dispersion northwards. In contrast, Zhejiang's BIs are largely concentrated in the northeast, especially around major cities, and have minor clusters in other key coastal cities. Shanghai, although having a high density of BIs, shows a lesser presence in its eastern and southern coastal regions.

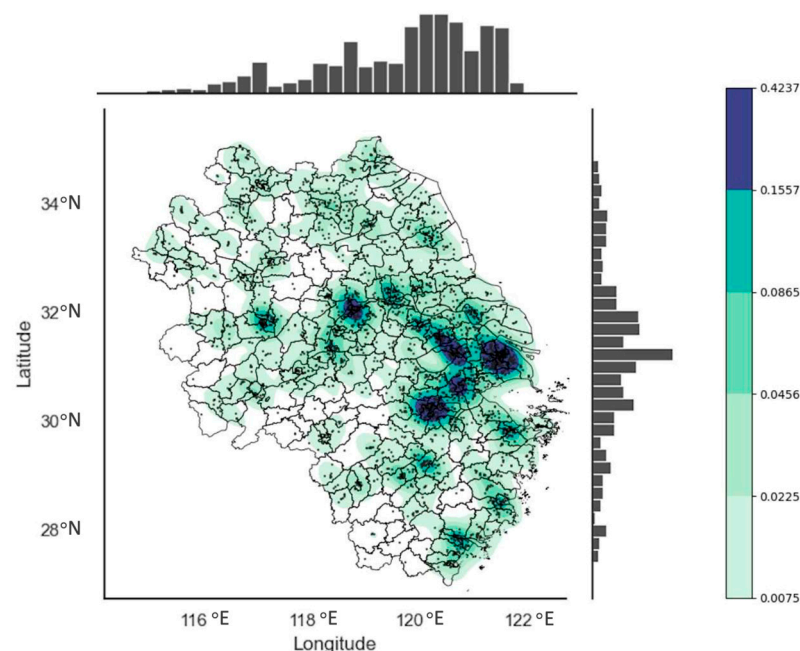


Figure 4. The kernel density distribution of BIs in YRD.

Over 98% of the CAUs build business incubators (BIs), but there is a significant difference in their density distribution. There is a marked concentration in the eastern and central areas, in contrast to the sparser presence in the western and north–south extremities. It is in line with common sense that the CAUs under the jurisdiction of central cities generally have more BIs, and the number of BIs starts to decrease as the distance from the city center increases. Interestingly, however, even in the marginal areas, namely those CAUs

dominated by agriculture and forestry, almost all of them have established BIs. These counties have lagged behind in the process of modernization due to factors such as geography and transportation, and some of them are even key targets for poverty alleviation efforts (e.g., Xiangshui County in Jiangsu, Xiao County in Anhui, and Jingning County in Zhejiang). In these disadvantaged counties with a per capita GDP of around USD 10,000, the presence of “at least one” BI seems to have become an undiscovered feature of their distribution. These areas suffer from severe brain drain, lack of industrial clusters and soft support for entrepreneurship, and the political significance of BIs may outweigh their actual functions.

The distribution of BIs in the YRD exhibits statistically significant clustering characteristics (Figure 5). By mapping BI POIs to CAU based on their latitude and longitude coordinates, we can ascertain the number of BIs in each CAU. The Global Moran’s I value is 0.26, with a corresponding p -value of less than 0.001. This indicates a significant level of spatial autocorrelation, suggesting that the distribution of BIs is not random but exhibits a patterned clustering.

