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Research Paper

Is polycentricity a promising tool to reduce regional economic disparities? Evidence from China's prefectural regions

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ABSTRACT

Although polycentrism is widely regarded by city planners and policymakers as a potential solution for reducing regional disparities, there is currently little empirical basis for accepting or rejecting this claim. Our study aims to fill this empirical gap by providing reliable evidence as to whether or not a polycentric urban structure can reduce regional economic disparities. However, we reach a counter-intuitive result: monocentricity, from the morphological perspective, is robustly associated with less territorial economic disparity in China's prefectural regions. Further analyses illustrate that the core cities in monocentric regions can share the benefits of agglomeration through labor mobility, and monocentricity does not introduce an extra agglomeration shadow. Meanwhile, cities within polycentric regions may not "borrow" as much function or performance from each other as expected. These results suggest that polycentric-oriented spatial strategy, at least in terms of morphology, may not be an appropriate policy to enhance cohesion in China.

1. Introduction

Polycentricity is currently a buzzword in regional development. Conceived by planners and policymakers, polycentricity is considered a useful policy tool to level out differences among regions and generate a more balanced territorial development (Baudelle & Peyrony, 2005; CEC, 1999; Rauhut, 2017). However, this assumed relationship between a polycentric urban spatial structure and reduced regional disparities lacks sufficient empirical justification. In fact, there is a long-standing lack of empirical evidence to support the validity and reliability of polycentric growth. According to Meijers (2008, p. 1314), "it appears that there are at present no conclusive answers regarding the question of whether polycentricity is instrumental to achieving economic competitiveness, territorial cohesion, and environmental sustainability." Rauhut (2017) believes that Meijers's conclusion still holds to today. Moreover, an increasing number of urban planners and policymakers use the concept of polycentricity to bolster the continued progress towards polycentric development in China (Wang, Sun, Qiao, & Zhou, 2012). Likewise, few empirical studies support the validity of this polycentric-oriented development in China.

The primary aim of this paper is to assess whether or not a polycentric spatial structure can account for fewer intra-region economic disparities in China. Our study contributes to the literature in at least two important ways. First, this paper fills the empirical gap by providing reliable evidence as to whether a polycentric spatial structure is useful in reducing regional economic disparities. Research on this topic is surprisingly rare and lacks reliable econometric analysis (Hāzners & Jirgena, 2013; Lotfi, Shahmiri, & Roushenas, 2015; Malý, 2016a; Meijers & Sandberg, 2008; Veneri & Burgalassi, 2012). Our work is one of the first such quantitative attempts, and we are careful to establish this causal relationship by using two-stage least squares (TSLS) regressions and serious robustness checks. Second, this paper also sheds light on our counter-intuitive finding, i.e., why monocentricity can, or polycentricity cannot, reduce regional economic disparities. Although previous studies have already arrived at this conclusion, none of them provide further evidence to explain it (Malý, 2016a; Meijers & Sandberg, 2008).

The paper is structured as follows. The next section reviews polycentricity and its development in China, the theoretical explanations of poly-/monocentricity and regional economic disparities, and the findings of previous empirical studies. This is followed by a discussion of data, model, and estimation strategy in Section 3, after which we present our empirical results in Section 4. Sections 5 and 6 explore the possible reasons for our counter-intuitive finding. The last section sums the results and concludes.

