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Analysis of Dual-Core Type City and Its Hinterland Contact Pattern under the Background of High-Speed Rail Networking—Urban Agglomeration in Zhejiang Province as an Example

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Abstract

Under the background of high-speed rail networking, this paper uses the passenger trains, the type and direction of the railway via Hang Yong and its extension road line, to construct adsorption and dependency index among cities, depict the contact pattern between the Hang Yong dual-core and its hinterland, measure the "net effect" that two center cities (Hangzhou, Ningbo) have on their hinterland, and estimate population agglomeration potential and future possible population flows of Zhejiang Province and the main sample cities. The result shows that, compared with Ningbo, Hangzhou has stronger radiation force to the vast majority of sample cities, and the sample cities affected more by Ningbo mainly concentrates in Ningbo-Taizhou-Wenzhou along; in addition, the sample cities such as Hangzhou, Ningbo and so on show better population agglomeration, then the population "scramble" phenomenon between cities has begun to appear.

Keywords

High-Speed Rail Networking, Contact Pattern, Measurement

1. Introduction

The contact strength between cities is gradually enhanced by the increasingly perfect high-speed rail (HSR) network. In China, original orbit of urban population agglomeration is much likely to be rewritten by HSR.

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Since 2008, at a distance of 300 - 750 km between cities, HSR is gradually becoming the best mean of transportation, and the twins linkage development era within a radius of 500 km has been opened. At present, almost every Chinese coastal province is dual-core [1]. In the group of dual-core cities which has opened HSR in the same province, Hangzhou (Hang) and Ningbo (Yong) of Zhejiang Province are fairly representative. With the opening of the Yong-tai-wen Railway, Wen-Fu Railway, Hang Yong specialized passenger railway, Shanghai-Hangzhou intercity high-speed railway and Hangzhou high-speed rail, Zhejiang has become one of the most intensive provinces in China high-speed rail network. Hangzhou metropolitan area was selected as China first comprehensive reform experiment site of metropolitan area economic transformation and upgrading in 2014, therefore the practice of Zhejiang shoulders great times responsibility that leads Chinese cities linkage and regional integration. Take Zhejiang province as an example, to discuss the linkage relationship between the Hang Yong dual-core and its hinterlands in Yangtze River Delta polycentric urban system pattern, measuring Hang Yong dual city and its hinterland contact pattern under the background of high-speed rail networking are helpful to understand the evolution trend of the future contact pattern between China coastal regions as well as other urban agglomerations and provide observation sample for the linkage development between China central city and its hinterland.

A more extensive exploration on regional spatial contact patterns measurement has been made by academia. Relative research can be summed up in the following two aspects: one is describing the regional economic contact pattern based on population, GDP and other related socio-economic indicators [2]-[4]. The other is measuring the regional spatial contact pattern based on the traffic accessibility, cargo flow, passenger flow and information flow [5]-[13]. However, the possibility of cities contact and attracting scope [14] are offered by analysis based on the transportation network accessibility, but the actual flow occurred among cities can't be represented by the index. Although analysis based on social network can judge the city's close contact degree and the overall pattern, it can't offer urban linkage directions, dependency or radiation relationship. Except that, proximity effect and distance attenuation characteristics have been largely ignored. The study of Chen Jianjun etc. has made the beneficial attempt, but the relative importance of the category of the trains is still unable to be identified by the adoption of commuter frequency indicator between any two cities [13]. Throughout, the urgent needs are to reconstruct methodology, and to find new way of data sources, especially assessment method whose form is simple but connotation is rich [15]. Four effects caused by high-speed rail, which are space-time, border breakthrough, regional enhancement, and elements integration, so far lack much data to support, and the study of the influence high-speed rail has on urban system spatial pattern is mainly in form of qualitative description, synthesize and technology-based tool [16]. In addition, the domestic related research tends to be "heavy grade, light contact", which lacks systematic study on directed contact between cities [17] [18]. The research based on relationship data's influence on the networking contact between cities is still rare, and research on the relationship of interaction and linkage between cities is still in the initial exploratory stage [19].

In view of this, urban agglomeration in Zhejiang Province is taken as an example to depict the space contact pattern between the Hang Yong dual-core and its hinterland, measure the "net effect" that two center cities (Hangzhou, Ningbo) have on their respective hinterland, and fit and contrast the population of Zhejiang Province and other main central cities in Yangtze River Delta, according to the passenger trains, the type and direction of railway to construct adsorption and dependency index among cities. This research is based on the following considerations: First, the flow of people implies most information of various elements flows. The quantity and structure of population are ultimate decision variables of urban development, whose flow direction determines physical capital, information and goods flow directions, and population scale and direction in the flow can be well characterized by the railway passenger trains and running direction. Second, because of the difficulties in obtaining the data, current research on the accurate measurement of urban association, which is based on the comparability, is very rare. There is no substantial change in the function of railway transportation since the 19th century, and the space-time effect based on the connection of railway passenger transportation to evaluate the high-speed networking can undoubtedly establish an analytical framework in which the urban contact pattern is more accurate.

