

Article

Spatial Stickiness, Location Choice, and Mechanisms of Talent Flow in Urban Agglomerations: Evidence from University Graduates

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Abstract

The rational allocation of talent resources is significant to regional transformation and upgrading high-quality development. Focusing on urban agglomerations in China, this study examines the spatial patterns and underlying mechanisms of graduate talent mobility using employment data from the Ministry of Education Graduate Employment Quality Reports. We utilized the social network analysis method, stickiness rate, external attractiveness index, and directed migration model. The results reveal the following. (1) Spatial Stratification and Typology: A significant “Matthew Effect” characterizes China’s talent landscape. While the Yangtze River Delta and Pearl River Delta exhibit a “high stickiness–high attractiveness” dual-drive pattern, emerging inland agglomerations like Chengdu–Chongqing rely on high internal stickiness as a critical “stabilizer,” maintaining regional resilience through local stock retention despite limited external pull. (2) Complexity of Driving Mechanisms: Ridge regression indicates that while economic development (GDP per capita) and innovation capacity remain core drivers of external attractiveness, public services and institutional costs exert stronger constraints on mobility. (3) Policy Implications: In contrast, monetary talent policies show limited marginal utility. The study concludes that talent governance in urban agglomerations must shift from homogenous “talent wars” to differentiated sustainable strategies. Advanced regions should foster polycentric networks to mitigate overcrowding, while emerging regions should prioritize “soft infrastructure” to lower social costs, leveraging endogenous stickiness for long-term human capital accumulation and spatial equity.

Keywords: talent flow; college graduates; urban agglomerations; spatial stickiness; mechanism analysis



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1. Introduction

Talent resources have been turned into a strategic asset in the global competitive arena in the knowledge economy era. More significantly, human capital is the very heart of regional systems of innovation and sustainability of urban development [1]. Nevertheless, overconcentration of talent in a few areas could worsen regional inequality, thus putting less developed areas in danger of reduced social sustainability and resilience. Such imbalance is an indicator that talent mobility is not a market-driven consequence; it is a policy-sensitive process that dictates regional sustainability by attracting and retaining skills in differentiated ways. Thus, it is important not only that spatial distribution of talent

contributes to economic transformation but also that it facilitates the growth of regions in a balanced and high-quality form.

Being the largest developing nation globally, China offers a special and essential case for analyzing these processes, as urbanization there is fast and the strategic transition of demographic dividend to talent dividend takes place [2]. Following the 2014 reform of the household registration (*hukou*) system and the intensification of “talent wars”, talent competition has escalated from individual cities to urban agglomerations [3–5]. In particular, urban agglomerations, such as the Yangtze River Delta and the Guangdong–Hong Kong–Macao Greater Bay Area, are attempting to build a sustainable talent ecosystem through the integration of industrial chains and innovation chains [6,7]. These processes underscore the critical importance of the use of urban agglomerations in influencing China to transform towards high-quality, innovation-based, and sustainability-based regional development.

Nevertheless, existing studies have predominantly focused on talent mobility within individual cities or provincial-level administrative regions, leaving a notable gap in the in-depth examination of urban agglomerations as meso-scale entities and their internal mobility networks [8]. Moreover, current research often fails to distinguish between a region’s capacity to attract external talent and its ability to retain locally cultivated talent. As a result, policy recommendations derived from these studies tend to prioritize short-term attraction strategies while underestimating long-term retention capacity.

University graduates have now become one of the main stakeholders in talent recruitment policies in urban agglomerations in this context. Graduates are the most active aspect of human capital—especially when it comes to the postgraduate level—and therefore may serve as an important factor in the creation of competitive regional environments [9]. Their relatively high mobility, youthfulness, and advanced skills position them as a key resource for fostering resilient and sustainable urban agglomerations. Accordingly, this study adopts university graduates as its fundamental analytical unit to disentangle the spatial processes and underlying rationales governing talent mobility within and across urban agglomerations.

At the urban agglomeration scale, talent flow is not only an economic allocation process but also a determinant of regional cohesion and long-term sustainability. By transcending the conventional single-city analytical framework, this study innovatively adopts urban agglomerations as integrated regional units to examine how talent flow dynamics contribute to sustainable regional development, thereby providing empirical evidence for optimizing human capital allocation in heterogeneous urban agglomerations. To address existing research gaps, this study integrates theoretical insights from economic geography to reconceptualize “spatial stickiness”. Drawing on Markusen’s [10] seminal typology of “sticky places” and Fotopoulos’s [11] analysis of regional persistence, we define spatial stickiness in this context to distinguish between the “pull” of external attractiveness and internal capacity for talent retention. Framed through the lens of regional resilience, this capacity to retain talent transcends static stock measurement. “Sticky” relationships act as buffers against economic volatility [12], and we define spatial stickiness as a dynamic “stabilizer” that shields regions from external shocks and prevents human capital hollowing-out. Unlike simple retention rates, spatial stickiness is operationalized in this study as a measurable indicator of local talent retention, rather than a direct observation of social embeddedness. Using employment data from graduates of universities directly under the Ministry of Education for 2019—the pre-pandemic year that serves as a benchmark for examining talent mobility under relatively stable institutional and market conditions—this study seeks to address the following key questions. What are the distinct spatial characteristics of graduate employment mobility across China’s major urban agglomerations? How

can urban agglomerations be categorized based on their dual performance in stickiness and attractiveness? From the perspective of regional sustainability, what structural factors are associated with different patterns of talent flow?

To address these questions and contribute to a more comprehensive understanding of talent flow at the urban agglomeration scale, Section 2 presents an overview of the related literature, including spatial characteristics of talent flow across different scales and mechanism theories and analysis of talent flow. Section 3 describes the data, study area, and methodology. Section 4 presents the results of spatial stickiness patterns, external attractiveness disparities, and a typology of nine agglomerations. Section 5 discusses the mechanism analysis of graduate employment mobility. Finally, Section 6 concludes the study by synthesizing the key findings, discussing their policy implications for sustainable regional development, and acknowledging the research's limitations.

2. Literature Review

The mobility of human capital is not merely a demographic phenomenon but a critical determinant of regional resilience and sustainable development [13]. While early research focused on the linear movement of labor, contemporary scholarship has shifted towards complex network dynamics, exploring how talent flows shape—and are shaped by—the socio-economic fabrics of urban agglomerations.

2.1. Talent Mobility and Regional Sustainability

Human capital mobility is generally accepted by existing research to be an important factor in regional innovation, economic upgrading, and urban competitiveness. A recent accumulation of literature suggests that talent mobility is not a zero-sum game of brain drain or of brain gain but an interactive process where regional resilience serves as a foundational condition for long-term sustainability. The long-term capability of any region to de-develop is not only determined by its talent attraction ability but also by the strength of its talent flow system, especially how it is able to cope with any external shocks, like a pandemic or an economic recession [14,15]. In broader sustainability science, stickiness is increasingly conceptualized as a critical metric in system stability and governance efficacy [16]. Extending this logic to human geography, recent scholarship offers a nuanced interpretation of retention mechanics. While recent economic geography studies emphasize transcending geographical stickiness to achieve industrial diversification [17], for developing urban agglomerations, maintaining a high level of stickiness is often a prerequisite for resilience rather than a barrier. It acts as a mechanism of “social embeddedness” that secures a stable human capital base during transition periods. Furthermore, as Liu et al. [18] argue, migration and settlement decisions are increasingly environment-driven, suggesting that spatial stickiness is also a reflection of a region's environmental livability and social sustainability beyond mere economic utility.

In the specific development context of China, urban agglomerations serve as the primary spatial units for fostering such systemic resilience. The multilayered spatial structure of these agglomerations, including, in particular, the relationship between core cities and peripheral areas, plays a major role in the economic stability of the region as a whole and its capacity to overcome risks [19,20]. Although high-skilled migration contributes to the progress of the core cities, it tends to increase spatial disparity, which can be a threat to social sustainability. The absence of an effective coordination mechanism lets the peripheral to core regional brain drain increase the development gap, which creates polarization, eroding the stability of the whole region in the long run [21]. This is especially observed in China, where industrial agglomeration has been reported to be inversely related

to income inequality in an inverted U-shaped form, indicating that high concentration of talent and capital may cause serious regional inequality.

2.2. Spatial Patterns of Talent Mobility Across Multiple Scales

Empirical studies of mobility of talent have been performed at various spatial levels. On the global scale, research has been performed on brain drain, brain gain, and brain circulation, with a focus on cross-border transfers of highly skilled labor [22,23]. Social network analysis and spatial econometric methods at the national and provincial level have shown a strong core–periphery pattern in the distribution of talent and spatial spillovers [24,25]. The associated research that employs index-based assessment methods also implies a conclusive influence of general stickiness of prominent areas in the development and establishment of talent centers [26]. In terms of the urban level, the current literature is inclined to dwell on the issues around the migration of certain groups of talent, especially university graduates, who are traditionally discussed as an important source of human capital. Research has revealed that the economic development status of the places of origin of graduates and general geopolitical interaction have been found to greatly influence graduate mobility patterns [27]. In earlier quantitative research investigating mobility of talent, the ability of cities to recruit, retain, and develop talent was frequently lumped together into the holistic concept of urban talent attractiveness [28,29], and the scope of the research focused on talent inflows. Nonetheless, the use of inflow metrics only clouds the structural variation of talent accumulation. As one example, the use of inflow alone conceals the difference between strong talent hubs (high retention) and ones perceived as transit (high inflow but high outflow). Thus, recent scholarship has struggled to start distinguishing between the concept of stickiness (retention of stock) and the concept of attractiveness (attraction of flow) in order to better plot the spatial heterogeneity of the urban agglomeration [30].