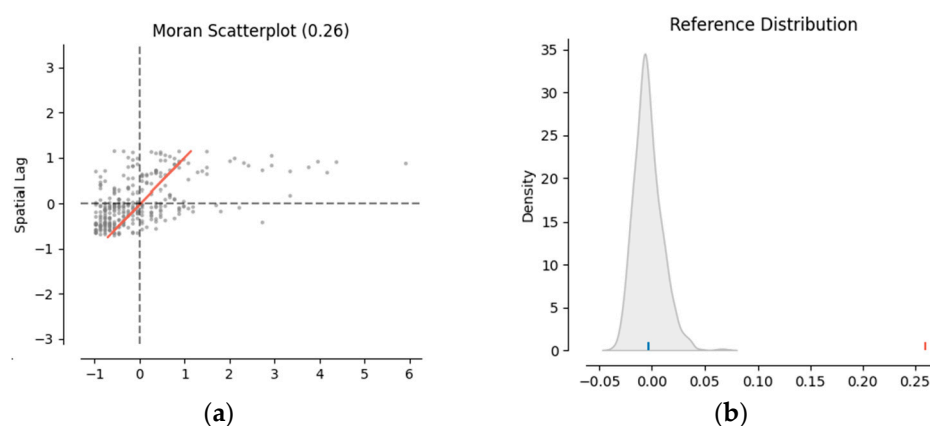


Figure 5. (a) The Moran scatter plot of normalized BI counts; (b) the reference distribution of the observed value.

To further explore the local spatial association characteristics of county-level BI distribution, a Local Indicators of Spatial Association (LISA) analysis is conducted and visualized (Figure 6). The areas with a p -value less than 0.05 are categorized into four types: High-High (HH), Low-High (LH), High-Low (HL), and Low-Low (LL). The HH and LH areas are contiguous with each other, as are the HL and LL areas. These categories are distributed at the eastern and western ends of the YRD, separated by continuous areas that are not statistically significant.

The H-H type is entirely surrounded by the L-H type, with the latter sporadically embedded in the H-H region. The H-H type is primarily located in the Y-shaped region formed by suburban CAUs of Shanghai and its neighboring counties around Lake Taihu, as well as those counties from Chun’an county to Beilun district (forming an east-west corridor). The highly developed economic level of these regions could be the reason for the dense distribution of BIs. Although the surrounding L-H type regions are geographically adjacent to the H-H regions, they are detached from the economic activities of the core urban clusters, potentially explaining the divergence between the two. The embedded L-H type regions are predominantly found in the early urbanized CAUs (e.g., Jing’an, Huangpu, etc.) dominated by residential functions, which may have a crowding-out effect on BI characterized by productive service industries.

The H-L and L-L CAUs form a continuous area, with the H-L type dispersed along the edges and within the L-L type. The agglomeration effect of the H-L type occurs in two areas: parts of CAUs in Hefei, the capital of Anhui province, its neighboring city Lu’an, and the jurisdiction of Suqian city in northern Jiangsu province. The L-L type comprises most CAUs in Anhui province and some districts in northern Jiangsu and southern Zhejiang

provinces along the provincial borders. The economic level of these areas is relatively backward in the YRD region, and infrastructure construction may take precedence over BI development.

