Research Paper

Development beyond the edge

Assessing the externalities of the dual-track urban network at township level in Shanghai Metropolitan Areas

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Abstract

At the township level, rapid development beyond the edge is achieved through a dual network connection of urban functions and urban innovation. The article takes the towns and villages in Shanghai and its hinterland Suzhou, Jiaxing, and Huzhou as the research objects. POI data and patent cooperation data from 2018 and 2022 are used to construct a dual network of urban innovation under the influence of geographical proximity and information topology. The deviation from mean standard deviation multiple method is used to quantitatively evaluate the two types of externalities of the towns. The results show that: (1)The township functional network shows a 'dendritic' development; the spatial distribution of the agglomeration externalities facilitated by this network is inclined to 'circle diffusion', primarily concentrated in the core areas of the metropolitan. (2)The township innovation network shows a 'free-style' development, with resulting network externalities characterized by 'multi-point dispersion', the positive externalities also appear in the peripheral area of the metropolitan. (3) According to the combination of dual network externalities, different towns can be classified into four types: 'integrated, agglomerated, networked, isolated'.When formulating regional development policies, the differential impact of different networks on urban development should be comprehensively considered.

Keywords

Urban network; Agglomeration externalities; Network externalities; Shanghai metropolitan area

1. Introduction

In the wave of globalization and informatization, various production factors cross geographical boundaries through the internet and flow intricately in the global urban regional network. In China, due to the unique administrative division system, resources should have been given priority to higher-level central urban areas. However, in recent years, with the continuous maturity of urban network connections, the population, capital, knowledge and technology of some small towns have begun to actively interact with large cities to varying degrees, and even surpassed their own administrative levels by borrowing their scale. This change is becoming increasingly pronounced in the metropolitan area of Shanghai and its hinterland in China. With the rise of the "integrated development of the Yangtze River Delta" as a major national strategy

and the joint promotion of the regional strategy surrounding the construction of the Shanghai metropolitan area for a long time, the urban network has undergone drastic evolution, bringing about rapid development beyond the edges at the township level.

Scholars have summarized the role of this urban network in urban development as "externalities" (Burger M, 2016). The agglomeration externality brought about by the previously popular reliance on geographically close urban networks cannot fully explain this cross regional urban interaction effect. Therefore, the externality of information association networks that break through spatial limitations has emerged (Capello, 2000). These two externalities are not completely substitutable, but should be combined with each other to perform complex geographical transformations in a dual network, jointly promoting the development of the city. Existing research on network externalities often focuses on analyzing cities or districts as nodes. But in fact, in China, especially around major cities, some townships are large in scale and have even transformed into fully functional new centers. It is urgent to re explore the network externalities that emerge in the metropolitan areas and their hinterland at a more refined township level.

Based on the above analysis, this article takes the towns in Shanghai and its hinterland Suzhou, Jiaxing, and Huzhou as the research object, constructs a dual network of urban innovation under the influence of geographical proximity and information topology, and quantitatively evaluates the externalities from a comprehensive perspective of agglomeration and network integration. The study collected POI data and patent application address data from various towns in 2018 and 2022, and constructed urban functional networks based on industrial connections and geographical distances to study agglomeration externalities; Constructing an urban information network based on the number of patent collaborations to study network externalities. Adopting social network analysis methods to observe the spatial evolution characteristics of dual networks, and using the deviation from mean standard deviation multiple method to quantitatively evaluate the two types of externalities in urban areas from the perspective of borrowing scale. Divide the "agglomeration network" matrix based on the results, classify different towns, and explore the differences in their formation mechanisms.

The aim of this study is to explore the network externalities under finer spatial units, which is of great significance for improving the flow efficiency of elements in metropolitan areas and their hinterland regions from a structural perspective, as well as for small towns to break through edge limitations and seek new development drivers and planning ideas.

2. Research Design

2.1. Research object and data selection

In 2018, the integration of the Yangtze River Delta region became a major national strategy. As the core area of the Yangtze River Delta, the planning and construction work of the Shanghai metropolitan area has made rapid progress in recent years, and it has become the most globally influential region in China. This article selects the towns and villages of the typical metropolis Shanghai and its hinterland Suzhou, Jiaxing, and Huzhou (referred to as the Shanghai Suzhou Jiahu region) as the research objects. The four cities are closely adjacent in space, with developed functions and information networks, and are closely connected in the process of urbanization. According to statistics, there are a total of 453 township administrative units (Figure 1).Please fill in the authors' names as in the example below.