In spite of such conceptual gains, research is still spatially bounded. The literature is still largely affected by administrative limits and city-specific analytical problems. The urban agglomeration is still not taken into consideration by studies on the spatial patterns of talent mobility as it is a meso-scale spatial unit featuring an inter-city nexus and functional integration. There are a few studies that have started to study talent flows on the scale of urban agglomeration (with an interest in factors such as the level of regional integration [31], the regional soft environment [32], intergovernmental competition, and patterns of talent agglomeration [33]), but those studies are explanatory rather than investigating the spatial makeup and the multi-scale nature of the topic of talent mobility. This leads to inadequate knowledge concerning the spatial arrangements, internal differentiation, and cross-scale associations of flows of talent in and within urban agglomerations.

2.3. Mechanism Analysis of Talent Mobility

Theoretical frameworks regarding talent mobility have evolved from classical macro-level observations to complex micro-foundations. Early scholarship, grounded in Bange's Push–Pull Theory [34] and Schultz's Human Capital Theory [35], primarily viewed mobility as a utility-maximizing response to regional economic disparities. These theories make assumptions of the fact that the flow of talent is inherent between low-paying and high-paying areas to ensure that the returns on investment remain maximized. According to this reasoning, the actual literature has categorized the influencing factors into either subjective motivations (e.g., career development, self-worth maximization) [36] and objective environments (e.g., economic scale, industrial structure) [37,38].

The immediate transfer of these market-based theories to the Chinese situation, however, needs to be seriously reexamined. In China, talent mobility is deeply influenced by institutional frictions, unlike in the Western literature, which is marked by assumptions of

the free market. Market mechanisms are usually miscarried out through administrative interventions. An example is that despite the shift of the demographic dividend into a talent dividend [1], such institutional barriers as the household registration (hukou) system continue to have a tremendous influence on spatial distribution [39]. In an effort to defeat these limitations, local governments have vigorously initiated the so-called talent wars through housing subsidies [1,40–42]. However, such policy instruments tend to be ineffective in dealing with structural problems because of two reasons [43]. First, talent competitiveness is increasingly driven by complex innovation ecosystems rather than simple monetary incentives [1,44]. Second, the spatial spillover effects of housing prices may negate the benefits of incentive policies, leading to an inefficient allocation of fiscal resources rather than genuine talent retention [45,46]. That is, one may be effective in getting talent inflow through subsidies in a region and experience a leakage bucket due to poor social embeddedness.

This paradox shows the weak nature of studying talent mobility using a single dimension. Factors affecting the movement of talent in the urban agglomeration are extremely differentiated and entangled; they can be economically inducement, government services, societal networks, and institutional impediments. Although others have observed the high turnover of local jobs among graduates [47], other scholars have cited the overflowing effect of agglomeration in megacities resulting in wastage of skills and talent [48]. Applying piecemeal indicators or canonical models does not provide a complete picture of these interactions. Thus, there is an urgent need to provide an integrated analysis that combines both spatial stickiness and external attractiveness. Only such a framework accompanied by solid quantitative means to deal with the complex correlations between factors can be used to objectively assess the spatial balance of human capital and define the structural aspects of regional capital flows.

2.4. Summary and Research Framework

Existing studies have made substantial progress in explaining the drivers and consequences of talent mobility, yet several limitations remain when examined from the perspective of sustainable regional development. First, most empirical analyses are confined to provincial or single-city scales, while urban agglomerations—despite functioning as integrated systems of talent circulation—have not been adequately explored. Second, most existing studies implicitly conflate external attractiveness with internal retention capacity. Consequently, current research lacks a unified framework to distinguish whether regional talent shortages stem from weak external appeal or low internal stability, making it necessary to introduce spatial stickiness as a complementary indicator to attractiveness for constructing a more comprehensive typology of talent spatial patterns. Third, existing mechanism analyses tend to rely on fragmented explanatory variables or single-theoretical perspectives, which are insufficient for capturing the complex interplay of economic development, public services, institutional environments, and regional integration. This limits the ability of current research to explain how talent mobility contributes to long-term regional resilience and balanced development.

Based on this, the current study focuses on urban agglomerations and adopts 2019 graduate employment data released by 75 universities directly under the Chinese Ministry of Education. It employs methodologies such as the social network analysis method, stickiness rate, external attractiveness index, and directed migration model to study the choice of employment location and the mechanism analysis of talent flow within urban agglomerations under the perspective of spatial stickiness to enrich the research on talent flow on different scales and perspectives. Figure 1 presents the overall framework of the research.

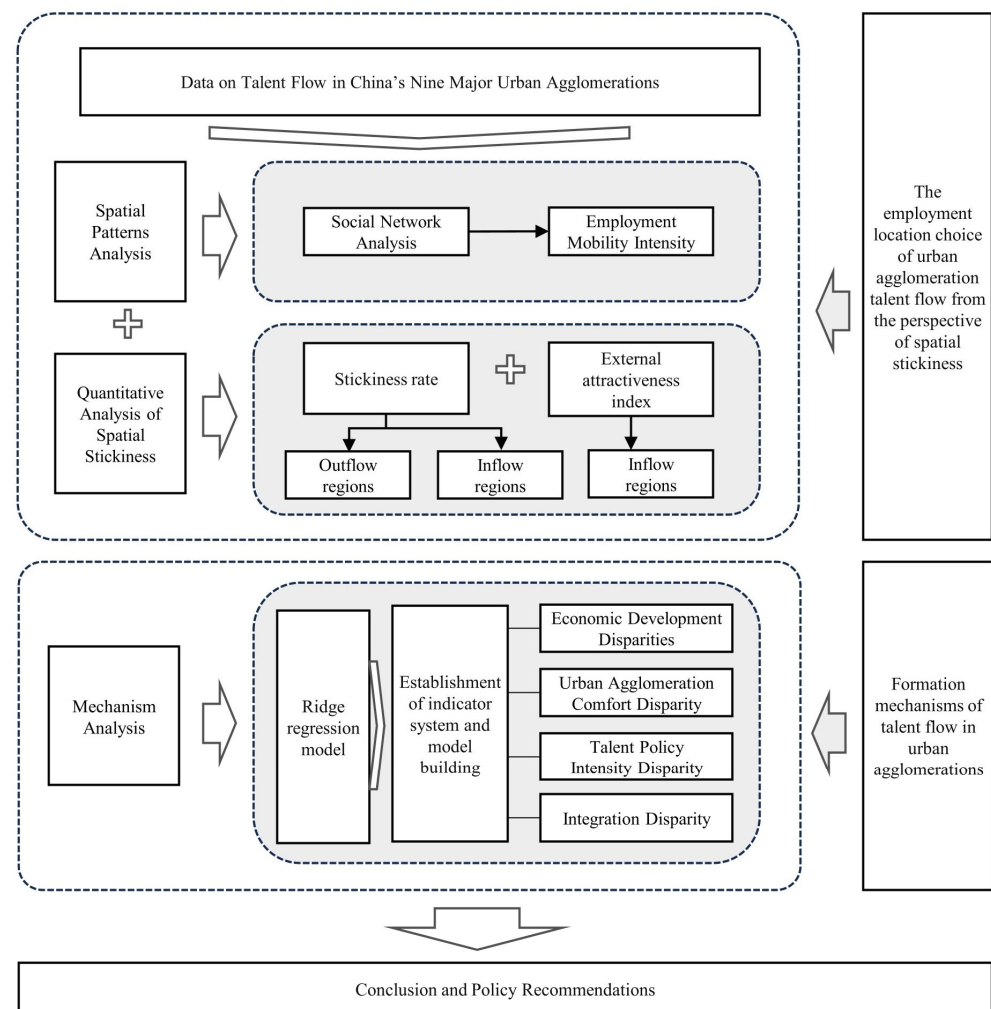


Figure 1. Framework of this study.

3. Materials and Methods

3.1. Data

In the era of the knowledge economy, the initial employment flow of college graduates holds an essential position in talent flow in urban agglomerations. This study focuses on graduates from the 75 universities directly affiliated with the Ministry of Education (MOE). Specifically, we prioritize postgraduate students as the core analytical sample, given their higher labor market participation rates compared to undergraduates, who frequently pursue further education. It is important to note that this sample delimitation does not aim to represent the entire graduate population but rather targets a specific segment of “elite high-skilled talent”. These individuals possess strong mobility potential and are the primary targets of regional “talent wars”, making them ideal subjects for analyzing spatial stickiness and attraction mechanisms.