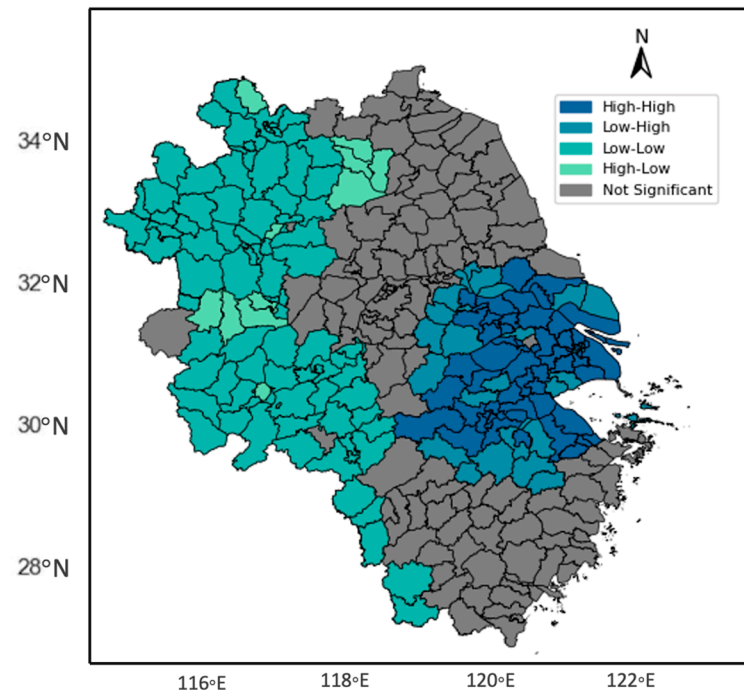


Figure 6. Local indicators of spatial association (LISA) for CAUs' local Moran's I values.

4.2. Factors Driving Variations in BI Distribution across CAUs

Due to the significant differentiation in the number of BIs among different CAUs in the YRD, this study classifies CAUs based on per capita GDP levels to compare the mechanisms influencing BI quantities within each CAU type. The elbow plot (Figure 7a) demonstrates a pronounced reduction in the Sum of Squared Errors (SSE) transitioning from one to two clusters, with the rate of decrease decelerating beyond this point. Notably, the plot levels off at the three-cluster mark, indicating that subsequent additions of clusters result in marginal decreases in SSE. Hence, three emerges as the optimal number of clusters. Subsequently, the K-means algorithm was employed to divide the CAUs (Figure 7b), resulting in three groups: Low GDP CAUs (LGC, 177 units), Medium GDP CAUs (MGC, 109 units), and High GDP CAUs (HGC, 15 units). The economically less developed LGC areas, with a per capita GDP of RMB 68,000, are primarily located in the western and north–south regions of the YRD. In contrast, the economically more developed MGC (per capita GDP of RMB 138,000) and HGC (per capita GDP of RMB 294,000) regions are mainly situated in the core areas of the eastern and central parts of the delta.

In the LGC regions, the per capita number and the total count of BIs in CAUs are significantly lower than in other regions (Figure 8a). Conversely, the MGC and HGC regions exhibit similar per capita and total numbers of BIs. Specifically, the number of BIs in LGC is mainly distributed between 0 and 20, averaging 7.5 BIs, with 1.2 BIs per 100,000 people. The MGC regions have 5–40 BIs, averaging 13.8 BIs, with 1.7 BIs per 100,000 people. The HGC regions show a range of 5–20 BIs, averaging 16.0 BIs, with 1.6 BIs per 100,000 people (Figure 8). The majority of counties have 0–10 BIs, their distribution shows a sharp decrease in the number of counties with higher BI counts, aligning with a power-law distribution pattern. Significantly, the top 30% of counties in terms of BI numbers (comprising 90 counties) possess 1939 BIs, accounting for 62% of the total 3137 BIs, underlining a pronounced disparity (Figure 8b).