2. Method Design and Data Collection

The passenger trains, the type and direction of the railway via Hang Yong and its extension road line are used in the paper to measure the cities adsorption index and dependency index among cities, and the associated features between central cities and their hinterlands are analyzed. **Figure 1** is a flow block diagram of study method.

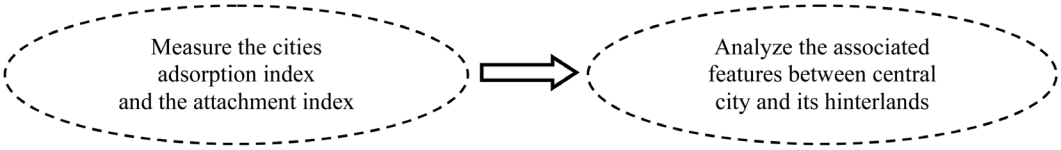

Figure 1. A flow block diagram of study method.

2.1. Delimit the Distribution Area of Sample Cities

Based on railway passenger links, to depict the correlation features of Hang Yong twins and urban agglomeration in Yangtze River Delta, and the geographical scope of the sample cities: Shanghai and all prefecture-level cities in Zhejiang provinces, Jiangsu provinces and Anhui provinces as well as those counties in their railway lines, part cities of Hunan, Jiangxi, Fujian via by the railway extension line, which passes Hang Yong dual cities, as well as a part of the reference cities beyond Hang Yong railway and its extension line, including Shanghai, Nanjing, Hangzhou, Ningbo, Hefei, Changsha, Nanchang, and other cities. Then based on the main railway and its extension line via Hang Yong twins, to determine the sample city unit and site. Sample cities are mainly located in Hang Yong railway line and within the distance of 500 km radius, and parts of sample cities are distributed in 500 - 1000 km railway extension line. What's more, we introduce a small amount of reference cities. By screening, there are 93 sample cities and 106 sites included in the analysis and measurement at last. Among them, there is one municipality, three deputy provincial cities, 49 prefecture-level cities (including a small area of municipalities), and 40 county-level cities (districts and counties). Sample cities and its provincial domain refer to **Table 1**.

At present, the main railway lines operated in Yangtze River Delta region include Beijing-Shanghai Railway, Nanjing-Qidong Railway, Shanghai-Hangzhou Railway, Zhejiang-Jiangxi Railway, Xin Chang Railway, the Longhai Railway and other ordinary railway lines, as well as the Shanghai-Nanjing high-speed railway, Shanghai-Hangzhou high-speed railway, Nanjing-Hangzhou high-speed railway, Beijing-Shanghai high-speed railway, Hening part of Shanghai-Chengdu high-speed railway, NingAn intercity railway, railway Ningbo-Taizhou-Wenzhou high-speed railway and other high-speed railway lines. Railways under construction include Shanghai-Nantong railway, Lianyungang-Yancheng railway, Jiangsu coastal railway, Lian-Huai-Yang-Zhen railway, Hangzhou-Huangshan high-speed railway and Shang-He-Hang high-speed railway, etc. High-speed rail lines in Yangtze River Delta region, which have been opened and are about to open by the end of 2016 and the site details are shown in **Table 2**.

2.2. Index Construction

According to method of Zhou Jingxiang [20] and the railway passenger trains, type and the corresponding weights to construct city's adsorption (Adsorption) and dependency (Dependency) index. Calculation method of city's adsorption index is

$$\text{Adsorptivity} = \frac{1}{\sum_{j=1}^{n} n} \sum_{i=1}^{3} \left(\eta_i \sum_{j=1}^{8} X_{ij} j \right) \tag{1}$$

where X_{ij} is the quantity of trains, j is the weight of trains' type, according to the importance of different train-types, the weight is decreasing in turn. I is the ways passenger trains go through the city which include "originator", "route" and "end to", and its weight (η_i) is assigned 0.35, 0.3 and 0.35. Calculation method of city's dependence index:

$$\text{Dependency}_{A\to B} = \frac{1}{\sum_{j=1}^{n} n} \sum_{i=1}^{2} \left(\eta_i \sum_{j=1}^{8} X_{ij(A\leftrightarrow B)} \cdot j \right) + \frac{1}{\sum_{j=1}^{n} n} \sum_{i=1}^{2} \left(\eta_i \sum_{j=1}^{8} X_{ij(A\vee B)} \cdot j \right) \tag{2}$$

where A → B means the dependency relationship of city A to city B, and vice versa. $X_{ijA\to B}$ is the quantity of trains which is "originator" and "end to" from city A to Band vice versa; $X_{ijA\vee B}$ is the train from A to B or via A end to B. The assignment of weight and the meaning of other letters are the same as the way of adsorption index.

Table 1. Sample cities and its belonging province area.