The data used in this study were sourced from the 2019 Graduate Employment Quality Reports of the selected universities. Given the profound impact of COVID-19 on employment dynamics, 2019 represents the final complete employment cycle where interregional mobility was driven by “normal” market forces and institutional factors, unconstrained by the large-scale public health interventions and extraordinary policy adjustments (e.g., expanded enrollment) seen post-2020. Furthermore, 2019 coincided with the peak effectiveness of “talent recruitment” policies in major cities. Therefore, this dataset serves as a robust benchmark for exploring the intrinsic mechanisms of talent flow under stable market conditions.

A key challenge in this study is the alignment of spatial scales. While the analysis focuses on urban agglomerations, the official employment reports predominantly release destination data at the provincial level rather than at the city or urban agglomeration scale. To address this data availability constraint, this study adopts a proxy strategy, utilizing provincial inflows to approximate flows to the primary urban agglomerations. This approximation is theoretically grounded in the highly polarized “core–periphery” structure of regional development in China. Given graduates’ strong preference for employment in centrally administered municipalities and provincial capitals, together with the dominance of these core cities in absorbing intra-provincial employment inflows, provincial-level destination data can, to a significant extent, reflect the dominant spatial orientation of talent flows towards these urban agglomeration cores. Nevertheless, we acknowledge that this proxy may obscure intra-provincial heterogeneity.

For data processing, different strategies were adopted to handle missing values. For individual schools with missing data, 2018 employment data were used as substitutes. For schools where the Employment Quality Report fails to disaggregate employment destinations by city or province, the aggregate proportional distribution of other local universities within the same municipality was applied instead.

In the empirical analysis of talent flow formation, given that the employment of 2019 graduates primarily occurred in the first half of the year, data for the indicators within the variables of economic development level and comfort level of urban agglomerations were sourced from the China City Statistical Yearbook 2019 [49]. Considering the difficulty of data acquisition, relevant indicators under the variables of talent policy strength [30] and the degree of urban agglomeration integration [50] adopt relevant data from existing studies.

3.2. Study Area

There are 23 cities in the outflow region of employment flow, of which 20 are located in Beijing–Tianjin–Hebei, the Yangtze River Delta, the middle reaches of the Yangtze River, the Guanzhong Plain, the Pearl River Delta, Chengdu–Chongqing, the Shandong Peninsula, the south–central Liaoning Province, and the Harbin–Changsha Urban Agglomeration. These nine urban agglomerations are relatively mature and diverse, covering most of China’s significant urban agglomerations in the east, central, west, and northeast regions. Given the available data conditions, they represented optimal study areas. For the sake of study convenience, provincial data were chosen for the inflow area instead of urban agglomeration data (see Table 1).

Table 1. Outflow and inflow areas.

Outflow Area (City)	Inflow Area (Provincial Data Substitute for Urban Agglomeration Data)	Agglomeration of Cities
Beijing, Tianjin	Beijing, Tianjin, Hebei	Beijing–Tianjin–Hebei
Shanghai, Nanjing, Wuxi, Hangzhou, Hefei	Shanghai, Jiangsu, Zhejiang, Anhui	Yangtze River Delta
Wuhan, Changsha	Hubei, Hunan	The middle reaches of the Yangtze River
Xi’an, Xianyang	Shanxi	Guanzhong Plain
Guangzhou	Guangdong	Pearl River Delta
Chengdu, Chongqing	Sichuan, Chongqing	Chengdu–Chongqing
Jinan, Qingdao	Shandong	Shandong Peninsula
Shenyang, Dalian	Liaoning	Central and southern Liaoning
Changchun, Harbin	Heilongjiang, Jilin	Harbin–Changchun

3.3. Methodology

This study establishes a multidimensional and systematic research framework for talent flow mechanisms from a theoretical perspective. Social network analysis is employed primarily to visualize the spatial trajectory and magnitude of talent flows, mapping the connectivity between cities. The retention capacity of cities and urban agglomerations for talent is quantified through the calculation of stickiness rates, with a focus on deconstructing the internal stability of urban agglomerations. The external attractiveness index is used to analyze the role of interregional competitiveness in driving the direction of talent flows. Additionally, a directed migration model is utilized to examine the influence of economic, environmental, and policy factors across regions, thereby exploring the driving mechanisms behind talent flow.

3.3.1. Social Network Analysis

Social network analysis is widely applied in population studies to examine the structural characteristics of spatial interactions [24]. In this study, it is employed primarily to visualize the spatial trajectories and volume of talent flows, rather than focusing on complex topological metrics. By mapping the linkage intensity between origin and destination nodes, we aim to intuitively characterize the macro-level patterns of talent dispersion in space. Outflows are from cities or urban agglomerations at the spatial scale, and inflows are from provinces (replacing urban agglomeration data with provincial data). Mobility intensity is assessed based on the proportion of the scale of graduates' migration from the outflow region to the inflow region, and it is calculated as

$$OD_{ij} = \frac{F_{ij}}{\sum_{j=1}^n F_{ij}} \quad (1)$$

In Formula (1), OD_{ij} represents the mobility intensity of postgraduate career migration from city or urban agglomeration i to province j . F_{ij} represents the number of postgraduate graduates from universities in the city or urban agglomeration i who migrate to province j for employment. n represents the number of provinces as destination regions for inflow.

3.3.2. Stickiness Rate

The spatial characteristics of talent flow are typically assessed using ratio-based indicators, such as inflow and net mobility rates [51–53]. However, these indicators often mix inflows and outflows. To specifically measure the “holding power” of a place, this study employs the stickiness rate. Distinct from a simple retention ratio, “stickiness” here characterizes the region's endogenous capacity to retain locally cultivated human capital through social embeddedness and institutional anchorage, thereby reflecting the internal stability of the talent stock [54,55]. To measure the attractiveness of the place of origin in retaining locally trained talent within employment flows [30], the stickiness rate R_i is calculated using the following formula:

$$R_i = \begin{cases} N_i/T_i & (\text{the urban stickiness rate}) \\ L_i/T_i & (\text{the urban agglomeration stickiness rate}) \end{cases} \quad (2)$$

In Formula (2), R_i represents the stickiness rate of city/urban agglomeration i . N_i is the number of graduates remaining in the outflow region i . T_i is the total number of graduates in the city/urban agglomeration i . L_i is the number of graduates staying in the city or urban agglomeration where city i is located, considering the provinces or centrally administered municipality where the urban agglomeration is situated (provincial data replace inflow data for urban agglomerations).

3.3.3. External Attractiveness Index

The attractiveness index is a comprehensive weighted indicator used to measure the attractiveness of different provincial or centrally administered municipality units for employment talent, reflecting their talent attractiveness ability and potential [26]. This study eliminates the impact of employment flow caused by the stickiness of the outflow region and constructs the attractiveness index, departing from the perspective of spatial stickiness effects. The external attractiveness index is slightly changed based on the attractiveness index calculation method and is calculated as follows:

$$TA_j = \sum_{k=1}^n \left(\sum_{i=1}^m \frac{RA_{ij}}{m} \right) \quad (3)$$

In Formula (3), TA_j represents the external attractiveness index of province j or the centrally administered municipality j . RA_{ij} represents the capability of province j or the centrally administered municipality j to attract postgraduate students from university i . The specific values are determined by sorting the number of postgraduate students from each university flowing into the province or centrally administered municipality (excluding the province or centrally administered municipality where the university is located). The top two universities are assigned values of 2 and 1, respectively, with all others given a value of 0.1. The variables m and n represent the number of universities within city k and the number of cities within province j or the centrally administered municipality, respectively.

3.3.4. Directed Migration Model

Existing studies commonly use the conditional logit model to analyze individual decision-making behavior under the framework of utility maximization analysis, while, for macro-level mobility data, some scholars use the transformed-directed migration model. This study draws on this model, and it is calculated as follows:

$$\ln(N_{ij}/N_{ii}) = \alpha X_{ij} + \varphi_{ij} \quad (4)$$

In Formula (4), N_{ii} represents the number of graduates remaining in the urban agglomeration i , the outflow region. N_{ij} is the number of graduates from urban agglomeration i migrating to urban agglomeration j . X_{ij} denotes the disparity in relevant attributes between urban agglomerations i and j . It is measured as the ratio of the difference between the indicators in the inflow region j and the outflow region i to the value in the outflow region i . α represents the value of the regression coefficient of X_{ij} . φ_{ij} is the constant term.

4. Employment Location Choice for University Graduates in Urban Agglomerations

To better understand the employment location choices of university graduates within urban agglomerations, this study adopts the inflow–outflow decomposition approach from demographic research [56,57], dividing the talent absorption capacity of urban agglomerations into two components: the stickiness effect and the attractiveness effect. First, it examines the proportion of graduates who remain in their city of study or within the same urban agglomeration to assess the talent retention capacity of urban agglomerations as places of origin and to explore regional disparities. Second, it evaluates the ability of each agglomeration to attract non-local graduates, capturing their level of external attractiveness. Building on this, a two-dimensional framework integrating stickiness and attractiveness is developed to classify major urban agglomerations nationwide, aiming to reveal their relative positions and functional roles within the national talent mobility network.