Figure 1. Urban spatial units in the Hu Su Jia Hu area. Source: Author's drawing

This study used three major data sources: (1) Point of Interest (POI) data collected from the Gaode Map Open API platform for Shanghai, Suzhou, Jiaxing, and Huzhou in 2018 and 2022. And by sorting and filtering out POI data related to service functions, we finally obtained 512596 points of interest in 2018 and 995020 points of interest in 2022. (2) Using the Innojoy patent website as the data source, filter based on the number of applicants>2, and crawl patent application data from the research area in 2018 and 2022; And further cleaning will be carried out, retaining only the patent data of pairwise cooperation between cities within the research scope. In the end, a total of 8111 collaborative patents were obtained for the construction of the network in this article in 2018, and 14224 patents were obtained in 2022. (3) The population attribute is derived from the population data of administrative townships in the sixth national census in 2010.

2.2. Analysis Approach

2.2.1 Building a dual network

(1) Constructing urban functional networks under the influence of geographical proximity

Firstly, based on the "Classification of National Economic Industries" (GB/T 4754-2011), this study integrates four major urban service functions, namely circulation, finance and commerce, science, education and culture, and public services, and summarizes and integrates POI data (Table 1).

Table 1. City POI Data and City Function Integration Division. Source: Author's drawing

Town functions	Industry Integration	Industry Division	Contents of POI
Circulation function	Transportation and communications industry	Transportation, warehousing and postal services	Long-distance buses, trains, subways, airplanes, ports, toll booths, post offices, logistics
		Information transmission, software and information technology	Telecommunications Business Hall

		services	
Financial and commercial functions	Financial and commercial industry	Wholesale and retail	Shopping malls, supermarkets, convenience stores, electronics stores, healthcare sales stores, gas stations, gas stations, other energy stations, charging stations, flower, bird, fish, and insect markets, home building materials markets, cultural goods stores, sports goods stores, clothing, shoes, hats, leather goods stores, special buying and selling places, cosmetics stores, car sales, car parts sales
		Accommodation and catering	Chinese restaurant, foreign restaurant, fast food restaurant, coffee shop, tea house, cold drink shop, pastry shop, dessert shop, hotel, hotel guesthouse
		finance	Banks, securities companies, insurance companies, finance companies
		real estate	Buildings and residential areas
		Leasing and commercial services industry	Car rental, travel agencies, advertising companies, law firms, talent markets
Scientific, educational and cultural functions	Science, education and cultural industry	Scientific research, technical services, and geological exploration industry	Research institutions, photography and printing shops
		education	Schools and training institutions
		Culture, sports, and entertainment industries	Science and education cultural venues, museums, exhibition halls, convention centers, art galleries, libraries, science and technology museums, planetariums, cultural palaces, archives, literary and artistic groups, media institutions, sports venues, entertainment venues, vacation resorts, cinemas, lottery sales points
Public service function	Management service industry	Water conservancy, environment and public facilities	Related to scenic spots, parks and squares, scenic spots, public toilets
		Residential services, repair and other services	Beauty salon, bath, car repair, motorcycle repair, repair station, laundry, funeral facilities
		Health and social work	Healthcare service facilities, general hospitals, specialized hospitals, clinics, emergency centers, disease prevention institutions, animal medical facilities
		Public administration, social security and social organizations	Government agencies, foreign institutions, democratic parties, social organizations, public security, procuratorial and judicial institutions, transportation vehicle management, industrial and commercial tax authorities

Referring to Shilin's (2016) method, the location entropy model is used to determine whether a town has outward oriented functions (Equation 1), and the outward oriented function quantity of each town in the study area is calculated (Equation 2). Finally, by combining the gravity model,

the strength of outward functional connections between cities and towns (Equation 3) was obtained. Using this as an edge and the center point of the city as a network node, urban functional networks under geographical proximity in 2018 and 2022 were constructed, and their evolutionary characteristics were compared and observed.

$$L_{qij} = \frac{G_{ij} / G_i}{G_j / G} \quad (i = 1 \ldots\ldots n;\ j = 1 \ldots\ldots m) \tag{1}$$