Area	Main sample cities
Zhejiang	Deputyprovincial cities(Hangzhou, Ningbo); Prefecture-level cities (Wenzhou, Jiaxing, Huzhou, Shaoxing, Jinhua and Quzhou, Zhoushan, Taizhou, Lishui); County-level cities (Yuhang, Lin'an, Chun'an, Yuyao, Fenghua, Ninghai, Rui'an, Leqing, Yongjia, Cangnan, Shangyu, Zhuji, Deqing, Changxing, Anji, Haining, Pinghu, Tongxiang, Jiashan, Haiyan, Dongyang, Yiwu, Linhai, Wenling, Sanmen)
Shanghai	Municipality (Shanghai); Deputy prefecture-level cities (Songjiang, Jinshan)
Jiangsu	Deputyprovincial cities (Nanjing); Prefecture-level cities (Wuxi, Xuzhou, Changzhou, Suzhou, Nantong, Lianyungang, Huai'an, Yancheng, Yangzhou, Zhenjiang, Taizhou and Suqian); County-level cities (Yixing, Liyang, Kunshan, Danyang, Jurong, Jiangning, Lishui)
An'hui	Prefecture-level cities (Hefei, Wuhu, Huainan, Ma'an'shan, Huaibei, Tongling, Anqing, Huangshan, Fuyang, Suzhou, Chuzhou, Liu'an, Xuancheng, Chizhou, Haoozhou); County-level cities (Quanjiao, Dingyuan, Guangde, Dongzhi)
Jiangxi	Prefecture-level cities (Nanchang, Jiujiang, Shangrao, Pingxiang, Yingtan); County-level cities (Yushan, Pengze, Hukou)
Fujian	Prefecture-level cities (Fuzhou, Ningde); County-level cities（Fuding）
Hu'nan	Prefecture-level cities (Changsha, Zhuzhou, Xiangtan, Changde)

Note: According to history and publicly reported data sorting summary. **Table 2** is the same.

Table 2. The Yangtze River Delta high-speed rail line and the site overview.

Line	Site	Mileage	Design speed/ Actual operating speed	Planning Year	Start Year	Opening Year
Shanghai-Nanjing intercity high-speed railway	First built 21sites: Nanjing, Xianlin, Baohuashan, Zhenjiang Dantu, Danyang, Changzhou, Qishuyan, Huishan, Wuxi, Wuxi New District, Suzhou New District, Suzhou, Suzhou Industrial Park, Yangcheng Lake, Kunshan Nan, Huaqiao, An'ting Bei, NanxiangBei, Shanghai Xi, Shanghai Reserved 10 sites: Qixia, Xiashu, Gaozi Nan, Lingkou, Lvcheng, Benniu Dong, the New Zhadong, Henglin, Wangting Dong, Weiting Xi	301	300/264	2004	2008	2010
Shanghai-Hangzhou intercity high-speed railway	9 sites: Shanghai Hongqiao, Songjiang Nan, JinshanBei, Jiashan Nan, JiaxingNan, Tongxiang, Haining Xi, Yuhang,, Hangzhou Dong	169	350/212	2004	2009	2010
Nanjing-Hangzhou specialized passenger railway	11 sites: Nanjing Nan, Jiangning, Jurong Xi, Lishui, Wawushan, Liyang, Yixing, Changxin, Huzhou, Deqing, Hangzhou Dong	249	350/310	2004	2008	2013
Beijing-Shanghai high-speed railway	12 sites: Suzhou Dong, Bengbu, Dingyuan, Chuzhou, Nanjing Nan, Zhenjiang Nan, DanyangBei, Changzhou Bei, Wuxi Dong, Suzhou Bei, Kunshan Nan, Shanghai Hongqiao	551	380/300	2004	2008	2011
Yong-Tai-Wen railway	12 sites: Ningbo, Fenghua, Ninghai, Sanmen, Linhai, Taizhou, Wenling, Yandangshan, Shenfang, Yueqing, Yongjia, Wenzhou Nan	268	250/200	2004	2005	2009
Wen-Fu railway	4 sites: Wenzhou, Ruian, Pingyang, Cangnan	69	250/200	2004	2005	2009
Hening specialized passenger railway	8 sites: Hefei Nan, Feidong, Chaobei, Huang'an, Quanjiao, Tingzishan, Jiangpu, Nanjing Nan	166	200/200	2004	2005	2008
Hang Yong specialized passenger railway	7 sites: Hangzhou Dong, Hangzhou Nan, Shaoxing Bei, Shangyu Bei, Yu Yao Bei, Zhuangqiao, Ningbo	150	350/200	2004	2009	2013
Hang Chang high-speed railway	7 sites: Hangzhou Dong, Hangzhou Nan, Zhuji, Yiwu, Jinhua,, Longyou, Quzhou, Jiangshan	269	350/300	2004	2009	2014
He Wu specialized passenger railway	10 sites: Hefei, Taohuadian, Hefei Xi, Chang'anji, Nanfen Road, Liu'an, Dushan, Jinzhai, Tiantangzhai, Dunyitang	202	250/200	2004	2005	2009