4.1. Spatial Pattern of Stickiness at the Place of Study

4.1.1. Stickiness of Urban Agglomerations

Urban agglomeration stickiness measures the proportion of university graduates who choose to stay and work within the same agglomeration after graduation, serving as a proxy for local talent retention capacity. Among nine major urban agglomerations, notable differences emerge. The Pearl River Delta (78.24%), Yangtze River Delta (77.86%), and Beijing–Tianjin–Hebei (58.42%) exhibit the highest stickiness rates, each exceeding the 50% benchmark. The Shandong Peninsula (49.61%) and Chengdu–Chongqing (48.98%) fall slightly below this threshold, while the remaining agglomerations—Middle Yangtze River, Harbin–Changchun, Guanzhong Plain, and Central–Southern Liaoning—register significantly lower levels (see Figure 2). Overall, eastern urban agglomerations have the highest stickiness, central and western have mid-level values, and northeast is the lowest.

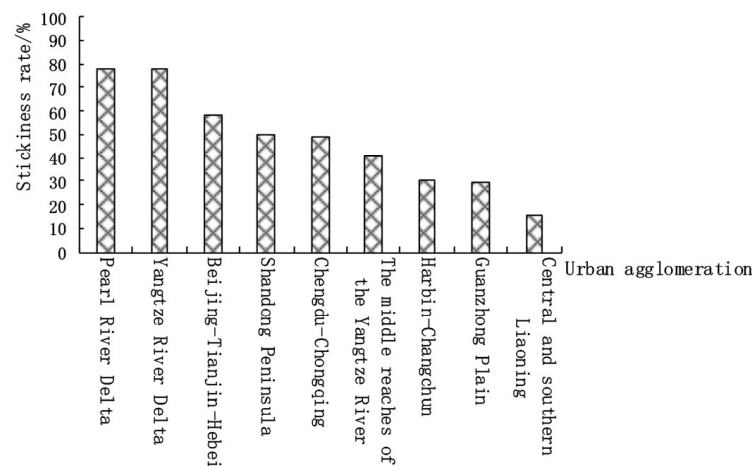


Figure 2. Stickiness rate of 9 urban agglomerations.

4.1.2. City-Level Stickiness Within Urban Agglomerations

Further analysis can be conducted in terms of individual cities to determine the functional role of individual cities as part of the overall urban agglomeration and their ability to absorb and retain graduates. Indeed, most cities in China show quite high levels of city-level stickiness, with Shanghai, Beijing, and Hangzhou showing the highest levels of over 50% of graduates staying at the city level, as indicated by Figure 3. This suggests that core cities possess strong talent retention capacity, often supported by abundant educational resources, robust economic structures, and favorable living conditions.

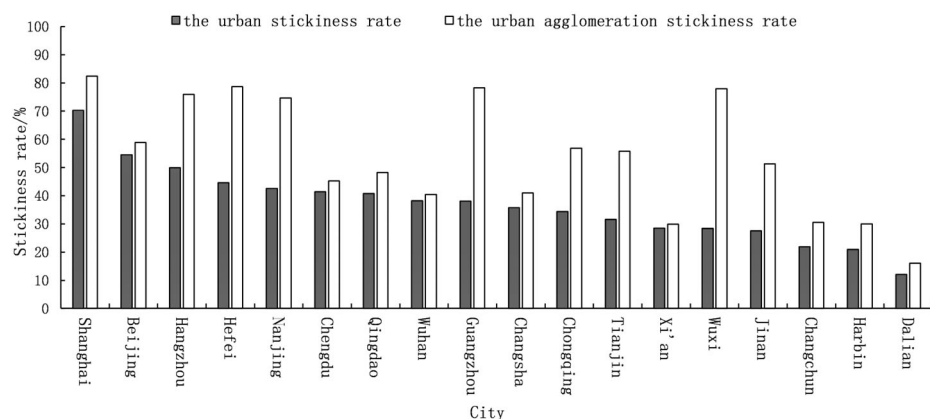


Figure 3. The urban stickiness rate of 18 cities and the stickiness rate of the urban agglomerations. Note: Due to the lack of data on retaining postgraduate students in Wuhan and Changsha, data from the respective provinces of Hubei and Hunan are used as substitutes.

The intra-agglomeration stickiness used in this paper describes the ratio of the number of university graduates that decide to work in the same urban agglomeration of their university. This statistic is aimed at determining how well an agglomeration is enabled to keep the talent they have developed at a local level. According to this indicator, the non-core cities like Hefei and Wuxi in the Yangtze River Delta will see a relatively high intra-agglomeration stickiness, which means high external coordination and talent capture in the area. By comparison, city agglomerations like Beijing–Tianjin–Hebei, Chengdu–Chongqing, and the Shandong Peninsula exhibit poorer internal talent retention abilities. A general lack of power in gradual retention of graduates exists in the Yangtze River Midstream and Harbin–Changchun agglomerations, especially.

Altogether, city-level and intra-agglomeration stickiness shows a positive correlation; however, to a certain degree, there is no complete coincidence between the two indicators. Some of those cities, like Shanghai and Guangzhou, exhibit a high city-level and intra-agglomeration stickiness, meaning that it is not only possible to keep local graduates but that the agglomeration is also able to attract and anchor talent on a wider scale. On the other hand, cities like Tianjin and Xi'an are characterized by high city-level stickiness but rather low intra-agglomeration stickiness, which implies some weak spillover effects when it comes to the attraction of graduates to adjacent cities. The need to enhance further the arrangements of coordination of talent at the urban agglomeration level is evidenced by this.

4.2. Spatial Patterns of Employment Inflows

In addition to stickiness, one of the most important aspects of competitiveness of an urban agglomeration as a source of inflow of talent is its external attractiveness. It also reflects the ability of an urban agglomeration to attract graduates of non-local universities, which demonstrates that the external competitiveness of the area is at the national level. The spatial distribution of inflows of graduates shows that there are significant regional inequalities (see Figure 4) as per the external attractiveness index results. Significant external pull is indicated by higher scores of the Pearl River Delta and the Yangtze River Delta. Beijing–Tianjin–Hebei has a moderately strong level, followed by the Shandong Peninsula. In contrast, the Guanzhong Plain and Central–Southern Liaoning have low levels of attractiveness, and Chengdu–Chongqing and the Middle Yangtze River appear lowest in the country.

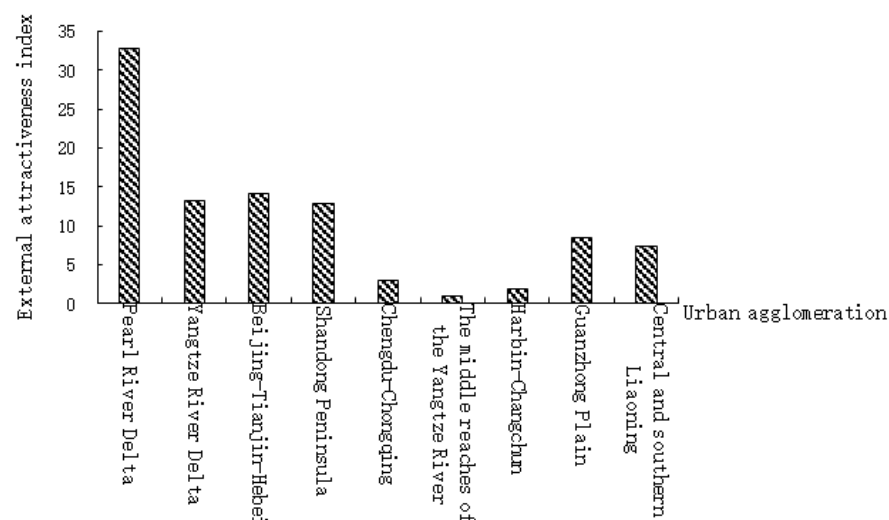


Figure 4. The external attraction index of 9 urban agglomerations.

This trend of attractiveness is especially outstanding in the national talent mobility network. The spatial pattern of graduate employment flows developed based on the social network analysis (see Figure 5) shows that the Yangtze River Delta, Pearl River Delta, and Beijing–Tianjin–Hebei urban agglomerations are the main areas getting graduate inflows, which manifest high capacity of absorbing talent. As per the inflow shares (see Figures 6 and 7), 23.54 percent of total inflows is in the Yangtze River Delta, which is the leading concentration point of graduates. Not only does it attract graduates in the locality, but it also receives a sizable number of graduates in the central city inland, including Wuhan, Xiang, Hefei, Changsha, and Chengdu, which also demonstrates a tendency of west-to-east migration of talent. The Pearl River Delta (23.04%) is another major node that has the widest spatial coverage as its graduates are absorbed by other parts of the country, like the northeast and northwest of China. The Beijing–Tianjin–Hebei region (14.71%) has a significant proportion of graduates of the northeast, central, and western regions of the country, as it is highly inclined towards northern China.

