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**| RESEARCH ARTICLE**

# Shaping a Polycentric Metropolis: A Case Study of the Intra-city Polycentricity of the Yangtze River Delta

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**| ABSTRACT**
The Yangtze River Delta (YRD) has emerged to become one of the most populous metropolises in the mainland China those days. While the government has reinforced the coordination of major cities located in the YRD, multiple issues have been found to interfere with the city agglomeration of the metropolis area. The objective of the study is to reveal the level of intra-city polycentricity of the cities in the YRD and provide possible solutions to improve the intra-city polycentricity. The study suggests that 63% of cities in the YRD have 2 or more centres and have an average polycentricity measure of 0.5449. Furthermore, the study suggests that most of the large cities have attempted to develop a polycentric urban system, though the development of intra-city centres is unbalanced.

**| KEYWORDS**

China, Urban Development, Polycentricity, Yangtze River Delta, Intra-city

**| ARTICLE INFORMATION**

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## 1. Introduction

Recently, numerous works of literature have emphasised city agglomeration (Burgess, 2022; Faggio et al., 2020). Through the use of transportation networks, geographically close-by cities of different sizes and types have created urban agglomerations throughout Western Europe and North America. The alteration of the urban spatial structure must therefore accommodate a far wider and more varied region (Zhang et al., 2020). Thus, a better urban agglomeration is needed to obfuscate the distinctions between individual regions. The YRD appears to be a suitable region for urban agglomeration between cities and suburban areas. The YRD has a history of being the economic centre of eastern China since the 12th century (Song Dynasty). While most of the residents of the YRD share similar dialects and cultures, it also holds multiple ports and rivers, making the delta a strategic place for both domestic and international trade. The integration plan of the delta began in 1982, with a proposition of a series of meetings of the governors of the related cities and provinces in the delta. The meeting was quickly cancelled, followed by the revitalization of Pudong (a municipal district in Shanghai) and replaced by a representative team of 14 major cities from the delta. While the coordinated development of the YRD has drawn attention from different backgrounds, it was officially proposed by the State Congress of China as one of the major strategic planning of city development in 2019.

Although the YRD appears to be a gigantic modern economic centre in the far east, which contributes around 23.61% of the total GDP of China, the YRD still faces multiple challenges in the balance of development of different cities, social and economic transfer, market integration, etc. Followed by the "New Form of Urbanisation Strategy", the polycentric urban system started to manifest its place in national urbanisation plans (Zhang et al., 2020). Multiple cities started to build satellite cities to ease the overconcentration of the traditional city centre. For instance, the plan to relocate the municipal administration of Beijing, together with tens of thousands of employees and other supporting functions, from the congested old city to a satellite town is an example of the push for polycentricity (Liu & Wang, 2016). Moreover, according to research conducted by China's National Reform and Development

Commission, 133 out of 144 prefectural level cities featured in the research intend to create or develop new districts or towns outside of their original metropolitan cores. Although several kinds of literature on the coordinated development of the YRD have emphasised the importance of inter-city linkage, little has analysed the connectivity of the internal regional structure of the cities in the YRD. While the National Statistics has witnessed a gradual fall in the ratio of GDP between Shanghai and the other 5 major cities, the difference in economic growth is still significant in other suburban areas such as western Zhejiang and northern Suzhou. Therefore, one may argue that the distribution of resources and economic activity may be unbalanced across the cities in the delta. This study will focus on the intra-city polycentricity of the cities of YRD and provide an explanatory analysis.