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2. Literature review

2.1. Polycentricity and its development in China

Polycentricity has been widely criticized for its ambiguity (Meijers, 2008; Rauhut, 2017), which lies mainly in its definition and measurement. Without a universally accepted definition, polycentricity seems to mean different things at different scales and to different authors (Meijers, Waterhout, & Zonneveld, 2007; Rauhut, 2017; Van Meeteren, Poorthuis, Derudder, & Witlox, 2016; Waterhout, 2008). Moreover, because of its vague definition, several disparate approaches have been utilized in measuring it. Broadly speaking, there are two different perspectives, morphological and functional, to approach the meaning of poly-/monocentricity in the previous literature. While defining morphological poly-/monocentricity mainly focuses on the size and territorial distribution of urban areas in a given territory, functional poly-/monocentricity is based on the networks of flows and cooperation among urban areas. Following Meijers and Burger (2010), we adopt the first approach in this paper to measure poly-/monocentricity in its morphological aspect, which was considered the first and least restrictive way of understanding the spatial structure. Hence, we will refer herein to polycentricity as the even distribution of urban population among multiple cities within a prefectural region and to monocentricity as the uneven distribution of urban population, which is dominated by the core cities.

As for the application of this concept, polycentricity has its roots in the framework of the nonbinding European spatial planning tradition. However, introducing this polycentric trend in China's spatial development cannot be conceived as being affected by European-originated polycentricity at the outset, and this is especially true at the national level. In fact, this national or 'macro' scale is one of the two primary scales applying polycentric development in China.

At the national scale, the orientation towards polycentricity mainly refers to the long-term small-city-biased urban development policy in China (Kamal-Chaoui, Edward, & Zhang, 2009; Wu & Zhang, 2007). In 1989, the National Urban Planning Law offcially confirmed the three cornerstones of China's national urbanization policy, i.e., "control the size of large cities, rationally develop medium-sized cities, and encourage the growth of small cities." The following National Eighth Five Year Plan (1991–1995) and National Economic and Social Development of 10-years Plan (1991–2000) were reiterations of this policy orientation. Even though this small-city-biased policy was replaced by the "coordinated development of large, medium, and small-sized cities" after 2000, controlling the size of big cities still plays an important role in practice currently. The primary reasons for giving priority to the development of small cities in China are to fuel the growth of its surrounding rural areas (Wen, 2000) and to promote the rational distribution of productivity and population to achieve a balanced development (ESD & EFYP, 1991; UPL, 1989). Avoiding a possible future "city disease" is another critical concern. In addition, without using the specific term 'polycentricity', this small-city-biased policy fostering balanced development is in line with the spirit of polycentricity in Europe.

Polycentricity in China has also been widely adopted at the urban regional scale. It is widely believed that polycentricity at this level is deeply affected by European-derived polycentricity. Cheng and Shaw (2018) maintain that the idea of polycentricity had been articulated in a number of super/mega-city regions' master plans across China at the end of the 20th century. For example, the Shanghai Urban Master Plan (1999–2020) proposes a modern regional urban system with 'multi-cores', which was regarded as the first example of polycentric spatial structure and the first application of polycentricity to master planning in China. The Beijing City Master Plan (2004–2020) proposes a more integrated spatial structure comprising 'multi-centers', and the establishment of *Xiong'an* New Area is the latest typical application of polycentricity. In addition, the City Master Plan of Guangzhou for 2001–2020 introduces the idea of transforming its urban spatial structure from monocentricity to polycentricity along the Pearl River.

Although the term polycentricity is used in China, the advocacy argument for adopting polycentricity in Chinese mega-cities is primarily used to overcome the diseconomies of agglomeration associated with monocentric urban forms. Moreover, the agglomeration diseconomies are becoming increasingly serious currently. According to Fang, Gu, Xiong, and Zhou (2016), house prices in Beijing increased 660% from 2003 to 2013, and the city's average daily congestion time was approximately 2 h and 40 min in 2017 (BTAR, 2018). As an added benefit, this transition of spatial structure in city regions may provide further opportunities for lagging sub-centers and, thus, may help the balanced development within the region. This is in line with the motivation behind polycentric development in Europe. Moreover, different variations of polycentricity terminology are used at this level, including multi-cores, multi-clusters, clustered spatial layout, and others.