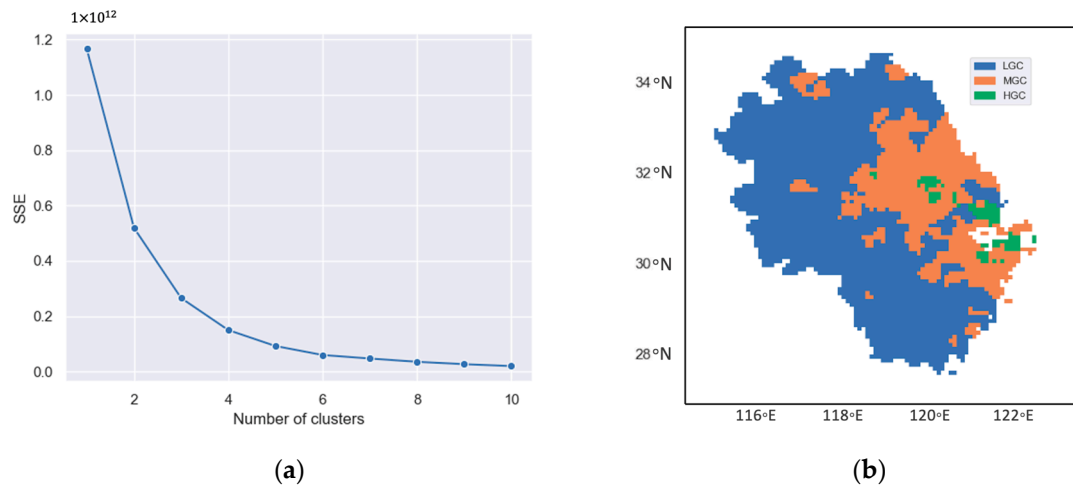


Figure 7. (a) Elbow method graph for cluster count; (b) spatial distribution of k-means clusters.

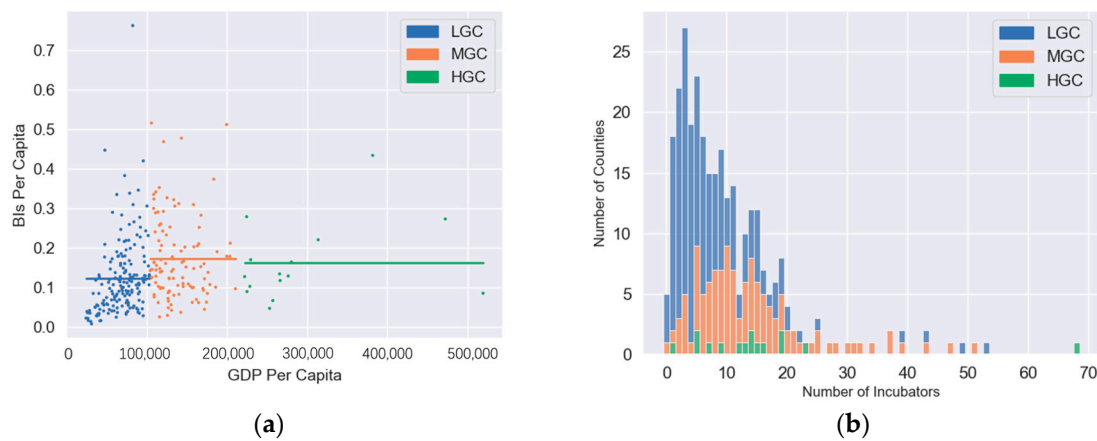


Figure 8. Numerical correlations between (a) BI counts per capita and GDP per capita; (b) BI counts vs. CAU counts.

Utilizing the analytical framework outlined in Figure 2, this study scrutinizes the correlation between per capita numbers of BIs and key industrial and fiscal indicators. The findings delineate pronounced parallels within MGCs and HGCs. In stark contrast, these correlations significantly diverge in LGCs, suggesting distinct developmental dynamics.

Our analysis reveals a strong positive correlation between tertiary industry output per capita and BI numbers (Figure 9), most pronounced in the economically less-developed LGCs. A general positive correlation exists between BI numbers and GDP, although this varies across industries and regions. Notably, primary industry output consistently shows an inverse correlation with BI numbers across all CAUs. In LGC, secondary industry output positively correlates with BI numbers, unlike in MGCs and HGCs, where the relationship is negative or insignificant. Tertiary industry output consistently shows a positive correlation with BI numbers across regions, with the strongest effect in LGC, as indicated by the steepest linear regression slope.

The relationship between BI numbers and fiscal indicators differs markedly across regions. In LGC, there is a positive correlation between BI numbers and general public expenditure, revenue, and fiscal pressure, suggesting that higher financial stress correlates with more BIs. Conversely, in MGC and HGC, these fiscal indicators negatively correlate with BI numbers, indicating a trend where reduced fiscal pressure is associated with increased BIs in these economically advanced regions.