Continued

He Bang specialized passenger railway	6 sites: Hefei, Hefei North City, Dabao Ying line Station, Shuijia Lake, Huainan Dong, Bengbu Nan	131	350/208	2004	2009	2012
He Fu railway	11 sites: Hefei Nan, Changlin Rive, Chaohu, Wuwei, Tongling Bei, Nanling, Jingxian, Jingde, Jixi Bei, Shexian Bei, Huangshan Bei	343	350/300	2004	2010	2015
Zheng Xu specialized passenger railway	4 sites: Dangshan Nan, Yongcheng Bei, XiaoxianBei, Xuzhou Dong	109	350	2004	2012	2015
Ning An high-speed railway	12 sites: Nanjing Nan, Jiangning Xi, Ma'anshan Dong, Dangtu Dong, Wuhu new railway (in situ conversion), Fanchang Xi, Zhongming Bei (Reserved), Tongling, Maya (Reserved), Chizhou, Yan Tang (Reserved), Q An'qing New	257	250	2005	2008	2015
Zheng Xu specialized passenger railway	5 sites: Dangshan Nan, Yongcheng Bei, Xiaoxian Bei, Xuzhou Dong, Lianyungang (New plus)	109	350	2005	2012	2016

2.3. Data Collection

The actual city passenger train data used in this paper is all from the website: *Where to go*. *Where to go* provides sites, lines, trains and other information of railway passenger transportation query time between April 20, 2015-May 20, 2015.City site information includes all trains and types of the "originator", "route" and "end to" in railway stations. After choosing departure and arrival, information of the line shows all trains and types of the "originator", "route" and "end to". When making data statistics of city sites and passenger trains between cities, according to the type of trains (G, C, D, Z, T, K, L, O, etc.) to classify, to distinguish the importance of different types of trains in urban linkages. Empirical part involves urban household population, the resident population, GDP, total fixed asset investment as well as its growth rate of the whole society and other variables, whose data is derived from "National Economy and Social Development Statistics Bulletin" and "Government Work Report" of the city over the years. What is more, other data that can't be obtained is filled by "China city statistical Yearbook" and "regional economic China statistical Yearbook".

3. Calculation Results

After 2008, high-speed rail lines are opened one after another in the Yangtze River Delta region, which increases the uncertainty of the city population size and flow direction. Transportation system reform caused by high-speed rail is changing the spatial connection and development pattern among cities.

3.1. Adsorption Capacity and Spatial Distribution Pattern of Hinterland Cities

According to the adsorption capacity of sample cities calculated by Formula (1), the cities whose absorption index greater than 20 are Shanghai, Nanjing, Hangzhou, Suzhou, Wuxi and Changzhou, and three cities of the top are Shanghai, Nanjing and Hangzhou, whose city absorption index in order are 62.73, 40.78, and 32.29. Shanghai's is nearly 20 more than Nanjing's which ranked second, showing a very strong adsorption capacity of the population. Cities whose absorption index ranges from 10 to 20 include: Xuzhou, Jinshan, Hefei, Zhenjiang, Kunshan, Jiaxing, Jinhua, Ningbo, Yiwu, Bengbu; absorption index ranges from 5 to 10: Danyang, Shaoxing, Wenzhou, Quzhou, Huzhou, Yuyao, Taizhou, Haining, Yixing, Zhuji; absorption index less than 5: Chuzhou Shangyu, Tongxiang, Changxing, Huainan, Wenling, Liyang, Deqing, Quanjiao, Jiashan, Fuyang, Yushan and Songjiang etc. Take Zhoushan as an example of reference points of the city although located in the axis of development (Shaoxing, Huzhou) or have special industries (Zhoushan's Fishery), the absorption index is 0 due to traffic inconvenience. **Table 3** shows the top 30 sample cities and their rank features, and **Figure 2** shows their spatial distribution.

3.2. The Dependency Pattern of Hinterland Cities on the Central City

According to Formula (2), first measure the dependent pattern between each two cities of the five central cities:

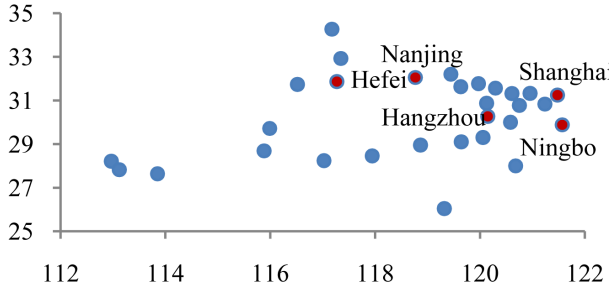

Figure 2. The spatial distribution of the top 30 cities of Adsorption index. Note: **Figure 2** and **Figure 3** respectively combined with data of **Table 3** and **Table 4**, draw according to the city's latitude and longitude.

Table 3. Absorption index and its rank of sample cities in Zhejiang province.