2.2. Theoretical background of poly-/monocentricity and regional economic disparities

Disparities among cities are, to some extent, inevitable; nevertheless, a widely held view is that uneven regional development can undermine social cohesion and generate political tensions in the long run (Breinlich, Ottaviano, & Temple, 2014). Meanwhile, there appears to be equity inherent in the polycentric development pattern (Baudelle & Peyrony, 2005; Rauhut, 2017). According to Meijers and Sandberg (2008), polycentric development is more or less synonymous with balanced urban or territorial development. However, there is a weak theoretical underpinning in explaining the connection between polycentricity and regional disparity (Copus, 2001; Meijers & Sandberg, 2008), much less to explain the common counter-intuitive finding that monocentricity leads to a reduction in territorial economic disparities. Fortunately, we can borrow ideas from related theories.

2.2.1. Agglomeration economies and diseconomies

Agglomeration economies—the clustering of economic activity created and sustained by a virtuous cycle—have been regarded as the driving force of growth (Fujita & Thisse, 2002, p. 391). Nevertheless, agglomeration is believed to be a win-lose bargain (Baldwin & Martin, 2004), particularly when examining the core cities and secondary cities separately. To be more specific, the core cities featured with a higher degree of spatial concentration typically enjoy an increase in economic growth and welfare, because of easily shared public facilities and infrastructure, the significant improvement in probability and quality of matching, and the efficient diffusion and accumulation of information/knowledge (Duranton & Puga, 2004). At the same time, the secondary cities may shrink due to the outflow of scarce resources. This inevitably gives rise to the emergence of regional imbalances, such as real per capita income increases in the core cities and declines in the secondary cities. Therefore, we may conclude that a monocentric region, dominated by a large core-city and together with a number of secondary cities, is more likely associated with imbalanced territorial development; a polycentric region, characterized by a series of cities that do not differ greatly in terms of size or agglomeration economies, is more likely associated with balanced territorial development.

However, a counter-intuitive scenario may emerge when placing the emphasis of agglomeration economies on labor mobility. According to the World Bank (2009, p. 158), labor mobility or migration for economic gain is the human side of the agglomeration story, and they maintain that internal migration can indeed offer societies an opportunity for economic growth and the convergence of welfare. The underlying logic is that higher wages at the destination reflect an initial shortage of workers, and the arrival of new migrants will slow the growth of wages for the labor market, as they are more competitive. In contrast, the accumulation of capital per worker in those places migrants vacate will speed up as they leave, accelerating wage growth for

workers who stay behind. In addition, most migrants maintain strong and active links with their home communities and send back remit capital, information, and technical assistance. By this mechanism, the income gap between central cities drawing many immigrants and secondary cities losing workers is predicted to converge eventually. In other words, if a core city in a monocentric region can attract a large number of migrants, this region is likely to end up with a balanced development.

In addition, agglomeration diseconomies, or the costs of agglomeration, also promise that the above-mentioned scenario may come true. It is commonly held that spatial concentration is eventually offset by diseconomies, ranging from pecuniary diseconomies (e.g., high housing/land rents and wages) to traffic congestion and density-related pollution (Richardson, 1995). These diseconomies can not only reduce the economic growth of central cities but may also bring development opportunities to secondary cities. Therefore, the potentially significant economic gap of a monocentric region can be narrowed down.

2.2.2. Borrowed size and agglomeration shadow

Borrowed size and agglomeration shadow, which can be perceived as neighboring agglomeration economies and diseconomies, also play an essential role in the relationship between spatial structure and regional disparities. Regarded now as an organizing principle in discussing polycentricity (Hesse, 2016), the concept of borrowed size was introduced by Alonso (1973) to explain why smaller cities positioned close to large metropolitan areas perform relatively better than isolated cities. Generally, borrowed size means that cities, especially the small- and medium-sized cities, can borrow, or share, size (including function and performance) from their large neighbors due to geographical proximity or functional interconnectedness (Burger, Meijers, Hoogerbrugge, & Tresserra, 2015; Meijers & Burger, 2010, 2017). It is beneficial for small cities to overcome their lack of critical mass and boost their growth, and further bring cohesion to the entire region. Moreover, it is widely expected that the processes of borrowed size appear to occur more frequently in polycentric regions (Alonso, 1973), and Meijers and Burger (2017) provide empirical support to validate this claim. Hence, we can infer that a polycentric region, where cities can borrow size from each other, is more likely characterized by fewer regional disparities.