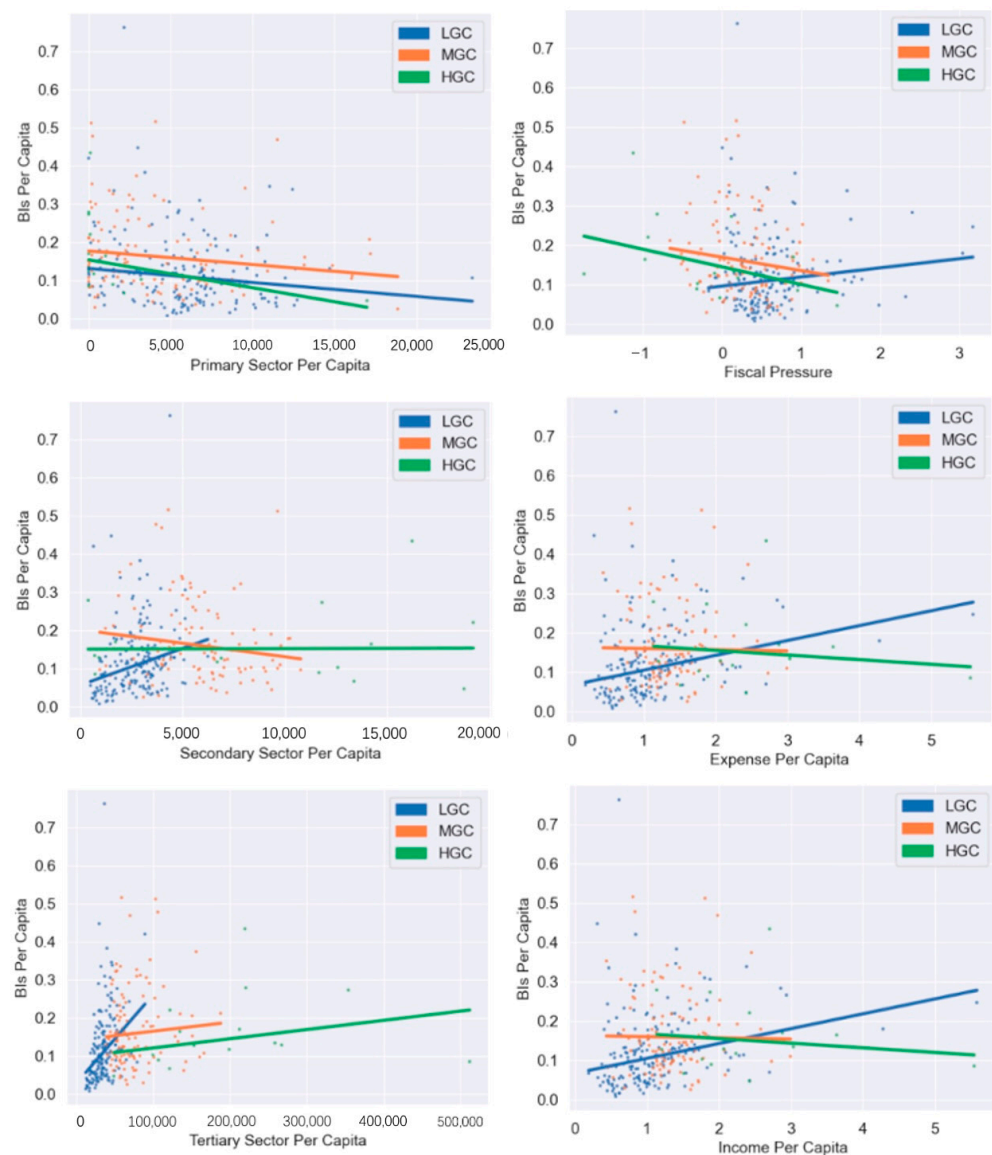


Figure 9. Correlations between BIs and industrial (left column) and fiscal indicators (right column).