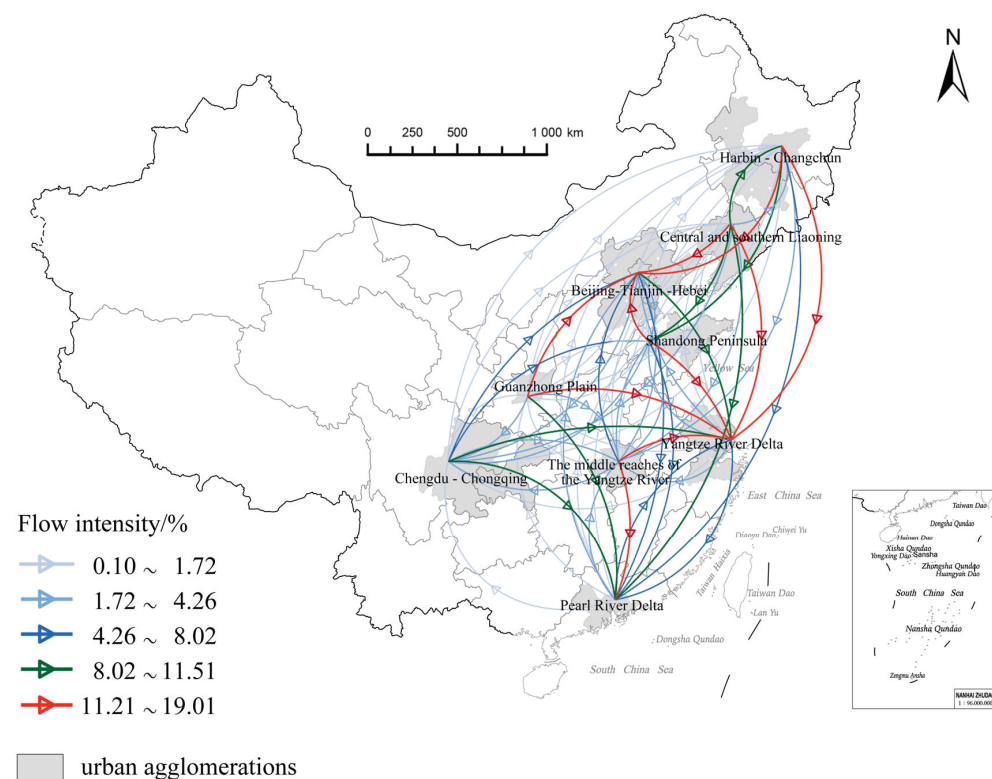


Figure 5. 2019 Graduates' employment flow intensity network of universities. Directly under the Ministry of Education. Note: The base map is sourced from the Standard Map Service of the Ministry of Natural Resources (<http://bzdt.ch.mnr.gov.cn/>), with map approval number GS(2019)1823.

Conversely, high outflow and low inflow rates of urban agglomerations that are more or less areas of talent export, like Chengdu–Chongqing, the Middle Reaches of the Yangtze River, Shandong Peninsula, the Guanzhong Plain, and Harbin–Changchun, are typical features of the regions. An acute shortage of talent is observed especially in the Middle Yangtze River region, where 20.09% of the graduates leak out and only 12.29% move in. Although more recent policies, including the provincial capital strengthening program, the targeted policy of talent, and the industrial transfer reception, have tried to improve human capital in central and northeastern cities, they have not managed to make the difference between their peripheral position in the national talent structure. In comparison, eastern coastal urban agglomerations possess systematic advantages in economic scale, employment capacity, developmental prospects, and urban livability, enabling them

to better align with graduates' dual aspirations for career advancement and quality of life—thus maintaining their position as the primary destinations for high-quality talent.

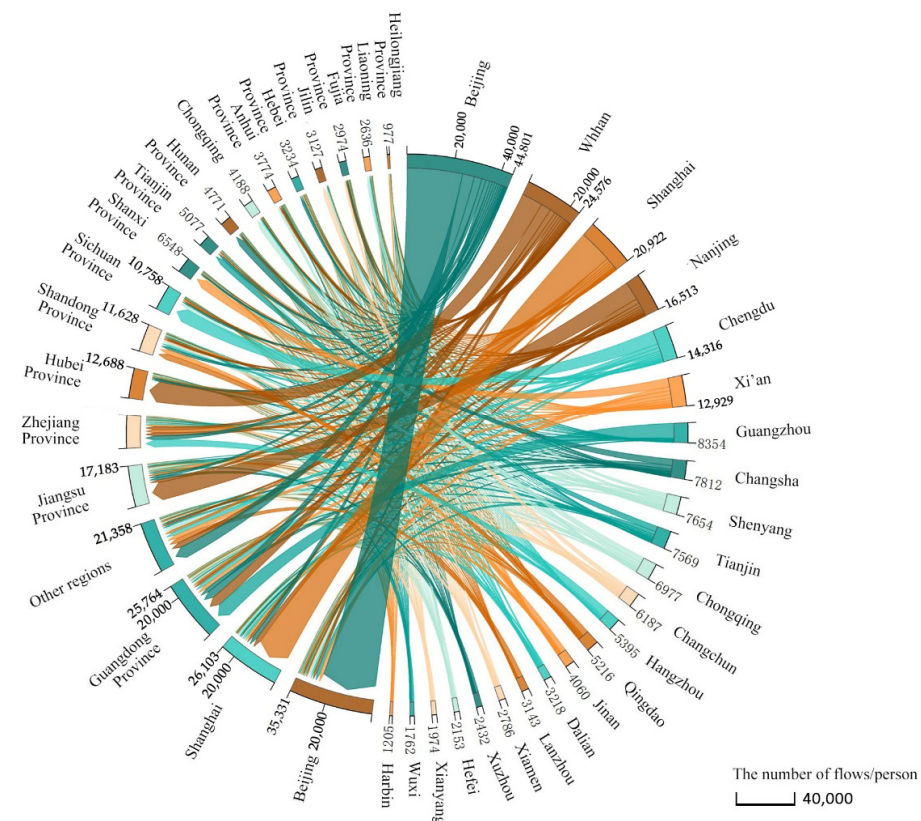


Figure 6. Employment flow of graduates of universities directly under the Ministry of Education in 2019.

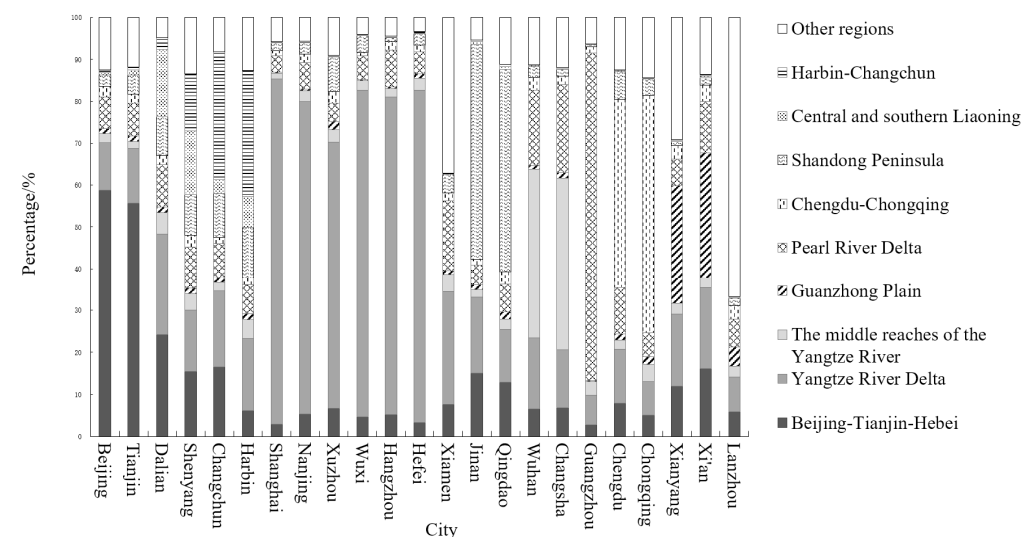


Figure 7. The proportion of graduates' employment flow in colleges and universities directly under the Ministry of Education in 2019.

4.3. Typology of Urban Agglomerations Based on Talent Mobility

To further identify the position and functional differences of urban agglomerations within the national talent mobility network, this study constructs a quadrant chart using urban agglomeration stickiness and the external attractiveness index as two analytical dimensions (see Figure 8). Based on this framework, urban agglomerations are classified into four types: high stickiness–high attractiveness, high stickiness–low attractiveness,

low stickiness–low attractiveness, and low stickiness–high attractiveness. The quadrant chart is divided based on the mean values of urban agglomeration stickiness and external attractiveness index, which are 47.69% and 10.53%, respectively. This typology not only captures variations in the ability of agglomerations to retain local graduates and attract external talent but also offers a clear spatial lens for interpreting current patterns in China’s human capital flows.

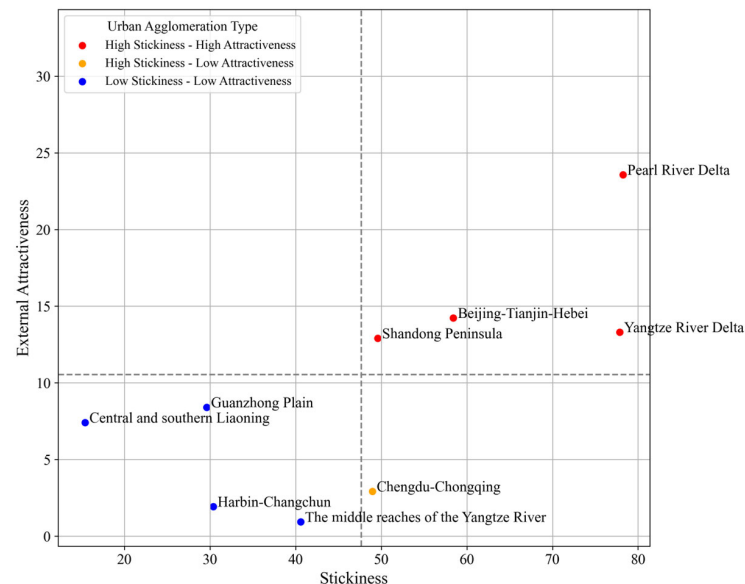


Figure 8. Classification of urban agglomeration talent flow types based on stickiness and attractiveness.