Contrary to the notion of borrowed size, the New Economic Geography (NEG) also predicts a negative shadow effect (or “agglomeration shadow”) associated with proximity to the central city (Fujita, Krugman, & Venables, 1999). Essentially, higher-order cities can cast growth shadows over their surroundings due to competition effects and consequently limit their development opportunities (Burger et al., 2015; Fujita et al., 1999). Moreover, a monocentric region, which generally has a larger core city, can potentially bring a greater shadow effect to its secondary cities. Thus a monocentric region is likely to be associated with higher regional disparities.

However, a counter-intuitive scenario may also emerge under the framework of borrowed size and agglomeration shadow, primarily because the borrowed size is not reserved for polycentric regions. The dominant cities in a monocentric region may also encompass an evident case of borrowed size, as its size and function may become disconnected through interactions with surrounding smaller or lower-tier cities. In fact, this logic is consistent with the possible lacking agglomeration shadow, another possible reason for the counter-intuitive scenario. As shown by Partridge, Rickman, Ali, and Olfert (2009), larger cities have positive, rather than negative, growth effects on their surrounding small cities. Taken together, this information suggests that a monocentric region with a large core city does not necessarily imply an imbalanced regional development.

2.3. Findings of previous empirical studies

There is a longstanding lack of empirical evidence to support the validity and reliability of polycentric development. Of the handful of existing studies that assess polycentric development and its effect on regional disparities, all of them generally fail to validate the suggested reduction effect of polycentricity and even reach the opposite conclusion, finding that a correlation exists between monocentricity and a lack of regional disparities. Considering the scale-dependency of polycentricity, existing studies can be grouped into country-level and region-level studies.

At the country level, Meijers and Sandberg (2008) find there is no significant or reversed correlation between the morphological aspects of polycentricity and regional disparities in 27 European countries; they hold that polycentricity appears to be a placebo rather than a panacea for reducing regional disparities. By expanding the sample size to 188 countries, Hāzners and Jirgena (2013) reach a similar conclusion by using similar approaches; they find that a higher polycentricity score can be associated with more marked intra-country disparities in GDP per capita and strongly believe that polycentric development cannot be considered as a tool for diminishing regional disparities.

Other attempts made at the regional level are also far from optimistic. Veneri and Burgalassi (2012) show that the more polycentric the region, the more unequal the income distribution in the context of Italian NUTS-2 regions, and this correlation is particularly highlighted by functional polycentricity. Lotfi et al. (2015) find no evidence to support the association between morphological polycentricity and regional disparities in the provinces of Iran. Malý (2016a) finds no consistent evidence for the relationship between polycentricity—in both morphological and functional approaches—and regional disparities in Czech functional regions; the connection of polycentricity with balanced spatial development also responds to the type of polycentricity (morphological/functional), the size of the region, the chosen method of measuring disparities and the specific indicator of intra-regional disparities.

It is also worth noting that the research mentioned above is pioneer studies with limited explanatory power. The common methods used in these studies to examine the assumed relationship between polycentricity and regional disparities are (Pearson) correlation analysis (Lotfi et al., 2015; Malý, 2016a), simple multi-regression with limited control variables (Veneri & Burgalassi, 2012), or both (Hāzners & Jirgena, 2013; Meijers & Sandberg, 2008). Further judgment based on these methods is always questionable. In addition, the longstanding endogeneity problem in the field of evaluating polycentricity has not been addressed in these studies. It is widely accepted that urban spatial structure can be regarded as both a cause and a consequence of economic development (Li & Liu, 2018; Meijers & Burger, 2010) and that the economic development of sub-regions has a direct impact on overall regional disparities. Moreover, regions with a higher disparity level may be more willing to adopt a polycentric development pattern.