Rank	City	Absorption index	Rank	City	Absorption index	Rank	City	Absorption index
1	shanghai	62.733	11	hefei	17.244	21	zhuzhou	10.126
2	nanjing	40.778	12	zhenjiang	16.742	22	shangrao	9.750
3	hangzhou	32.292	13	kunshan	15.008	23	danyang	9.350
4	changsha	29.818	14	jiaixng	14.525	24	shaoxing	9.200
5	suzhou	27.311	15	jinhua	13.119	25	wenzhou	8.526
6	wuxi	24.378	16	yingtan	12.483	26	hengzhou	8.058
7	nanchang	22.324	17	fuzhou	12.408	27	pingxiang	6.647
8	changzhou	21.914	18	ningbo	11.782	28	liuan	6.606
9	xuzhou	18.651	19	yiwu	11.207	29	huzhou	6.367
10	jinshan	17.792	20	bengbu	10.314	30	jiujiang	6.015

Note: According the results by author's calculation, then sort out this table.

Shanghai, Hangzhou, Ningbo, Nanjing and Hefei. The dependency index of Hangzhou to Shanghai is 525.1, and Shanghai to Hangzhou is 340.2. The dependency index of Shanghai to Nanjing is 634.3, and Nanjing to Shanghai is 884.55. Likewise, Hangzhou to Ningbo is 239.2, and Ningbo to Hangzhou is 179.3, Hangzhou is most closely related to Ningbo in the five cities, and the following city is Shanghai, whose dependency index to Ningbo is 108.95, and converse is 171.1. It is not difficult to find that there are significant spatial differences in the strength and direction of contact between each two cities of five cities. As shown in **Table 4**.

Next measure the dependency pattern of sample cities to regional center (Shanghai). Among them, the dependencyof Nanjing to Shanghai is the strongest, followed by four cities: Suzhou, Wuxi, Changzhou and Hangzhou, and their respective dependency indexes to Shanghai in the order are884.55, 769.05, 671.4, 616.15 and 525.1. The dependency index of Ningbo to Shanghai is 171.1, ranking 14th. These cities, which are not in the Yangtze River Delta and with a longer space distance away from Shanghai, such as Nanchang, Yingtan, Shangrao, Changsha, to Shanghai's dependency index also enter the top 30. The cities of the top 30 of dependency index gather in Nanjing to Shanghai, Shanghai to Hangzhou, but are relatively sparse between Hang Yongtwins, as is shown in **Figure 3**. Comparing **Figure 2** with **Figure 3**, it is not difficult to find that there is great overlapin the dependency index between the sample cities and the cities of the top 30 of dependency index. The latter's concentration degree between Shanghai-Hangzhou, Shanghai-Nanjing and Hang Yong is higher than the former. The top 30 cities of dependency index are shown in **Table 5**.

3.3. Comparison on the Adsorption Capacity of Hang Yong Twins to Hinterland Cities

Given that city's absorption index meets with additivity principle, we subtract Hang Yong twins' adsorption index to hinterland cities, then get the "net effect" that the twins have on their respective hinterland cities. To ma-

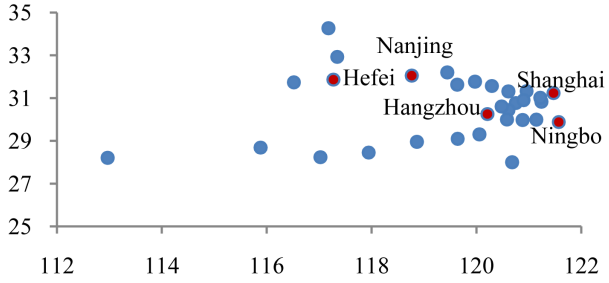

Figure 3. The spatial distribution of the top 30 cities toward Shanghai Dependency index. Note: **Figure 2** and **Figure 3** respectively combined with data of **Table 3** and **Table 4**, draw according to the city's latitude and longitude.

Table 4. Passenger trains contact and dependency index between core cities in the Yangtze river delta.

Contact direction	Dependency index	Contact direction	Dependency index	Contact direction	Dependency index	Contact direction	Dependency index	Contact direction	Dependency index
Hangzhou to Shanghai	525.10	Nanjing to Shanghai	884.55	Hangzhou to Ningbo	239.20	Hangzhou to Hefei	52.00	Ningbo to Hefei	36.60
Shanghai to Hangzhou	340.20	Shanghai to Nanjing	634.30	Ningbo to Hangzhou	179.30	Hefei to Hangzhou	87.95	Hefei to Ningbo	49.75
Ningbo to Shanghai	171.10	Hefei to Shanghai	174.50	Hangzhou to Nanjing	240.40	Ningbo to Nanjing	121.40	Nanjing to hefei	86.00
Shanghai to Ningbo	108.95	Shanghai to Hefei	127.50	Nanjing to Hangzhou	254.15	Nanjing to Ningbo	112.85	Hefei to Nanjing	135.00

Note: According the results by author's calculation, then sort out this table.