G_{ij} represents the total number of POIs for the functions of i town j; G_i represents the total number of POIs in town i; G_j represents the total number of POIs for all functions of town j; G represents the total number of POIs in all towns. If it is greater than 1, it indicates that town i has an outward oriented function; If<1, it indicates that there is no outward function in town i.

$$E_{ij} = G_{ij} - G_i \ (G_i / G) \tag{2}$$

The outward functional quantity of town i in j function is that the number of POIs in town j function exceeds the average number of POIs in j function for all towns within the research scope. The total external energy of city i is obtained by summing up the calculation results of various functions.

$$F_{mn} = \frac{E_m \times E_n}{D_{mn}^2} \tag{3}$$

In the formula of the gravity model, Fmn represents the strength of outward functional connectivity between m cities and n cities, Em and En represent the outward functional quantities of m and n cities, respectively, and Dmn represents the straight-line distance between m and n cities.

(2) Constructing an Urban Innovation Network under Information Topology Connection

Firstly, based on the Baidu Maps API, a Python program is used to geocode each patent application address and place it on the ArcGIS platform. It is then mapped to various towns using the "Spatial Join" tool.

Further statistical research will be conducted on the number of pairwise collaborations between towns within the scope of the study to characterize the strength of connections, and to use this as an edge to represent innovative connections between towns beyond administrative boundaries. Similarly, the centers of each town will be used as network nodes to construct urban innovation networks under information topology connections for 2018 and 2022, respectively, and their evolutionary characteristics will be compared and observed.

2.2.2 Assessment of dual network externalities

Drawing on existing literature, use the method of deviating from the mean standard deviation multiple to analyze the borrowing scale performance level of various towns. When the relative performance of each urban area is positive, there is a borrowing scale effect; When the relative performance of each urban area is negative, there exists a shadow effect of agglomeration (Meijers E, 2015). This study is based on data from 2022, and calculates the regional relative performance level of each town based on the node centrality of the dual network of urban function and innovation (i.e. the degree centrality of each town, as shown in Equation 4), and further evaluates the external effects of the dual network based on the results.

$$DC_i = \frac{k_j}{N-1} \tag{4}$$

Among them, k_j represents the number of edges connected to node i, and N-1 represents the number of edges connected to node i and other nodes. The larger the node degree, the higher the degree centrality of the node, and the more important its position in urban networks.

$$PER_i = (E_i - \sum_i \frac{E_i}{n}) \Big/ \sqrt{\frac{1}{n}\sum_i (E_i - \sum_i \frac{Ei}{n})^2} \quad (5)$$

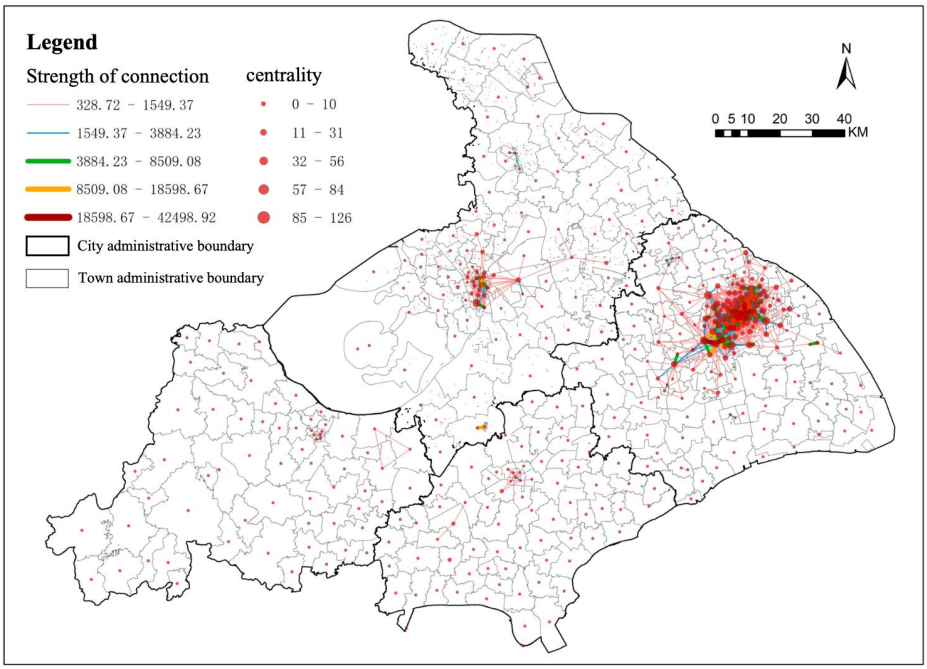
In the formula, PER_i refers to the relative performance of the i town region, E_i refers to the ratio of the centrality of the i town network to the population size of the existing town, and n is the number of towns.