## 2. Material and Data

### *2.1 Definition and Measurements of Polycentricity*

The debate over the distribution of power between monopolisation and regionalization has troubled scholars for some time. Many have argued that the drastic urbanisation of a single city would lead to the uneven development of other cities in the area. One may notice that a number of megalopolises have emerged to avoid this situation, whereas other metropolitan areas, such as Greater London, Frankfurt Rhine Maine, and Tokyo, have formed urban agglomerations through transportation and other policies to break the geographical boundaries of each city (Zhang et al., 2020). Meijers et al. (2007) suggest that polycentrism would be a solution to maintain a separate economic cluster but also be interdependent at the same time. Zhang et al. (2020)state that, unlike the concentric ring model and multi-centre model, polycentric urban regions emphasise urban agglomeration in inter-city and intra-city scales. While much literature has discussed polycentrism at an inter-city level, this paper will focus on the intra-city level. An intra-city polycentrism can be viewed as a shift of city development from a metropolitan to a more regionalized manner; it will redistribute resources from a city centre to another centre to ensure the emergence of new economic clusters outside the traditional CBD. Henderson (2000) also states that compared with the monocentric model; a polycentric system is more suitable for economic growth. He suggests that if an urban system is too concentrated, it may result in diseconomies. Moreover, polycentrism was adopted by 18 countries which participated in the European Spatial Planning Observation Network (ESPON) project as the primary policy in their national planning (Zhang et al., 2020). However, Meijers (2008) also points out that polycentrism may lead to other difficulties in transportation and a possible decline in sports and cultural amenities. He points out that compared to the monocentric model, a polycentric metropolis area will make travel flows less convenient.

The measurement of polycentricity varies across the literature (Derudder et al., 2021; Meijers, 2008; Sarkar et al., 2020). Most approaches to measuring polycentricity focus on either morphology or functionality, which widely covers both the connectivity and flow-based views (Sarkar et al., 2020). Liu and Wang (2016) have recently concluded that the measurements of polycentricity have three different approaches. The first approach to measuring polycentricity is based on the statistical interpretation (regression or standard deviation) of the rank-size distribution of centres inside a city (Liu & Wang, 2016). While this method has been revised to reduce small sample bias, other literature has argued that this approach may not be straightforward due to its difficulty in standardising ranked-size data (Green, 2007). The second approach refers to the cross measurement of equality measures, such as the Gini coefficient (Liu & Wang, 2016), while statistical data for this measurement can be hard to collect and compute. Nevertheless, Green (2007) has suggested another normative measurement to determine the functional polycentricity of different centres in any physical space. Formally, let *P* be the polycentricity for a given physical space, and the function of *P* becomes:

$$P = 1 - \frac{\sigma_{obs}}{\sigma_{max}} \quad (1)$$

It indicates the standard deviation of significance (such as population or GDP) of centres within a given physical space and indicates the standard deviation of a centre with zero significance and a centre with maximum significance. On the other hand, if the given physical space has only one city centre, it will have a minimum value of 0, which indicates no existing polycentrism in the area. On the other hand, it will have a maximum value of 1 when the given space has perfect polycentrism. Moreover, researchers are continuously improving the measurements of polycentricity. For instance, the ESPON has designed a group of sophisticated indicators for measuring the polycentricity of the EU nations, which requires a large amount of data from each nation (Meijers, 2008). Thus, this paper will use Green's (2007) measures to determine the polycentricity of the YRD.

### *2.2 Materials and Data*

The identification of the centres is important to the measurements of the polycentricity. Despite the fact that the scholarship still holds many arguments on what constitutes an "urban core," there is no consensus among scholars regarding the standards that should be applied to defining urban centres. Leslie (2010) contends that the density of population, employment, and business activities are essential to the contemporary definition of city centres. Furthermore, Derudder et al. (2021) suggest that an effective comparison between various research and measurement frameworks must take into account the applicability of a number of essential dimensions, of which two are relevant here: (1) a "centre" must be carefully defined, and (2) there must also be an understanding of the "balance" between those centres (Derudder et al., 2021). Overall, there is substantial literature mentioning the methods of identifying urban centres, which depend on different spatial units (such as census tracts and regular grids) and

diverse criteria (such as population size, employment size, and the mix of land use) (Liu & Wang, 2016). Although recent studies have updated the criterion that is used to identify urban centres, this paper will use the conventional method to identify urban centres, in which some cut-offs of population density and total population are selected to classify the centres in the given physical space; whereas the selected city centres will have a population density above the minimum cutoff and total population, while the other physical spaces outside the centres will be neglected in the study.

This part of the paper will focus on the polycentricity of the YRD. The YRD is composed of three provincial bodies (Zhejiang, Jiangsu, Anhui) and one direct-administrated municipality (Shanghai). The delta comprises 37 prefectural cities, 3 sub-provincial cities, and 1 municipality, while these cities are made up of 291 individual counties or districts. This study will utilise the population, city territorial size, and population density data of 291 individual counties from the Statistical Yearbook of each province and municipality in 2021 to create the population density profile. The minimum cutoff and total population will be generated to determine the urban centres in the selected cities.