4.3. Industrial Correlation of BI Distribution within CAUs

This section delves into the spatial distribution of BIs in categories (Figure 10). From uniform sampling and actual BI locations, we obtain two sets of coordinates to generate two probability density distributions against education, factory, and living POI densities for a comparative analysis in each CAU category. These maps reveal how BIs are spatially distributed in relation to different POIs, highlighting potential industry-driven factors in BI location decisions. The juxtaposition of two distributions offers insights into the strategic positioning of BIs in the urban landscape of various county areas.

In CAUs characterized by elevated economic development, a pronounced tendency is observed to situate BIs in locales with dense higher education and living facilities. However, the correlation between BI presence and factory density appears to be negligible. A comparative analysis of BI distribution and higher education density across LGC, MGC, and HGC regions reveals a direct relationship: the higher the economic development, the greater the concentration of BIs in areas with substantially higher education density. This trend is especially marked in HGC regions, where a majority of BIs are found in educationally dense areas. Conversely, the relationship between BI density and factory density does not follow this pattern, often appearing uniform or random. Notably, in LGC regions, a higher proportion of BIs is located in areas with high factory density.

The interaction between BI locations and living facility density also demonstrates notable regional variation. With increasing economic development, there is a heightened propensity for BIs to be located in areas rich in living facilities. In LGC regions, most BIs are positioned in zones with lower living facility density, while MGC regions exhibit a mixed pattern, with BIs in both lower and moderately dense areas. Conversely, in HGC regions, a majority of BIs are strategically located in areas with moderate to high living facility density.