On a national scale, there are not many urban agglomerations that would offer strong talent attraction and high retention. The only regions where talent attraction and absorption have distinct visibility are the Pearl River Delta, Yangtze River Delta, Beijing–Tianjin–Hebei region, and Shandong Peninsula. The strong industrial infrastructure in these regions, a high degree of concentration of universities, and an extensive supply of employment opportunities make it possible to satisfy the demand of graduates in the local area and attract new external talent at any given time. They therefore act as central nodes in the national talent mobility network of China.

In contrast, regions such as the Harbin–Changchun belt, the middle Yangtze, the Guanzhong Plain, and central–southern Liaoning struggle on both fronts. Limited educational quality, weak industrial foundations, and scarce job opportunities lead to significant outflows of local talent and minimal inflows of skilled newcomers. These dynamics risk further weakening regional development as talent continues to drain away.

Being strong in terms of attraction and retention in general, the Beijing–Tianjin–Hebei region displays the evident internal imbalance. The city of Beijing is highly concentrated in terms of talent, but the cities of Tianjin and Hebei perform poorly in terms of absorption and retention of talent. This can be called a monocentric pattern, which undermines region integration and reduces the overall synergy of the agglomeration.

Some regions, such as Chengdu–Chongqing, offer a contrasting dynamic. They may have no formidable outward pull, but high graduate retention is a sign of high internal stickiness. These agglomerations are more prone to work as internally self-reliant systems, which are underpinned by stable educational and employment systems. But, there could also be lack of openness and national visibility, which could limit their access to wider interregional talent flows.

Overall, the analysis based on quadrants uses spatial stratification of the talent functions of urban agglomerations of China. There has been a limited availability of core areas

that have been fully integrated so as to be strong in retention and attraction of talent. On the contrary, a significant number of other agglomerations continue to encounter the issues associated with low levels of cohesion, poor external connectivity, and unbalanced internal distributions of talent. With the reorientation of China towards a high-quality regional development paradigm, differentiated talent strategies (dependent on the structural profile of each agglomeration) are required to facilitate a shift from isolated node-based competition to integrated network collaboration.

5. Mechanism Analysis of Talent Flow in Urban Agglomerations

5.1. Selection of Impact Factors

Drawing on the theory of urban talent stickiness presented in the Global City Talent Retention Index 2025 [58], this study constructs a theoretical framework for the formation mechanism of talent flow in urban agglomerations, as illustrated in Figure 9. Guided by this framework, which emphasizes the critical roles of economic development levels, integration depth, comfort levels, and talent policies across urban agglomerations to determine the direction and extent of talent mobility, the subsequent analysis employs ten indicators—per capita GDP, talent policies, number of public buses, resident population, novel patent count, unemployment rate, pupil–teacher ratio in primary schools, number of museums, number of hospitals, and Euclidean distance—as influencing factors (see Tables 2 and 3). This framework further explores and quantifies the relationship between talent mobility intensity within urban agglomerations and these factors. The assessment of talent policy indicators encompasses housing and living allowances, home purchase subsidies, residency facilitation, and educational support for children. The ten indicators of Euclidean distance are influencing factors. This will further explore and quantify the relationship between talent mobility intensity within urban agglomerations and these factors. Given that policies vary for different educational attainment groups, the subsidy effect is quantified through the combined application of group size coefficients and educational attainment weighting coefficients.

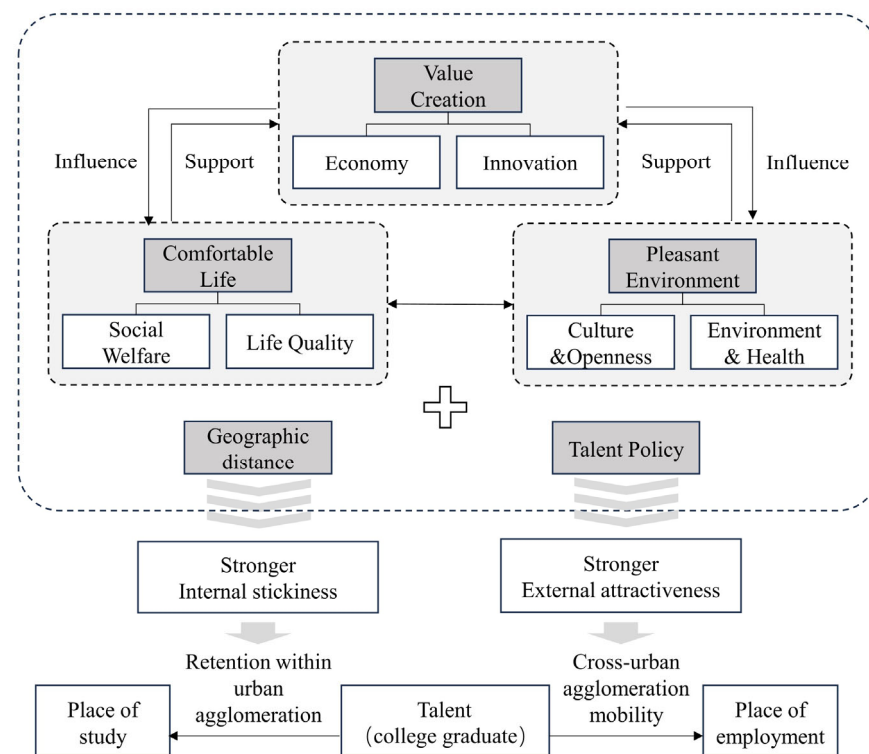


Figure 9. Theoretical framework for the formation mechanism of talent flow in urban agglomerations.

Table 2. Variable definitions and measurement indicators for the analysis of talent mobility.

Dependent Variable	Independent Variable	
	Variant	Specific Indicators
Intensity of talent mobility in urban agglomerations	Geographic distance	Euclidean distance
	Public service	Number of buses Number of hospitals Number of museums
	Economic and innovative development	GDP per capita Number of new patents
	Social environment	Unemployment rate Resident population
	Educational resources	Pupil–teacher ratio in primary schools
	Talent Policy	Housing subsidies Subsistence allowance Facilitation of settlement Children’s education

Table 3. The talent policy indicator system and scoring criteria.

Indicator	Weight Coefficient	Assessment Criteria	Scoring Criteria
Housing and living allowance (CNY)	0.29	2500–3000	6
		2000–2500	5
		1500–2000	4
		1000–1500	3
		500–1000	2
		0–500	1
		0	0
Home purchase subsidy	0.35	15–20%	4
		10–15%	3
		5–10%	2
		0–5%	1
		0	0
Residency facilitation	0.13	Recent graduates may apply for direct settlement or settle with their graduation certificate and identity card	3
		Social security contributions must be within the last six months, or educational qualifications may be as low as secondary technical school level	2
		Social security contributions must be made for over six months, or the minimum educational requirement is a college diploma	1
		Implementation of a points-based settlement system may require additional conditions, such as a residence permit	0

Table 3. Cont.

Indicator	Weight Coefficient	Assessment Criteria	Scoring Criteria
Children's education	0.23	The policy explicitly grants the children of talent the right to freely choose schools across school districts, regions, or citywide	3
		Policy commitment to prioritize placement of children of talent in high-quality state schools	2
		Coordinated school placement arrangements or provision of tuition subsidies limited to specific areas/school types	1
		"Arranged centrally according to proximity" without preferential treatment	0

Note: The housing subsidy standard is determined by the proportion of the subsidy relative to the local market price of a 60-square-metre commercial property. Living allowances and rental subsidies are calculated on a monthly basis.

5.2. Measurement Method

At the initial stage of the study, we used the ordinary least squares (OLS) method to estimate the impact of each factor on the intensity of talent mobility (measured in " $\ln(N_{ij}/N_{ii})$ ") between urban agglomerations (N_{ij} Indicates migration from region i to region j , N_{ii} represents the total resident population of the region i). The ratio of the two reflects the proportion of people moving out of the country. We transformed a non-linear proportional relationship into a linear one by taking the natural logarithm ($\ln$). This facilitates the construction of econometric models to analyze the marginal effects of various influencing factors on population mobility intensity. However, diagnostic tests revealed severe multicollinearity among the explanatory variables. As shown in the Pearson correlation matrix (see Table 4), the correlation co-efficient between "permanent resident population" and "number of hospitals" reached 0.911. Furthermore, the Variance Inflation Factor (VIF) diagnostics indicated that the VIF for "number of hospitals" (86.42) and "permanent resident population" (65.58) significantly exceeded the critical threshold of 10. Consequently, the OLS estimates yielded coefficient signs inconsistent with theoretical predictions and unstable significance levels.