**3. Results**

This study has primarily examined the population density and total population of the 41 cities in the YRD, while the test generated a minimum cutoff of 1000 people per sq. km and a total population cutoff of 20,000 people in the given physical spaces. Throughout the test, 14 out of 41 cities are eliminated from the study of polycentricity due to the failure to locate centres in these cities. A standard Green's (2007) measure of polycentricity (Eq. 1) was adopted to determine the polycentricity of the rest of the 27 cities in the YRD. However, the study has failed to measure the polycentricity of 10 cities in the sample since they only have 1 centre identified, whereas 17 cities with 2 or more centres are adopted to measure their individual polycentricity.

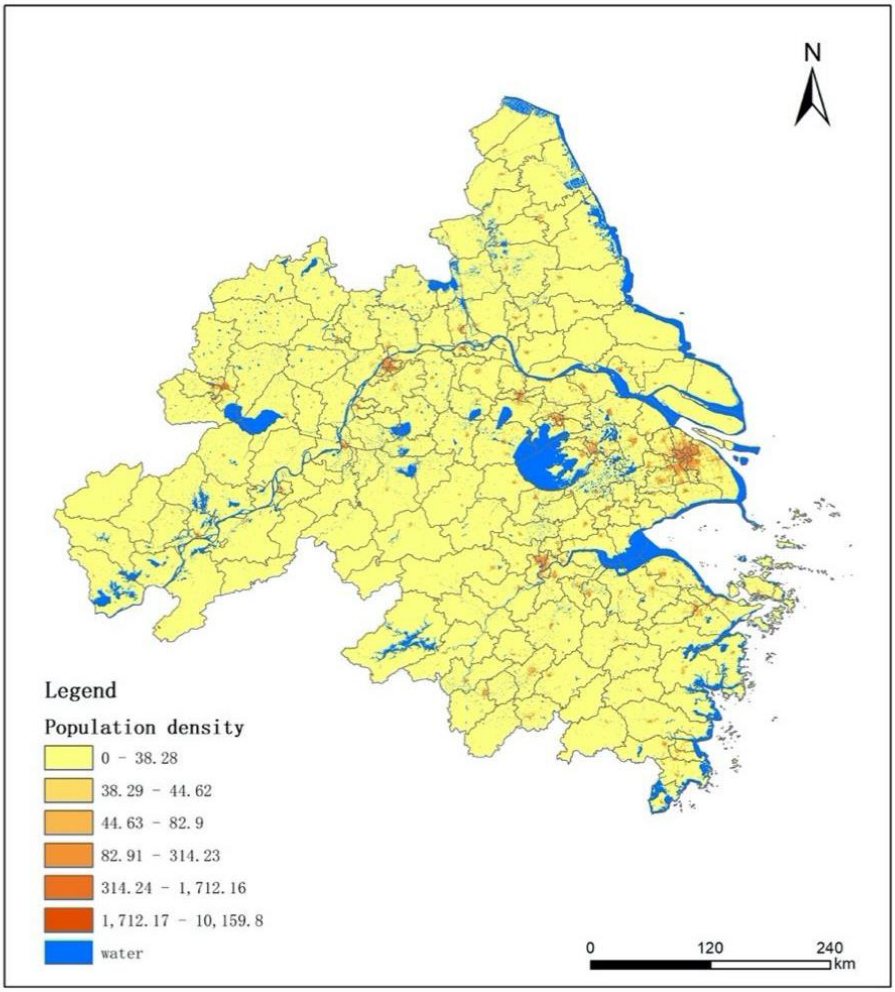


Figure 1. The population density of cities in the YRD.
Data collection and statistics by authors