Finally, based on the relative performance values of the dual networks in each town, a scatter plot is drawn. Using 0 as the benchmark, the towns within the research scope can be divided into four types: "comprehensive, clustered, network, and isolated", and their spatial distribution can be observed.

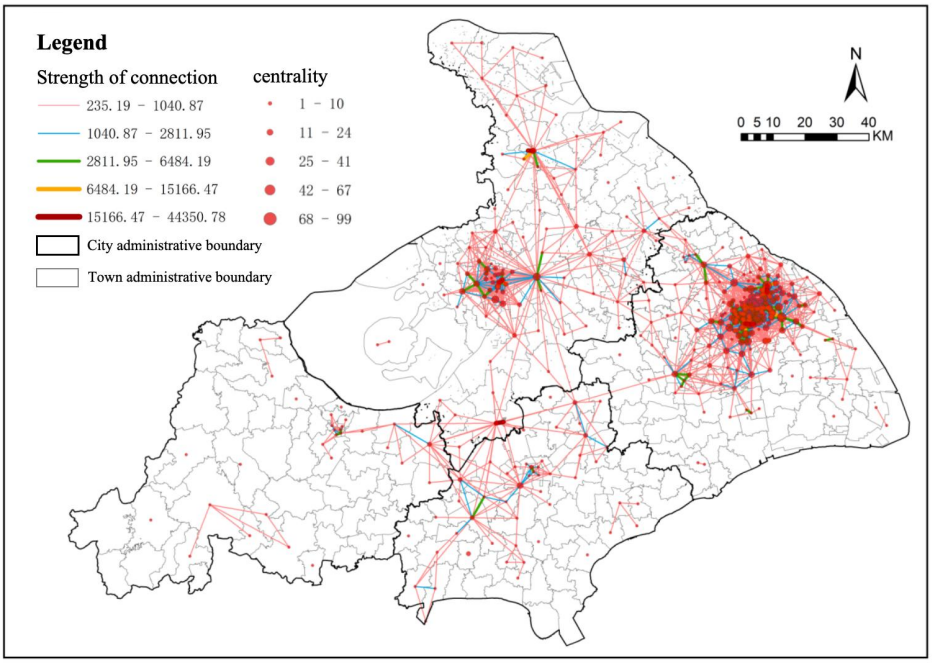
3. Result

3.1. The spatial evolution characteristics of dual networks

Visualize the dual network of urban areas in 2018 and 2022 using the ArcGIS platform. The effect of geographical proximity drives the development of urban functional networks in a "tree like" manner, and network connections become increasingly complex and dense over time (Figure 2). Specifically, the production and market size within the Shanghai Suzhou Jiahu area are mostly dominated by Shanghai, followed by Suzhou. With the continuous maturity of urban networks, smaller network subgroups have also formed in Huzhou and Jiaxing. However, due to the limitation of distance cost, it is difficult to accept the radiation and driving effect of Shanghai's core metropolis.