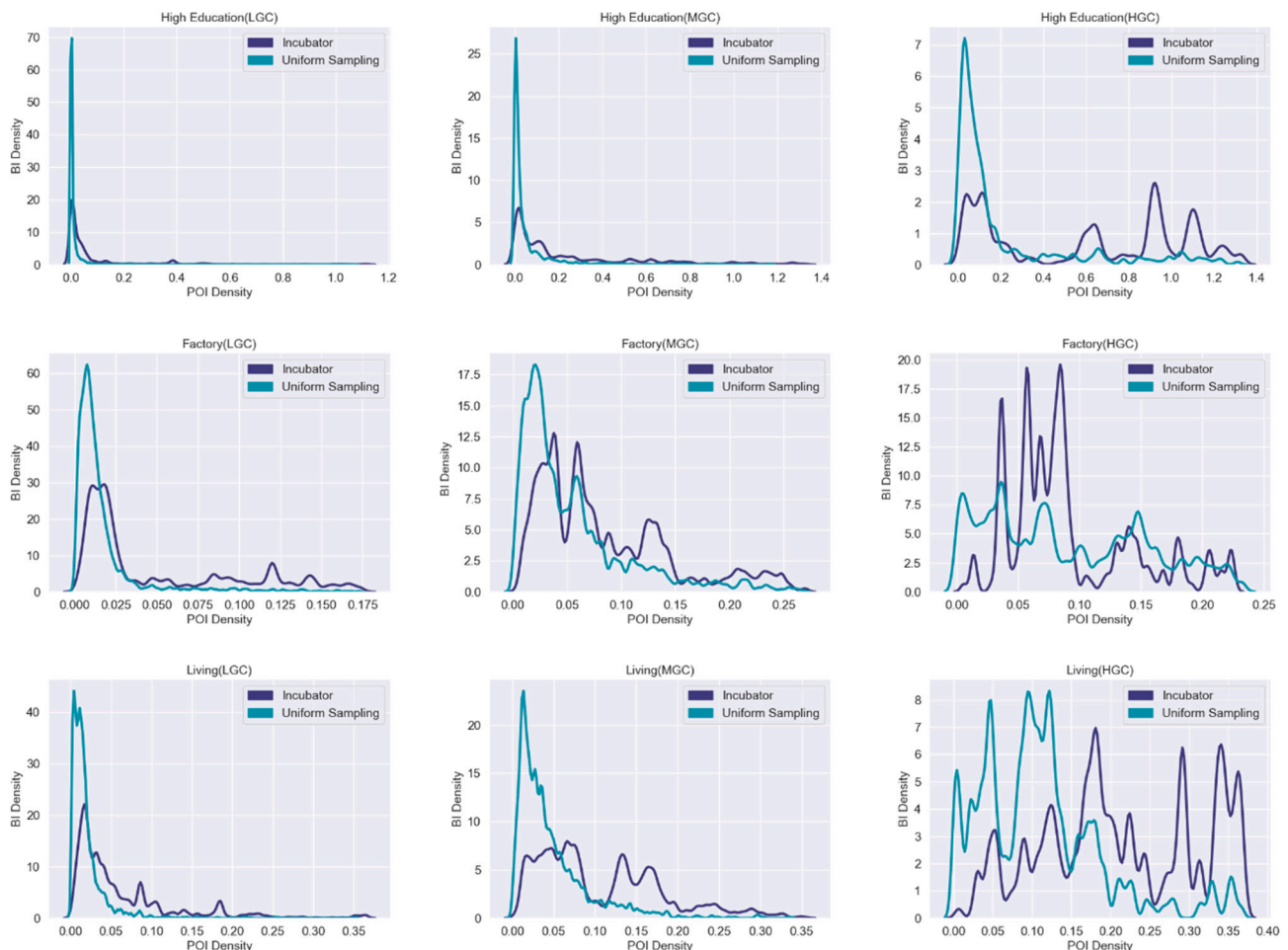


Figure 10. Density distributions of BIs in each CAU cluster in relation to selected POI densities.

5. Discussion

Our analysis examined the distribution of BIs in the CAUs of the YRD and the factors shaping this distribution. We highlighted the distinctive influence of fiscal operations and industry structure in this context. Further, leveraging the observed link between the tertiary sector and BIs, we conducted a micro-level analysis within CAUs to explore the interactions between various tertiary industries and BIs. We integrated the number of BIs and their site, facilitating a more diverse allocation of resources. With rising per capita income and growing public aspirations for improved living standards, governments increasingly cater to these evolving needs by enhancing social public goods provision, including science, education, culture, and also BIs.

5.1. BI as a Political Investment for the Poor Counties

In unaffluent CAUs, a pronounced effort to maximize BI construction is observed, as indicated by a stronger positive correlation between BI numbers and fiscal revenue [69]. This trend appears to contradict the above-mentioned norms, where resource constraints usually lead governments to adopt makeshift and deferred approaches across various

tasks [70]. Yet, a combination of performance-driven motives elucidates the rationale behind BI construction in these economically challenged CAUs. The disclosure of site selection strategies effectively eliminates the possibility of poorer CAUs using BIs as a means to catch up with the wealthier. In these financially weaker CAUs, their approach to BIs is not an investment expected to drive economic growth. This is evidenced by the placement of BIs in poorer CAUs, which are often located in undeveloped, peripheral “isolated islands”. Conversely, wealthier CAUs, despite incurring substantial land rent costs, tend to invest in BIs in more advantageous locations to optimize outcomes [71,72].

The shift in fiscal priorities towards BIs in less affluent CAUs is largely superficial. This redirection stems from the fact that BIs, being close to entrepreneurial activities [73], attract the attentions of higher government levels and offer high visibility for political investments. Even considering economic, resource, and task constraints, the performance-driven motives of local leaders are pivotal. Ambitious officials [74] tend to shift fiscal preferences towards high-visibility public goods, as these are favored by policymakers for demonstrating political performance [75]. Consequently, BI construction in poorer CAUs is primarily driven by political objectives, aiming to exchange minimal expenditure for quantifiable accomplishments. This rationale explains the prevalent strategy of erecting multiple cost-effective BIs in peripheral areas rather than investing in fewer, more expensive BIs in central locations.