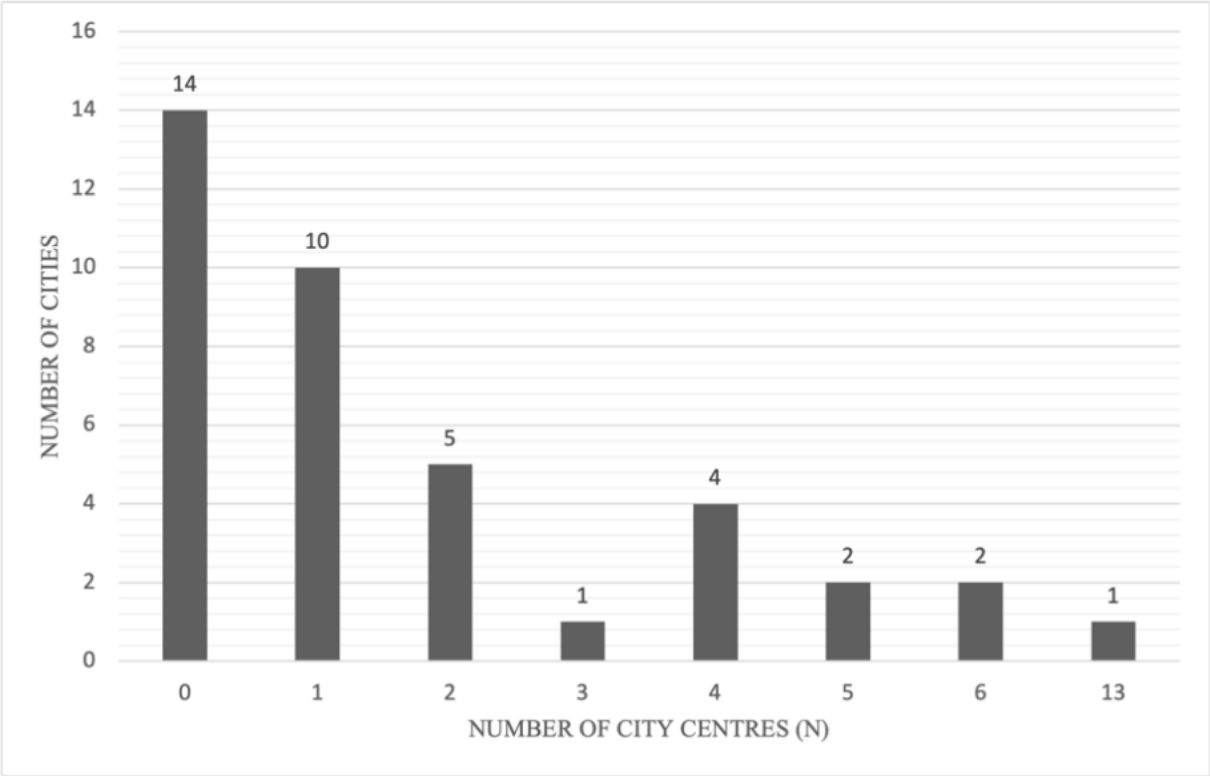


Figure 2. Number of city centres in the 41 cities.
Data collection and statistics by authors

### *3.1 The Polycentricity of the Selected Cities*

As Fig. 1 shows, the population density is unevenly distributed over the cities in the YRD. One may notice that most of the population is located in the eastern part of the YRD, where the megapolises like Shanghai, Nanjing, and Hangzhou meets, which is also shown by the ranking of the city centres. Although inter-city agglomeration is important for city development, this study of the polycentricity of YRD cities focuses on the intra-city level, as the measure of the polycentricity is based on the distribution of the population of an individual city across each city centre. The study has found that 63% of cities with centres identified have 2 or more centres, whereas the number of city centres ranges from 2 to 13, with an average of 4 and a mode of 2; whilst the polycentricity measure (P) ranges from 0 to 0.9582, with an average of 0.5449.

Table 1 summarised the ranking of the number of city centres (N), the total population, and the polycentricity (*P*) of each city, from the largest to the smallest. While 24 out of 41 cities in the YRD have less than 2 city centres identified, the test failed to define the polycentricity of these cities. Thus, the analysis will focus on the sample of the 17 cities that remained.