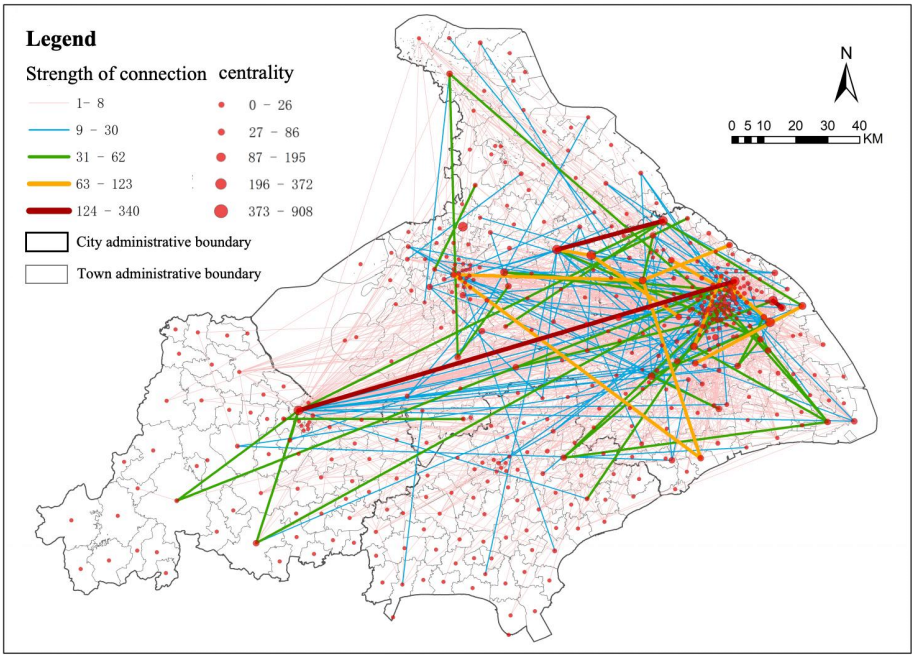
(a) 2018



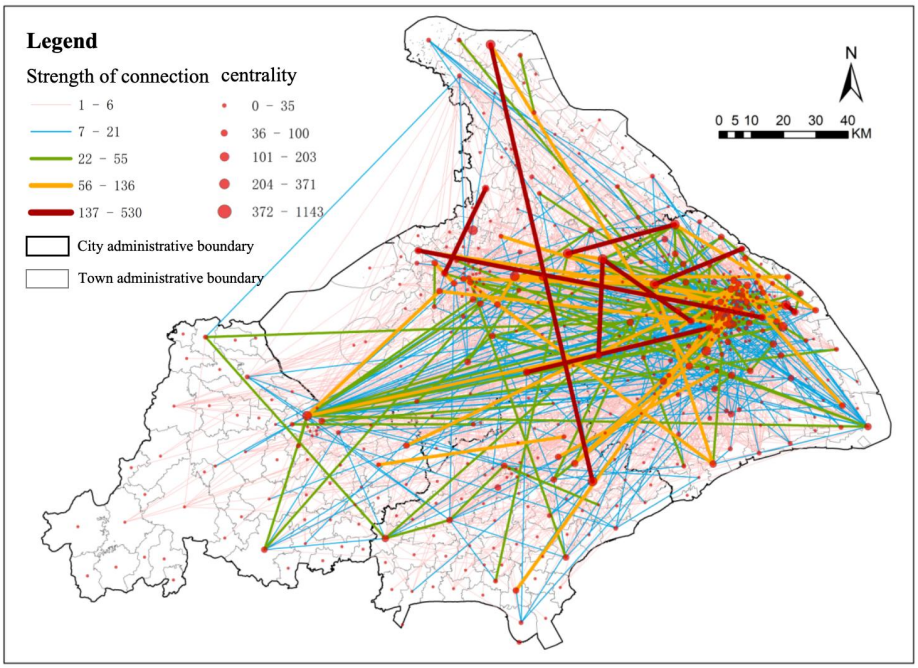
(b) 2022

Figure 2. Regional cooperation of urban functional networks. Source: Author's drawing

The information topology connection is driving the urban innovation network to present a "free-form" feature, and the network structure is developing towards an increasingly complex direction(Figure 3). Specifically, within the scope of the study, the innovation network has broken through the limitations of geographical space, without clear clustering subgroups, and there have been many towns that are far apart but have strong connections between the four cities. Compared to geographical proximity, information connectivity is more conducive to close communication between the urban clusters of Huzhou and Jiaxing and the metropolis of Shanghai.