Table 5. Dependency index and its rank of hinterland cities to Shanghai (At the top of 30).

Rank	City	Dependency index	Rank	City	Dependency index	Rank	City	Dependency index
1	Nanjing	884.55	11	Danyang	288.70	21	Quzhou	128.45
2	Suzhou	769.05	12	Jinhua	204.90	22	Changsha	124.05
3	Wuxi	671.40	13	Hefei	174.50	23	Bengbu	121.30
4	Changzhou	616.15	14	Ningbo	171.10	24	Jiashan	114.40
5	Hangzhou	525.10	15	Yiwu	168.40	25	Yuyao	112.80
6	Zhenjiang	485.50	16	Nanchang	163.90	26	Wenzhou	108.40
7	Kunshan	398.70	17	Yingtan	155.35	27	Tongxiang	107.20
8	Jiaxing	369.40	18	Haining	154.90	28	Songjiang	101.90
9	Jinshan	335.30	19	Shaoxing	152.10	29	Luan	99.00
10	Xuzhou	298.00	20	Shangrao	128.80	30	Shangyu	97.50

Note: According the results by author's calculation, then sort out this table.

jority sample cities, Hangzhou's radiation is more significant than Ningbo's, and Ningbo's radiation, only to Shaoxing, Shangyu, Yuyao, Ninghai, Linhai, Taizhou, Shen Fang, Chizhou, Cangnan, Fuzhou, Wenling, Yueqing, Yongjia, Xiapu, Fuding, Ningde, Lin'an, Rui'an and other 19 cities, is relatively strong. These cities, except for Shaoxing, Yuyao and Shangyu, mainly gather in Yong Tai Wen Railway along. Except the cities mentioned above, Ningbo's radiation to the other sample cities is less significant than Hangzhou's. The "net effect" which Hang Yong has on their respective hinterland cities is shown in **Table 6**.

3.4. Urban Population Agglomeration Potential under the Center-Periphery Pattern

Spatial interaction model shows that, the larger the scale of the urban population, the more potential inter-city

Table 6. Comparison on the net adsorption capacity of Hang Yong twins to hinterland cities.

City	Hangzhou's Absorption	Ninbo's Absorption	Comparison	City	Hangzhou's Absorption	Ninbo's Absorption	Comparison
Shaoxing	161.20	211.50	−50.30	Haiyan	0.00	0.00	0.00
Shangyu	81.90	85.35	−3.45	Jinhua	195.70	9.75	185.95
Yuyao	109.60	123.15	−13.55	Yiwu	158.75	9.75	149.00
Yuhang	61.00	35.20	25.80	Huzhou	146.60	64.50	82.10
Shanghai	347.40	108.95	238.45	Tongxiang	113.20	34.40	78.80
Nanjing	254.15	112.85	141.30	Yushan	35.05	11.05	24.00
Suzhou	76.20	39.55	36.65	Shangrao	121.85	9.75	112.10
Wuxi	75.30	39.55	35.75	Zhuji	100.60	9.10	91.50
Changzhou	72.45	39.95	32.50	Fenghua	10.80	10.80	0.00
Ninghai	38.80	31.80	7.00	Xuancheng	20.85	10.40	10.45
Linhai	30.00	33.90	−3.90	Wuhu	19.05	10.40	8.65
Taizhou	103.50	108.30	−4.80	Liyang	90.20	34.00	56.20
Deqing	101.45	43.55	57.90	Songjiang	50.90	17.80	33.10
Jvrong	24.80	20.00	4.80	Jiangning	28.80	9.40	19.40
Cangnan	39.80	42.00	−2.20	Jinshan	36.80	19.20	17.60
Wenzhou	137.60	125.10	12.50	Lishui	7.20	0.00	7.20
Wenling	68.20	65.10	3.10	Kunshan	40.50	24.80	15.70
Leqing	30.10	25.20	4.90	Huishan	2.40	0.00	2.40
Yongjia	24.30	22.20	2.10	Danyang	33.20	16.80	16.40
Haining	107.65	29.35	78.30	Zhenjiang	55.55	30.40	25.15
Jiaxing	281.25	94.75	186.50	Changxing	96.05	34.00	62.05
Jiashan	88.90	33.00	55.90	Yixing	138.90	55.50	83.40
Pinghu	0.00	0.00	0.00	Feidong	17.70	16.70	1.00
Lishui	45.30	24.60	20.70	Ningde	36.00	47.40	−11.40
Quanjiao	33.10	25.20	7.90	Chunan	0.00	0.00	0.00
Hefei	87.95	49.75	38.20	Dongyang	0.00	0.00	0.00
Huainan	20.75	8.70	12.05	Yangzhou	1.20	0.00	1.20
Guangde	9.90	2.60	7.30	Xuzhou	97.50	39.75	57.75
Chuzhou	27.15	17.00	10.15	Nantong	1.20	0.00	1.20
Dingyuan	2.10	1.80	0.30	Bengbu	42.45	11.35	31.10
Anji	0.00	0.00	0.00	Tongling	0.90	1.95	−1.05
Linan	0.00	0.00	0.00	Huangshan	0.00	0.00	0.00
Sanmen	21.90	23.70	−1.80	Nanchang	141.50	13.45	128.05
Ruian	28.30	31.20	−2.90	Yingtan	131.40	16.90	114.50
Pingxiang	51.95	13.00	38.95	Quzhou	114.75	13.00	101.75