Table 4. Collinearity diagnostics of explanatory variables.

Variable	VIF	Correlation with Population	Correlation with Hospital
Number of Hospitals	86.42	0.911	1
Resident Population	65.58	1	0.911
GDP Per Capita	35.6	−0.113	−0.044
Public Buses	18.41	−0.182	−0.231
Number of Hospitals	86.42	0.911	1

This led to estimates of the coefficients of some of the core variables with signs not predicted by the theory and an unstable significant value, which is highly discouraging with regard to the trustworthiness of the findings of the model. In order to address this econometric problem and achieve stronger estimates, this work instead resorted to ridge regression, which was implemented using IBM SPSS Statistics 27 (IBM Corp., Armonk, NY, USA) software. By introducing an L2 regularization penalty term, ridge regression effectively reduces model variance at the cost of introducing a small bias, thereby yielding

a set of stable and interpretable coefficients. We first standardized the raw data using the formula “Z-Score” and then employed cross-validation to determine the optimal regularization parameter (see Tables 5 and 6).

Table 5. Ridge regression parameters.

Punishment	Normalized R-Squared (1 – Error)	The Sum of the Absolute Values of the Standardized Coefficients	Apparent Prediction Error
0.12	0.864	0.246	0.136

Table 6. Ridge regression trace.

GDP per Capita	Talent Policy	Number of Buses	Permanent Resident Population	Number of Novel Patents
0.18	0.121	0.319	−0.123	0.193
Unemployment Rate	Primary School Pupil–teacher Ratio	Number of Museums	Number of Hospitals	Euclidean Distance
−0.202	−0.109	0.117	0.156	−0.35

Based on the results of the ridge regression analysis ($K = 0.12$), the direction and strength of influence exerted by each factor on talent mobility within the urban agglomeration are clearly demonstrated (see Figure 10). The model exhibits good goodness-of-fit ($R^2 = 0.864$).

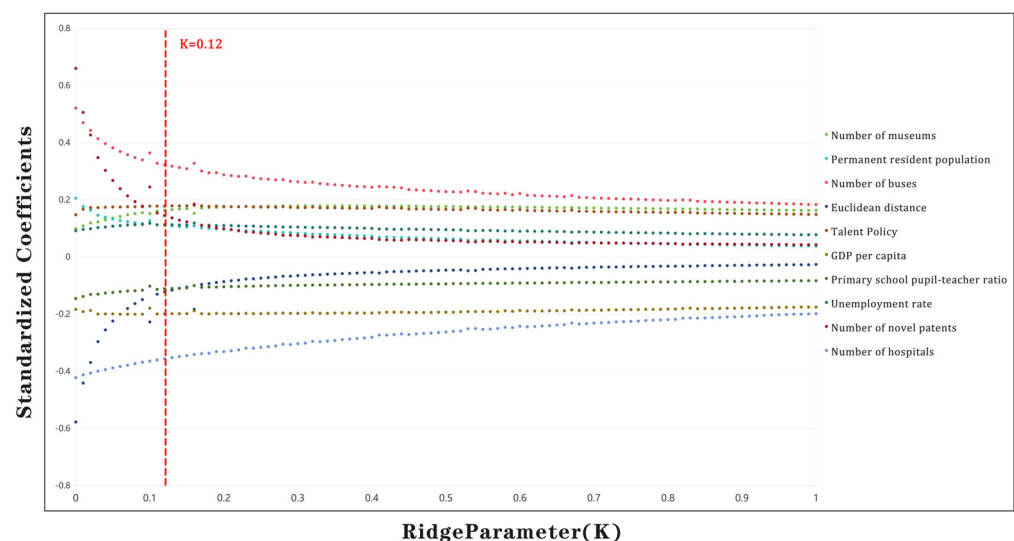


Figure 10. Ridge regression results.

5.3. Analysis of Results

5.3.1. The Pronounced Barrier Effect of Geographical Distance

The coefficients of the Euclidean distance (−0.35) have the largest absolute value of all of the variables, and this is good evidence of the presence of spatial stickiness. This implies that the geographical distance is the main constraint limiting the ability of talent to move across regions. The more edge in spatial distance between the agglomerations towards urbanization, the less likely the occurrence of talent movement, which proves the full effectiveness of the so-called distance decay law in the movement trends of talent.

5.3.2. The Foundational Supporting Role of Public Services

Access to public transport (coefficient 0.319) shows the largest coding, which means that well-developed infrastructure of public transport has a positive effect on reducing time and space costs of movement of talent and making the region more accessible.

Great effects of medical resources (coefficient 0.156), as well as supporting facilities (culture facilities 0.117), also show that talent focuses on quality of life and promotes services in the community.

5.3.3. The Core Attraction of Economic and Innovative Development

Economic development levels (coefficient 0.18 of per capita GDP) and innovation capacity (coefficient 0.193 of the number of new patents) are used together to make up the economic gravitational pull in terms of talent mobility. Talent is drawn to developed economies and strong innovation environments over an extended period.

Talent policy confirmation (coefficient 0.121) is ascertained, and this implies that a package of policies like housing subsidies, living allowances, and residency facilitation measures has a positive effect on amalgamating talent. Nevertheless, their influence is rather poor, implying space to streamline the existing policy structure; instead of material subsidies, more attention should be given to support of the public services and development opportunities. There should also be concern over policy coherence and sustainability so that resources cannot end up in the wrong hands due to policy competition.

5.3.4. The Regulatory Function of the Social Environment

The major influence of the unemployment rate (coefficient -0.202) also brings in focus how the job stability factor plays a critical role in talent choice, as a person would prefer to avoid those places where there is a higher occurrence of occupational hazards.

The coefficient -0.123 of the negative effect of permanent resident population size could indicate a kind of crowding effect in the megacities. Their economies of scale are generally counterbalanced by the overall cost-of-living pressures that are encountered in large cities (high rents, transport cost, etc.), and the end result is that talent will be drawn to smaller cities once the balance is checked in terms of lower costs of medium-sized cities versus large ones and the reverse. Along with the emergence of the digital transformation process and remote working formats, talent has become less dependent on physical location and has started to be dependent on the quality of life in a city, its environmental viability, and the balance between work and life.

5.3.5. The Complex Role of Educational Resources and the “Family Migration Cost” Effect

The “primary school pupil–teacher ratio”, which characterizes the strength of basic educational resources, exhibits a significant negative impact on talent mobility (with a coefficient of -0.109). This finding profoundly reveals the complexity of talent mobility decisions.

An important aspect that leads to this outcome is the obstacle that school district housing and high levels of settlement costs create. There is a close relationship in China between high-quality primary education resources (usually encapsulated in lower pupil–teacher ratios) and extortionate prices of school district housing. In the case of prospective migrant talent, the high pupil–teacher ratio in primary schools in a target city would be an indicator, to a certain degree, of its high settlement threshold as well as high living costs. Accordingly, this measure does not appeal to talent, but it can be used as an obstacle to settlement given the economic aspect. This implies that when making mobility choices, talent does not only consider the quality of public services but their availability and affordability.

Another important consideration lies in the lifecycle characteristics of the mobile talent cohort. The “graduates” and young professionals in career ascent studied here predominantly have children not yet of primary school age. This means that resources for primary education are not of central interest in their present decision making stage. Rather, they base their choices on immediate professional activities, wages, expenses of living, and growth potential. A factor such as the primary school pupil–teacher ratio, which is symbolic of high costs of living, creates a deterrent effect at this stage that overrides its marginal possible attractiveness.

This observation substantially indicates the cost of the migration dimension of family in the theory of spatial stickiness. It shows how decisions in talent mobility have rational tradeoffs: when inflexible and good-quality public services are prohibitively expensive to access, the stickiness characteristic of the resultant stickiness overrides the pull. This is to remind policymakers that talent strategies should not just involve hoarding superior public resources. They should also aim at reducing the institutional and economic barriers to accessing such resources and hence turn resource advantages into real talent magnetism.

6. Conclusions and Discussion

Our empirical analysis of the 2019 graduate employment data reveals a highly stratified spatial network of graduate talent mobility in China driven by a dual mechanism of talent stickiness (internal retention) and external attractiveness (interregional inflow). Examining talent mobility at the urban agglomeration scale, rather than at the level of individual cities or provinces, allows this study to capture the functional integration of labor markets, shared public services, and cross-jurisdictional commuting and migration patterns that increasingly characterize China’s regional development. This scale is particularly relevant for understanding talent allocation mechanisms, as graduates’ employment decisions often transcend administrative boundaries while remaining embedded within agglomeration-wide opportunity structures.