(a) 2018



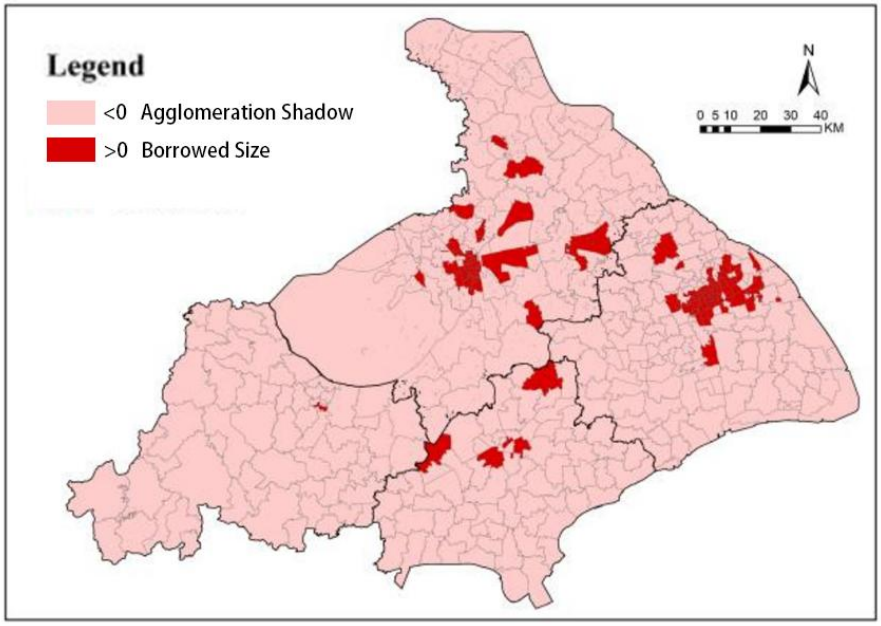
(b) 2022

Figure 3. Regional Cooperation of Urban Innovation Network. Source: Author's drawing

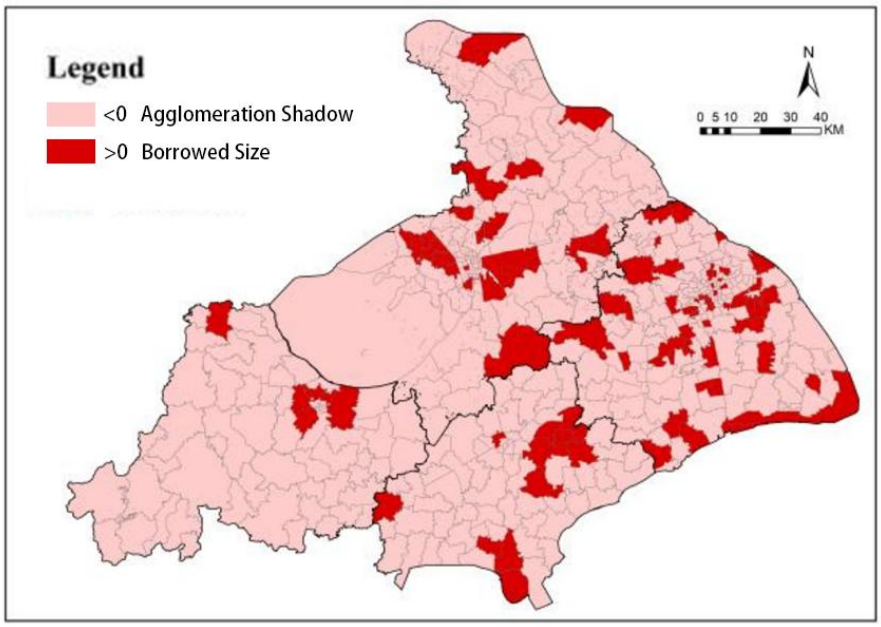
3.2. External effects of dual networks

The agglomeration of dual networks and network externalities at the township scale do not occur synchronously, and the two exhibit differentiated spatial distributions. The spatial distribution of agglomeration externalities based on urban functional networks presents the characteristics of "multi-core" and "circle diffusion". The borrowing scale characteristics of the main urban areas and a few suburban towns in various cities are particularly prominent, such as Wujiaochang Street, Hongqiao Town, Jinqiao Town and other areas in the suburbs of Shanghai's main urban area, as well as Guanqian Street, Shuangta Street and other areas in the suburbs of Suzhou's main urban area. And the towns in the peripheral range show obvious "agglomeration shadow" characteristics, such as Huating Town and Fengcheng Town in the outer suburbs of Shanghai's main urban area. The main urban area of a metropolis usually serves as the center of regional economic development, with concentrated and diverse service functions. It has strong borrowing advantages, such as a larger market and a more diverse workforce. Based on the advantage of geographical proximity, suburban areas prioritize interaction with the main urban area, making it easier to "borrow" its resource elements and profit in the functional network.