Continued

Liling	27.10	0.00	27.10	Zhousahn	0.00	0.00	0.00
Zhuzhou	32.20	7.80	24.40	Lianyungang	0.00	0.00	0.00
Changsha	83.00	5.60	77.40	Taizhou	1.20	0.00	1.20
Jiujiang	7.80	1.95	5.85	Huaian	0.00	0.00	0.00
Hukou	0.90	1.95	−1.05	Yancheng	0.00	0.00	0.00
Pengze	0.90	1.95	−1.05	Anji	0.00	0.00	0.00
Dongzhi	0.90	1.95	−1.05	Luan	26.80	15.85	10.95
Chizhou	0.90	1.95	−1.05	Bozhou	8.05	5.60	2.45
Fuzhou	61.80	71.10	−9.30	Maanshan	5.30	0.00	5.30
Xiapu	32.40	35.70	−3.30	Huaibei	0.90	0.00	0.90
Fuding	30.60	36.00	−5.40	Fuyang	10.90	5.60	5.30

Note: According the results by author's calculation, then sort out this table. "+" is the Hangzhou's "Net absorption", "−" is the Ningbo's "Net absorption", the size of the numerical represent the size of the "net absorption".

population flow. With Shanghai as the center, embedding the dependency index of the hinterland cities to Shanghai, we inversely deduce its "arrival" population scale, then generally judge the hinterland cities' population scale in deviation, growing space and flow direction, and reveal characteristics of population agglomeration and diffusion between hinterland city and Shanghai.

Dependency index of hinterland cities to Shanghai and its fitting resident population (2014) show strong positive correlation, as is showed in **Figure 4**, $R^2 = 0.3337$. Taking cities at prefecture level and above of Zhejiang Province and some of the major cities in the Yangtze River Delta as an example, according to the dependency index of hinterland cities to Shanghai, we fit their population scale. By comparing each hinterland city's fitting population and resident population, we find that, the fitting population scale of Jiaxing, Huzhou, Jinhua, Quzhou, Zhoushan, and Lishui in Zhejiang province, and Nanjing, Wuxi, and Changzhou in Jiangsu province is greater than their actual resident population scale in 2014. To a certain extent, these cities' population scale is "small", and there is still some room for its growth. The fitting population scale of Hangzhou, Ningbo, Wenzhou, Shaoxing, Taizhou, Suzhou and Hefei is smaller than the actual resident population scale, revealing better clustering ability. The result is shown in **Table 7**.

Compare changes on the resident population of cities at prefecture level and above in Zhejiang province since 2006, we find that except for Quzhou, the resident population showed an increasing trend in the rest cities before 2010. The resident population of Hangzhou, Ningbo, Shaoxing, Huzhou, Jiaxing, Jinhua, Zhoushan and Lishui in 2014 increased than that of 2013 Among them, Ningbo showed the largest growth, reaching 14.8 million people, followed by Hangzhou, with an increase of 4.8 million. Hang Yong twins both show great population clustering ability, and Quzhou remains constant, while the resident population of Wenzhou and Taizhou, which take on a greater population absorption ability, has decreased, as is shown in **Figure 5**.

4. Conclusions

Placing Hang Yong twins into the background of the Yangtze River Delta, the paper is based on the Dependency and Absorption index of railway passenger trains to depict the contact pattern between dual-core-type city and its hinterland, and to measure the "net effect" that two central cities of Zhejiang have on their respective hinterland city. By doing this, fit and compare the population agglomeration between Zhejiang province and the major cities in the Yangtze River Delta. The study finds that:

First, Hangzhou's radiation ability to the majority of sample cities is stronger than Ningbo's, and the cities which receive relatively strong radiation of Ningbo, mainly concentrate in Yong Tai Wen Railway along. Second, the fitting population scale of Hangzhou, Ningbo, Wenzhou, Shaoxing, Taizhou, Suzhou, Hefei and so on is smaller than their actual resident population scale, revealing better population agglomeration. Besides, for the cities like Jiaxing, Huzhou, Jinhua, Quzhou, Zhoushan, and Lishui in Zhejiang province, and Nanjing, Wuxi,