6.1. Interpretation of Talent Stickiness and Attractiveness: Mechanisms and Pathways

A key contribution of this study, contrary to the literature in which local talent dynamics are largely based on inflow-based indicators, is the proposed dimension of capital in terms of talent stickiness as a stabilizing and independent aspect of local talent dynamics. In the case of emerging urban agglomerations like Chengdu–Chongqing, which do not boast the pull of the Yangtze River Delta or the Pearl River Delta at the national level, internal stickiness rates above 48% are a crucial tool for ensuring a stable human capital base. This observation implies that “local stock-holding” should be used as a potentially more sustainable policy in local regions that are structurally limited in accessing incremental inflows of elite talent. Talent stickiness promotes the resilience of regions by concentrating on endogenous growth as opposed to competitive poaching so that there is less reliance on interregional flows that can fluctuate and instead continuity of labor markets in localities. This subtle insight contravenes the logic of “one-size-fits-all” policies that focus on aggressive talent acquisition models, which highlights the significance of differentiation in developing pathways based on the structural location of each urban agglomeration.

Unlike early scholarship that conceptualized talent mobility primarily as a linear response to wage differentials, our findings suggest a more complex interaction among regional economic foundations, public service accessibility, and institutional frictions, operating within an interconnected urban system. This perspective highlights that talent flows are not merely redistributive outcomes but structurally embedded processes with long-term implications for regional sustainability and resilience.

Consistent with classical Human Capital Theory and recent studies on interregional “talent competition”, the ridge regression results confirm that economic development level (GDP per capita, coefficient 0.18) and innovation capacity (patent output, coefficient 0.193) remain the primary drivers of external talent attractiveness. This mechanism explains the dominant position of the Yangtze River Delta and the Pearl River Delta within the typology of high stickiness–high attractiveness urban agglomerations. These regions have formed a self-reinforcing loop of cumulative causation whereby strong industrial foundations attract high-quality graduates whose agglomeration further enhances innovation performance and regional competitiveness. At the urban agglomeration scale, this dynamic manifests as a pronounced spatial polarization effect, intensifying talent concentration across regional boundaries rather than merely within individual core cities. This finding corroborates the “core–periphery” structure observed in provincial-level studies, but our urban-agglomeration-scale analysis further reveals that this polarization is intensifying across regional boundaries, creating a significant “Matthew Effect” where eastern coastal agglomerations siphon talent from the central and northeastern regions. From a sustainability perspective, this concentration pattern enhances short-term efficiency in innovation and productivity but simultaneously raises concerns regarding long-term regional balance and systemic vulnerability, as excessive reliance on a limited number of core agglomerations may weaken the adaptive capacity of the broader national urban system.

The mechanism analysis also further narrows amenity-based explanations of talent mobility by emphasizing the heterogeneous role played by public services. Transportation infrastructure, which is quantified in terms of provision of public buses (coefficient 0.319), is an effective pull factor as it reduces the daily friction of mobility both in-city and inter-city within an agglomeration. To the contrary, the fact that the ratio of primary school pupils to their teachers is negatively correlated with talent inflow (coefficients are negative: -0.109) demonstrates a more complicated restriction within the institutional setting of China. Rather than reflecting a simple preference for educational quality, this indicator serves as a proxy for family migration costs, encompassing competition for scarce high-quality public resources and the capitalization of educational access into housing prices. This finding establishes a critical dialogue with Western “consumer city” theories by demonstrating that amenity-driven migration in China is conditioned by high settlement thresholds and collective household decision making. Graduate mobility decisions thus extend beyond individual utility maximization to encompass long-term family livelihood considerations. The limited effectiveness of direct policy incentives (coefficient 0.121) further suggests that financial subsidies alone are insufficient to overcome structural barriers related to public service accessibility and affordability. Taken together, these results indicate an ongoing transition from a predominantly economic-driven mobility model towards a quality-of-life-constrained mechanism in which the sustainability of public service provision defines the upper limit of talent stickiness and long-term settlement.

This paper shows how talent stickiness and attractiveness can be combined at the urban agglomeration level to understand that graduate mobility does not only involve moving human capital around space but also a structural process with very deep implications for the sustainability of human capital and regional stability. Balanced retention and attraction have been found to be better placed to absorb external shocks, preserve labor market stability, and drive long-term innovation paths. In contrast, areas that depend on inflows only or experience chronic loss of talent have greater risks of developmental lock-in and systemic vulnerability. These findings provide a conceptual foundation for the sustainability-oriented discussion in the following section, where differentiated policy pathways are explored to enhance equitable and resilient human capital development across China’s urban agglomerations.

6.2. Sustainability Implications: Human Capital, Equity, and Resilience

The talent stickiness and attractiveness patterns differentiated in this paper have far-reaching consequences for the sustainability of urban agglomeration development in China. Graduate talent flows do not merely represent short-term responses in the distribution of labor but are an essential part of human capital accumulation over the long term, as well as equity between regions and systemic stability. Viewing talent mobility in this way provides a more in-depth perspective of development strategies rather than growth-based measures and means of devising sustainability-based labor governance provisions.

In terms of sustainability, high talent stickiness cannot be understood as some absolute benefit, and lower retention cannot be viewed as a loss only. Local labor markets become more sustained by high stickiness and help accumulate context-specific skills, which is especially relevant to urban agglomerations that aim at reinforcing endogenous growth. Simultaneously, excessive attention to retention without aligned industrial development can inhibit exposure to various experiences and external knowledge, particularly in places with relatively small-scale economies.

Empirical findings suggest that the level of economic development and capacity to innovate play a significant role in contributing to talent mobility compared to policy incentives with direct impact, showing that there are clear boundaries to the use of subsidies to encourage competition. In urban agglomerations with low external attractiveness but high stickiness, sustainability is not based on how well those agglomerates can attract additional inflows by using fiscal stimulation but how well they can turn the talent they keep into productive human capital. This means that policy frameworks ought to emphasize matching the importance of talent retention with industrial transformations and the development of ecosystems of innovation as opposed to achieving similar retention or attraction levels across regions. On the other hand, moderate talent outflows are not necessarily unsustainable in nature. Such flows can be useful in promoting interregional learning and knowledge diffusion when integrated into larger circulation networks. The growth of sustainable human capital is thus determined by a balance between localization or accumulation and external circulation and is hence dependent on the stage and absorptive capacity of respective urban agglomerations.

Inequality in attractiveness and stickiness in urban agglomerations indicates that flows of talent could support existing spatial inequalities, especially when more economically developed areas integrate dynamism of attraction with high retention. The issue of talent concentration in this situation goes beyond single urban areas to cover whole agglomerations, further increasing inequalities on the larger regional level. This equity dimension is also further highlighted by the fact that graduate employment figures of elite universities are used, as high-quality human capital displays more spin or cumulative effects of concentration.

More importantly, the results show that the problem of spatial equity is not only distributive but structural. The large negative value of the coefficients of the primary school pupil to teacher ratio to talent inflow (coefficient -0.109) indicates that lack of good educational facilities is a type of regressive tax of mobility that strengthens the benefits of established eastern agglomerations. Inequality in fundamental educational resources, in this case, serves as an unspoken obstacle, which tends to disadvantage lower-developed urban agglomerations in large numbers to strengthen selective polarization in the distribution of talent. In terms of sustainability, the minimization of these structural barriers is the main concern for encouraging more balanced regional development. Instead of imitating the mezzio agglomerations that rely on attractive talent management by high-profile coastal agglomerations, the lagging regions could pursue even larger equity returns via enhanced access and affordability of central public services. By reducing

family-related settlement levels, the same process can make attraction and retention more inclusive and enable the flow of talent to bring the regions together instead of making them increasingly polarized.

Connectivity infrastructure plays a pivotal role in shaping regional resilience. Agglomerations that rely heavily on a single dominant center for talent attraction are vulnerable to external disruptions. In contrast, our findings suggest that efficient transportation networks facilitate the internal circulation of talent, allowing for a more polycentric and resilient structure. For “high stickiness–high attractiveness” regions like the Yangtze River Delta, sustainability requires mitigating the “diseconomies of agglomeration” (indicated by the negative impact of population size) by guiding talent to secondary cities through improved inter-city connectivity. For regions facing outflow pressures, strengthening the “soft connectivity” of public services and the “hard connectivity” of transport infrastructure creates a buffer against brain drain. Resilience is thus better served by a policy shift from “hoarding talent” in core cities to building collaborative circulation networks where improved accessibility and service integration allow regions to play complementary roles, maintaining systemic stability amidst fluctuating economic conditions.

6.3. Research Prospects

Despite its contributions, this study has several limitations that also point to directions for future research. (1) The analysis relies on graduate employment data from a single year (2019), which constrains the ability to capture dynamic changes in talent mobility over time. Future studies could incorporate multi-year or longitudinal data to examine how talent stickiness and attractiveness evolve in response to structural shifts and external shocks. (2) The sample focuses on graduates from elite universities, representing a specific segment of high-quality human capital. While this choice is appropriate for analyzing mechanisms at the upper end of the talent spectrum, future research could extend the framework to include graduates from a broader range of institutions or other labor groups to assess the generalizability of the findings. (3) This study adopts a cross-sectional analytical approach at the urban agglomeration scale. Subsequent research may benefit from integrating micro-level individual data with meso-level regional characteristics to further unpack the interaction between personal attributes, institutional contexts, and spatial opportunity structures in shaping talent mobility decisions. Addressing these aspects would deepen our understanding of the sustainability implications of talent flows and enhance the robustness of policy-relevant insights across different spatial and temporal contexts.

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