Based on the network externalities brought by urban innovation networks, there is a characteristic of "multi-point dispersion" without a clear core, and positive externalities such as "borrowing scale" may also appear in towns in the outskirts of metropolises. For example, Nanhui New Town located in the outer edge of Shanghai and Huangwan Town in Jiaxing. Although these towns are located at the edge of spatial network nodes and have weak geographical connections with metropolitan centers, they can also achieve flexible nesting and scale borrowing of spatial networks within metropolitan areas through innovative cooperation that transcends spatial limitations.



(a) distribution under functional networks



(b) distribution under innovation network

Figure 4. The externalities of urban dual networks. Source: Author's drawing

3.3. Classification analysis of dual network externalities effects

The author categorized the external effects of each township based on the dual network into four types (Figure 5) and visualized them spatially in ArcGIS (Figure 6):

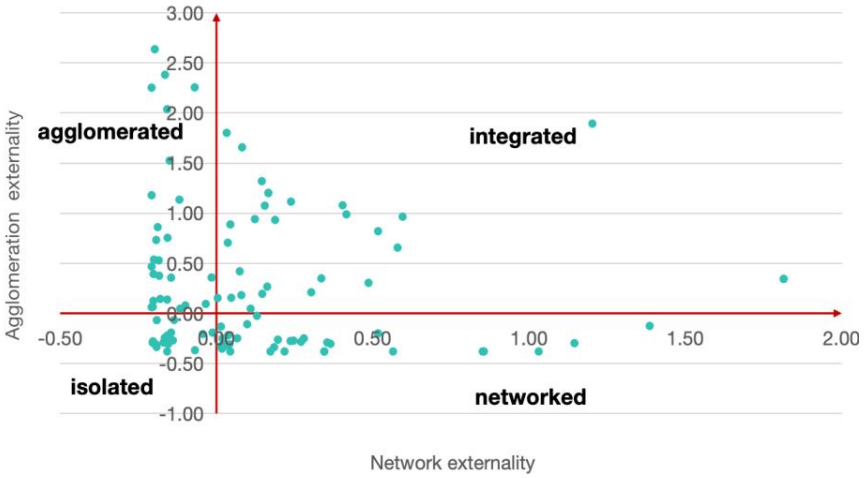


Figure 5. Scatter plot of dual network externalities. Source: Author's drawing

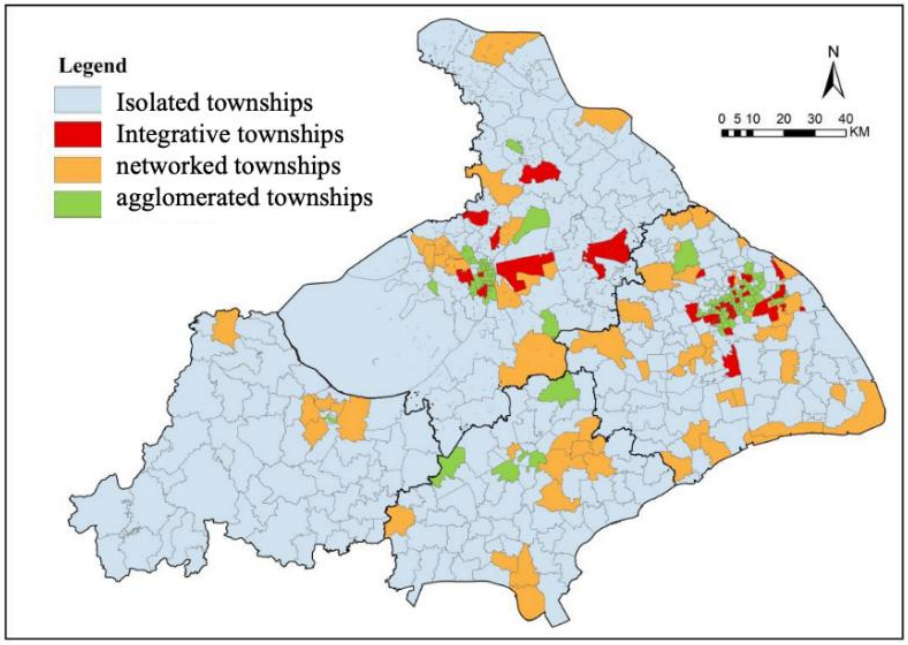


Figure 6. Spatial distribution of urban types. Source: Author's drawing

(1) Comprehensive towns with strong agglomeration externalities and network externalities, such as Jinqiao Town, Hongqiao Town, Wujing Town, etc. These types of towns are often hubs connecting the dual network of the region and surrounding towns, with a good economic foundation, concentrated service functions, and a concentration of innovative resources and more external cooperation. For example, Jinqiao Town, located in Pudong New Area, Shanghai, has a high degree of administrative overlap with Jinqiao Economic and Technological Development Zone. Under the policy of "management town linkage", it has become the first free trade pilot zone in China with innovative high-end manufacturing and productive service industries as its dual core development.