Table 1. Ranking of the selected YRD cities in terms of city centres, total population, and polycentricity

| **Name** | **Ranking** | **City Centres (N)** | **Name** | **Ranking** | **Total Population** | **Name** | **Ranking** | **Polycentricity (*P*)** |
|---|---|---|---|---|---|---|---|---|
| **Shanghai** | 1 | 13 | Shanghai | 1 | 24,870,895 | Huainan | 1 | 0.9582 |
| **Hangzhou** | 2 | 6 | Suzhou | 2 | 12,748,262 | Ningbo | 2 | 0.8494 |
| **Nanjing** | 2 | 6 | Hangzhou | 3 | 11,936.010 | Ma'anshan | 3 | 0.7409 |
| **Suzhou** | 4 | 5 | Wenzhou | 4 | 9,572,903 | Nantong | 4 | 0.6736 |
| **Wuxi** | 4 | 5 | Ningbo | 5 | 9,404,283 | Taizhou | 5 | 0.6614 |
| **Changzhou** | 6 | 4 | Hefei | 6 | 9,369,881 | Zhenjiang | 6 | 0.6339 |
| **Hefei** | 6 | 4 | Nanjing | 7 | 9,314,685 | Changzhou | 7 | 0.5898 |
| **Ningbo** | 6 | 4 | Xuzhou | 8 | 9,083,790 | Wenzhou | 8 | 0.5855 |
| **Taizhou** | 6 | 4 | Nantong | 9 | 7,726,635 | Hefei | 9 | 0.5241 |
| **Wenzhou** | 6 | 4 | Wuxi | 10 | 7,462,135 | Suzhou | 10 | 0.4663 |
| **Xuzhou** | 11 | 3 | Taizhou | 11 | 6,622,888 | Bengbu | 11 | 0.4409 |
| **Bengbu** | 12 | 2 | Changzhou | 12 | 5,278,121 | Xuzhou | 12 | 0.4314 |
| **Huainan** | 12 | 2 | Wuhu | 13 | 3.644,420 | Wuhu | 13 | 0.3930 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Ma'anshan** | 12 | 2 | Bengbu | 14 | 3,296,408 | Hangzhou | 14 | 0.3921 |
| **Nantong** | 12 | 2 | Zhenjiang | 15 | 3,210,418 | Wuxi | 15 | 0.3201 |
| **Wuhu** | 12 | 2 | Huainan | 16 | 3,033,528 | Shanghai | 16 | 0.3190 |
| **Zhenjiang** | 12 | 2 | Ma'anshan | 17 | 2,159,930 | Nanjing | 17 | 0.2843 |

Data collection and statistics by authors.

As table 1 suggests, around 50% of cities have city centres around 1-4, and a polycentricity measure ranges from 0 to 0.50, in which Shanghai has the highest number of centres (13), and Huainan has the highest number of polycentricity (0.9582). Moreover, the number of centres (N) and the polycentricity measure also vary between the cities listed; whilst the number of centres (N) has a standard deviation of 2.6095, and the polycentricity measure has a standard deviation of 0.1863.

### *3.2 The Analysis of Regression*

As Table 1 shows, most of the cities with high polycentricity have a relatively lower number of city centres compared with the cities with low polycentricity. Therefore, it is reasonable to assume that polycentricity has a negative relationship with the number of centres (N). After the calculation, the study found that the polycentricity is negatively correlated with the number of centres (N) with a correlation coefficient of -0.5073. This study has also performed a linear regression analysis of the relationship between the polycentricity and the number of centres (N):

$$P = \beta_0 + \beta_1 N \tag{2}$$

Table 2 summarises the results of the linear regression analysis, with an R-squared value of 0.3275697, which shows a moderate relationship between the polycentricity and the number of centres (N).

Table 2. The regression analysis of polycentricity

| | ***Coefficients*** | ***Standard Error*** | ***t Stat*** | ***P-value*** | ***Lower 95%*** | ***Upper 95%*** |
|---|---|---|---|---|---|---|
| **Intercepts** | 0.7280274 | 0.0782040 | 9.3093362 | 2.2497665 | 0.8957584 | 0.8957584 |
| **N** | -0.0408461 | 0.0156408 | -2.6115132 | -0.0743923 | -0.0072999 | -0.0072999 |

| **Regression Statistics** | |
|---|---|
| **Multiple R** | 0.5723371 |
| **R Square** | 0.3275697 |
| **Adjusted R Square** | 0.2795390 |
| **Standard Error** | 0.1647860 |
| **Observations** | 17 |

Data collection and statistics by authors

The curve has an intercept of 0.7280274 and a coefficient of -0.0408461. In general, polycentricity is negatively associated with the number of centres (N), whereas an increase of one more identification of city centre will lead to a decrease of 0.0408461 to the value of polycentricity. This result is consistent with the previous assumption, while the standard error of 0.1647860 suggests that numbers of other determinants are also affecting the polycentricity measure.