3. Data, model and estimation strategy

3.1. The chosen of spatial units

The territories examined in our study are Chinese prefectural-level city-regions (*shi yu*), or prefectural regions for short. A prefectural region consists of a core city (consisting of several districts, *shi xia qu*), county cities (*xian ji shi*), and counties (*xian*). Fig. 1 shows a typical prefectural region (*Cheng du*) in China. The sub-units of the prefectural region are 2547 km^2 on average and share a similar level of citizen income. Hence, selecting the prefectural region as a study unit is appropriate when examining regional disparities, as the ideal study region is the territory with a similar economic level of sub-territories.

In the study of poly-/monocentricity, the best study regions would be delimited based on intimate interaction. However, it is difficult to define a commonly agreed upon interactional city region, and the prefectural level city-region is a good alternative. The sub-units within a prefectural region, in most cases, have a close administrative and

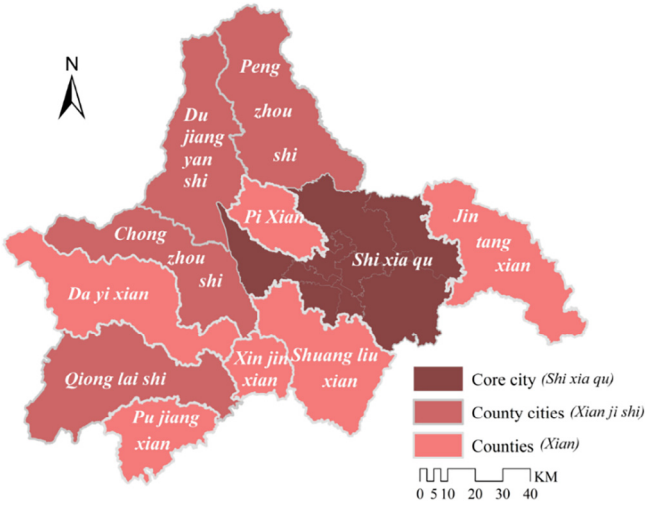

Fig. 1. A typical prefectural region (*Chengdu*) in China.

political interrelationship, and its economic power rests mainly in these county-level cities in China (Cheung, 2008). These make the next administrative level in the hierarchy, i.e., the prefecture, an appropriate unit with which to study the inner relationships among its sub-units. From a policy perspective, the use of prefecture-level data is also reasonable, as there can be several intra-prefectural policies based on the economic potential of the entire prefecture (Herrmann-Pillath, Kirchert, & Pan, 2002). Therefore, taking the prefectural region as the study unit is an appropriate choice for our study.

To be clear, the prefectural region is our main study unit, and its sub-units (*shi xia qu*, *xian ji shi*, and *xian*) are the primary territories used to calculate the core intra-prefecture indexes. Specifically, we use the data of subunits to calculate the region's intra-prefecture disparities and the index of poly-/monocentricity, which means we use them to obtain our dependent and core independent variable at the prefectural level. We then collected other independent data, also at the prefectural level, to carry out further regression analyses. Moreover, the subunit is used as a study unit in sections 5 and 6 to explain the possible reasons for our key finding.