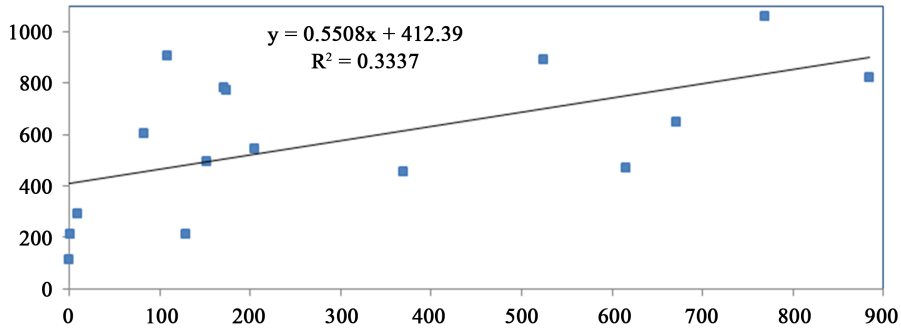

Figure 4. The relationship between Dependence index and the city's resident population (2014). Note: The figures are drawn according to the statistical bulletin of the city over the years and the author's calculation, the abscissa in **Figure 4** represents the Dependency index of part cities in Zhejiang and the Yangtze River Delta, toward Shanghai.

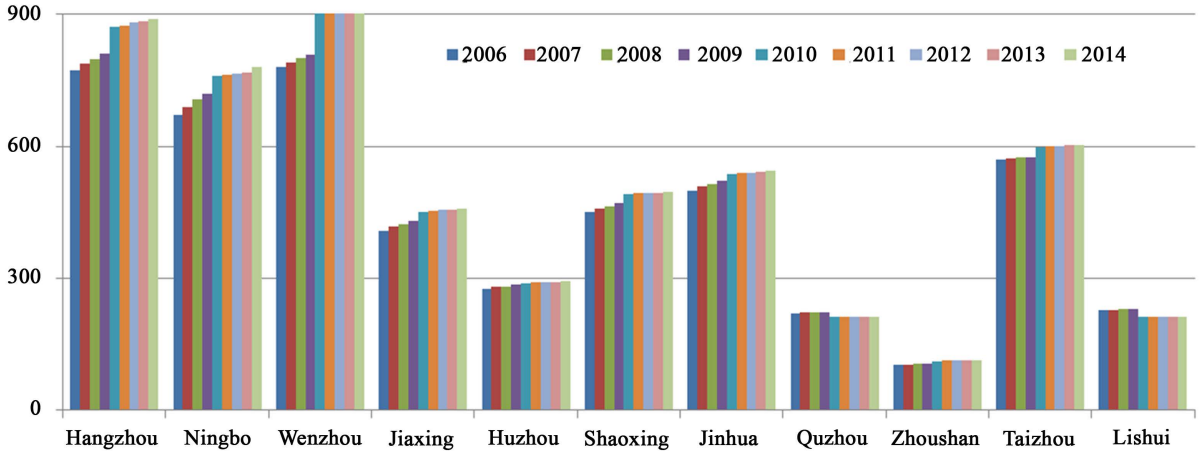

Figure 5. The resident population of major cities in Zhejiang province (2006-2014). Note: The figures are drawn according to the statistical bulletin of the city over the years and the author's calculation, the abscissa in **Figure 4** represents the Dependency index of part cities in Zhejiang and the Yangtze River Delta, toward Shanghai.

Table 7. The fitting population and deviation of Zhejiang province prefecture-level cities above and major cities in the Yangtze river delta.

Region	Dependency index	Resident population	Household population	Fitting population	Deviation	Region	Dependency index	Resident population	Household population	Fitting population	Deviation
Hangzhou	525.10	889.20	715.76	858.66	30.54	Zhoushan	0.00	114.60	97.49	344.90	−230.30
Ningbo	171.10	781.10	583.80	512.30	268.80	Taizhou	82.60	601.50	597.10	425.72	175.78
Wenzhou	108.40	906.80	813.69	450.96	455.84	Lishui	0.90	213.10	265.65	345.78	−132.68
Jiaxing	369.40	457.00	348.14	706.32	−249.32	Nanjing	884.55	821.61	648.72	899.60	−77.99
Huzhou	9.10	293.00	263.78	353.80	−60.80	Suzhou	769.05	1060.40	661.08	835.98	224.42
Shaoxing	152.10	495.60	443.04	493.71	1.89	Wuxi	671.40	650.01	477.14	782.20	−132.19
Jinhua	204.90	543.70	475.07	545.37	−1.67	Changzhou	616.15	469.60	368.60	751.77	−282.17
Quzhou	128.45	212.40	255.67	470.58	−258.18	Hefei	174.50	769.60	712.81	508.50	261.10

Note: "+"indicates "too much"; "–" indicates "inadequate", thus there still remains a huge space to absorb the population.

Changzhou in Jiangsu province, their fitting population scale is greater than their actual resident population scale in 2014. To some extent, these cities' population scale is "small", and there is still some room for its growth; while the resident population of Wenzhou and Taizhou, which take on a greater population absorption ability, has decreased, and the population "scramble" phenomenon between cities has begun to appear.

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