## 4. Discussion

While multiple cities in the YRD have shown some extent of polycentrism, it is important to notice the uneven development between the cities and the intra-city regions, especially for large cities (cities with a high total population listed in table 1) in the YRD. Most cities with high polycentricity are cities with a small population or unique geographical characteristics. As suggested in table 1, 3 out of the first 5 cities in the ranking of polycentricity (P) have only 2 city centres identified, which is below the average of 4, whereas Taizhou is known for its mountainous geographic features and Ningbo has a complex water system to naturally isolate residents. Though a high number of city centres should lead to a correspondingly high value of polycentricity, according to the ranking of the total population stated in table 1, the 8 most populous cities have an average of 0.4815, which is below the average of the sample. Even though many of these large cities have attempted to develop multiple city centres to ease the crowdedness of the traditional CBD, the study has indicated that the population is unevenly distributed across the individual city centres in the large cities, as the largest centre tends to be a dominant centre compared to others. This phenomenon is also mentioned in other literature studies on the polycentricity of Chinese cities (Liu & Wang, 2016). Despite the fact that large cities such as Shanghai and Nanjing have more than 6 city centres, the most populous centre in Shanghai has a population density that is almost 2300% higher than the population density of the least populous centre, whereas the most populous centre in Nanjing

has a population density that is 1400% higher than the population density of the least populous centre. As a result, the significant differences in the population density of city centres in large cities like Nanjing and Shanghai have led to a fall in their polycentricity.

Developing suburban city centres might be a solution to achieve higher polycentrism. Thus, it would be helpful to draw experience from other successful cases. Frankfurt Rhine Main, a large metropolitan region that stretches over parts of three states in Germany, has practised a polycentric urban system since the late 20th century. Whilst suburban areas may have multiple disadvantages in the park due to the inconvenience of transportation and other public facilities; those areas are now characterized by well-designed infrastructure, business parks, and international centres (Helbrecht & Dirksmeier, 2009). The suburbanization of Frankfurt Rhine Main has successfully decentralized business activities and led to a continuous division of labour between cities and suburbs, together with an increasing differentiation of business in cities and suburbs (Jansen et al., 2017). Jansen et al. (2017) also state that along with suburbanization, policymakers have cooperated with private sectors to reshape their orientations and focus more on the sustainable development of the metropolitan region than economic growth. Thus, by comparing the polycentric urban system in the Frankfurt Rhine Main, it appears to be essential to shift some of the resources from the more populous city centres to the less populous city centre and utilise some of the suburban regions to develop new centres.

## 5. Conclusion

In conclusion, by offering a systematic evaluation of the polycentricity of the YRD cities at the intra-city level and generating tentative but crucial hypotheses about the relationship between polycentric cities and the number of centres, this study has contributed to the literature on polycentric urban development. This study has identified the centres of 27 cities in the YRD and provides an explanatory measure of the polycentricity of the cities selected. The result shows that roughly 70% of cities in the YRD have fewer than 2 centres, and half of the cities are monocentric. Moreover, the regression suggests that most of the large cities, which have multiple centres identified, have performed poorly in polycentric urban development, whereas the cities that have fewer centres or unique geographical features generally perform better in the polycentricity test.

Overall, the analysis of the polycentricity of the YRD still faces several limitations. Firstly, the current identification of centres is based on the population density of each county in the individual cities. The identification will be more accurate when the details of other factors, such as employment rate, are available. Secondly, this study now focuses on the polycentricity of the YRD cities on an intra-city level, though an inter-city level measure of the polycentricity may present a different result. Thirdly, this study may generate a diverse conclusion by choosing a morphological measure of polycentricity as a functional measure of the polycentricity of the YRD cities.

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