5.2. BI as a Follower of Higher-Level Forms of Industry

Evidence shows a stronger link between BIs and higher-level industrial sectors, with BIs becoming less aligned with lower-level sectors when CAU industrial structures evolve. This pattern is consistent across both poorer and wealthier CAUs, where the sector of agriculture counters the effects of BIs, while the third sector (services) demonstrates a more pronounced positive impact on BIs. It is noteworthy that, compared to productive service industries defined as occupying higher positions in the value ladder, the linkage between lifestyle-oriented service industries and BIs is relatively weaker. Higher education institutions, typical of the productive tertiary sector, are concentrated in developed CAUs and exert significant attraction to BI construction. This suggests that China’s ongoing policy of relocating university branches to county areas might bring dividends to the development of BIs and associated entrepreneurial activities in these regions. Interestingly, several central CAUs in the YRD’s core municipalities, characterized by high land rents, become hubs for lifestyle services. The relocation of factories, companies, and research institutions has resulted in the decline of secondary and productive tertiary industries, subsequently diminishing BIs. This somewhat confirms that productive services exert the most significant positive effect on BIs.

The distinct positive correlation between BIs and the secondary industry is observed in less affluent CAUs. This is largely due to these CAUs being predominantly agricultural and industrially driven [76]. Although the service industry exerts a greater influence on BIs in poorer counties, akin to wealthier counterparts, the poorer CAUs face limitations in service sector development, underscoring the BI–secondary industry connection. As service sector growth in these counties is hindered by internal dynamics and a slow pace of industrial transfer, the nexus between BIs and secondary industry is continually strengthened by the integration of lower-tier secondary industries. In contrast, wealthier counties in the Yangtze River Delta (YRD) have predominantly benefited from the cumulative effects of industrial clusters, which foster an endogenous drive for industrial upgrading. This shift promotes the tertiary sector, reducing the prominence of the secondary sector and consequently weakening its connection with BIs.

6. Conclusions

This research explores the development and evolution of BIs in China, offering a fresh perspective for understanding their scale of construction and location layout. It begins by examining the policy history, uncovering the dynamic shifts and developmental trajec-

tories of Chinese BI policies, and establishing a comprehensive framework for empirical analysis, rooted in the inherent nature of BIs. Focusing on the YRD's CAUs, the study employs a blend of POI big data from a map service platform and industrial and fiscal statistics, conducting analyses at both county and micro scales. The findings show that BIs are hosted in 98% of YRD counties, confirming their widespread expansion across diverse CAUs. The underlying mechanisms of BIs in the YRD are revealed by stark disparities in BI distribution across CAUs with differing industrial statuses and fiscal operations. This reflects the distinct strategies of local policymakers tailored to regional characteristics.

The policy recommendation is based on the observation that while BIs are typically associated with advanced industries and wealthier areas, first, BIs should instead concentrate on offering dynamic support to entrepreneurs, encompassing soft services and policy facilitation, and leverage regional industrial strengths to strengthen information flows. Second, for economically challenged CAUs, a critical re-evaluation of BIs is necessary to guarantee impactful delivery and avoid fiscal extravagance, with a specific focus on minimizing physical infrastructure investments. Third, inter-regional alliances between BIs are strongly recommended. Such alliances would enable efficient resource and service sharing, thereby enhancing resource efficiency and stimulating collaborative innovation.

A limitation in acquiring long-term POI data restricts our current analysis of BIs' construction patterns, hindering our ability to discern their developmental trends and changes. Future access to longitudinal data could further enhance the understanding of the dynamic patterns of BI construction, enriching strategic planning and development for BIs. Another limitation stems from the inherent constraints of POI data, which prevent a comprehensive assessment of specific BI attributes, including quality, size, and occupancy rates, vital for assessing operational efficiency and effectiveness. The anticipated integration of these detailed attributes in future research would allow for a more nuanced exploration of the impact of BIs' location and distribution on their operational efficiency, providing decision-making insights in resource allocation and site selection of BIs.

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