(2) Agglomeration type towns with strong externalities but weak network externalities, such as Xitang Town and Malu Town. These types of towns generally have more functional elements,

relying on geographical distance to interact with surrounding cities, but lack innovative cooperation with cities located further away within the metropolitan area. For example, Xitang Town, located in Jiashan County, Jiaxing City, is committed to building a future water town community that is closely related to the ancient town. It has become a core component of the Yangtze River Delta Ecological Green Integration Development Demonstration Zone and relies more on the integration of the tertiary industry related to culture and tourism into the functional network; Patent cooperation related to technological innovation is relatively weak and not a key direction for its development.

(3) Network type towns with strong network externalities but weak agglomeration externalities, such as Nanhui Xincheng Town and Zhangjiang Town. These types of towns are generally driven by the radiation of innovation cooperation from other towns, with technology innovation industries as their leading industries. Due to geographical limitations, it is difficult to access the development dividends of towns with concentrated functional services. For example, Nanhui New Town in Pudong New Area, Shanghai, is located on the coast and far from the main urban area of the metropolis, with weak agglomeration externalities under its functional network. But as the core carrier area of Shanghai Lingang New Area, a special economic functional zone, it is fully committed to building a high-energy, intelligent, and modern future city. At present, the benefits of its innovative industrial cluster are constantly emerging, becoming an important node in the innovation network of the Shanghai metropolitan area.

(4) The "isolated" townships with weak agglomeration externalities and network externalities, such as Weiting Street, Guangfu Town, and many other townships. These types of towns are often located on the edge of the urban network in metropolitan areas, making it difficult to integrate into the functional network, and their service functions can only serve the local area; At the same time, there is relatively little involvement in the fields of technological innovation and cooperation, and the external effects of innovation networks also need to be developed.

4. Discussion

This article takes the towns and villages in Shanghai and its hinterland Suzhou, Jiaxing, and Huzhou as research objects to explore the external effects brought by urban networks. Based on the concept that the externalities of agglomeration brought by geographically close urban networks and the externalities of information related networks that break through spatial limitations coexist and jointly promote urban development, this study quantifies and evaluates the externalities of urban areas within the research scope from the perspective of functional and innovative dual networks. Towns are classified based on the four dimensions of the "agglomeration network" matrix to describe their differentiated types and spatial distribution, and to guide the formulation of relevant development policies for various towns in the region.

The main conclusions are as follows: (1) Geographical proximity promotes the "tree like" development of urban functional networks; The spatial distribution of agglomeration externalities brought about by it presents the characteristics of "multi-core" and "circle diffusion", mainly concentrated in the core areas of metropolises. (2) The information topology connection promotes the "free" development of urban innovation networks, and the network externality effect it brings is "multi-point dispersion", which can also have positive externalities in the peripheral areas of metropolises. (3) The agglomeration of urban functions and network innovation may not necessarily occur simultaneously, and the externalities of each town can be classified into four types: "comprehensive, agglomeration, network, and island". Each town chooses to embed different types of urban networks based on its own situation, resulting in

spatial spillover differences in externalities. Therefore, when formulating regional development policies, attention should be paid to the externalities of different networks of urban areas in the region; Avoiding islanding risks through effective interaction between cities with different development advantages.

This study explores the network externalities under finer spatial units, but there are still shortcomings: firstly, this study is only a preliminary exploration of the existence of network externalities in metropolises and their hinterlands, and there is still room for exploration on how to guide cities to avoid agglomeration shadow effects and strengthen borrowing scale effects. Secondly, the development stages of urban agglomerations in different regions of China vary. Therefore, the regional network of the Shanghai metropolitan area is only a representative case of developed urban areas in China, and comparative research with other regional urban areas still needs to be carried out, which can be further explored in the future.

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