3.2. Measure of poly-/monocentricity

Three indicators are employed to measure morphological poly-/monocentricity. The first indicator is the Pareto exponent, which is also the most commonly used proxy in previous studies at the regional scale (Meijers & Burger, 2010; Melo, Graham, & Noland, 2011; Parr, 2004). To correct for small sample bias, the parameter values have been estimated by subtracting 0.5 on rank (Gabaix & Ibragimov, 2011), which can then be calculated as:

$$\ln(\text{Rank}-0.5) = \alpha + \beta \ln(\text{Size}), \tag{1}$$

where *Rank* represents the rank of each sub-spatial unit in the prefectural region—including *shi xia qu, xian ji shi* and *xian*—according to their urban population. *Size* is the total urban population of each sub-spatial unit. The value of β indicates the level of morphological polycentricity: a higher coefficient, i.e., the Pareto exponent, means a higher probability of finding very large sub-cities in the prefectural region, implying a more polycentric structure.

The second indicator is the Hirschman-Herfindahl index (HHI), which is the sum of the squared share of the population of the region's secondary cities and is shown in the following form:

$$\text{HHI} = \sum_{i=1}^{n} \left(\frac{S_i}{S}\right)^2 \tag{2}$$

where S represents the overall population of the prefectural region; S_i represents the population of the i^{th} sub-cities of the prefectural region; i signifies different sub-cities; and n is the overall number of sub-cities.

The third indicator is the Primacy, which is typically measured as the largest sub-cities' share of the total regional urban population. It is shown in the following form:

$$\text{Primacy} = \frac{S_1}{S} \tag{3}$$

where S represents the overall population of the prefectural region and S_i represents the population of the i^{th} sub-cities of the prefectural region. In addition, it is worth noting that, for the last two indicators, the higher the value, the more monocentric the prefectural region is. Hence, the HHI and Primacy are expected to have a sign opposite that of the Pareto exponent.

The data source used to measure spatial structure is the population census of the People's Republic of China by county in 2000 and 2010. The population census is the only data resource containing accurate and reliable demographic information in China. We refrain from using previous years' censuses because the differences in the definitions of who counts as part of the urban population are too great, which makes consistent comparisons almost impossible (Yu, 2002). Furthermore, the regional spatial structure is a long-term process of slow changes; thus, measuring in ten-year increments ensures that variations are sufficient enough to be identifiable.

3.3. Measure of regional economic disparity

Following Lessmann (2009) and Rodríguez-Pose and Ezcurra (2009), we use regional GDP per capita as a starting point. A common alternative is income; however, the data are unfortunately unavailable in our sub-units, i.e., the county-level regions. Therefore, we use only regional GDP per capita to measure disparity.

An applicable concentration measure for regional disparities should be independent of the number of regions considered, should not be sensitive to shifts in average GDP levels, and should satisfy the Pigou-Dalton transfer principle (Lessmann, 2009). Measures such as the Gini coefficient, the Theil coefficient, the Atkinson coefficient, and the coefficient of variation can satisfy these requirements. Furthermore, weighting the abovementioned indexes by population can better capture the perceived spatial inequality (Breinlich et al., 2014). Hence, we resort to the population-weighted Gini (*Gini_weighted*) to measure disparity, which takes the following form:

$$Gini\_weighted = \frac{1}{\bar{y}} \sum_{i}^{n} \sum_{j>i}^{n} (y_j - y_i) p_i p_j \tag{4}$$

where $\bar{y}$ is the mean per capita GDP (at 2000's price level) of the prefectural region, and y_i and y_j are the per capita GDP (at 2000's price level) of county-level city i and j respectively; p_i and p_j are the populations of county-level city i and j respectively; and n is the number of county-level cities. We also calculate the population-weighted coefficient of Theil (*Theil_weighted*), Atkinson (*Atkinson_weighted*), variation (*Cov_weighted*), and the unweighted ones to serve as robustness checks. It should be noted that the ϵ of our Atkinson ratio is 0.5 in order to emphasize inequality at the top of the distribution.

To measure the regional economic disparity at the intra-prefectural level, we gather the GDP data at the county level from the *China County Statistical Yearbook* (2001 and 2011), which is the only official source of data at the county level.

3.4. Model and estimation strategy

To investigate whether polycentricity can diminish territorial economic disparities, we conduct an exploratory regression analysis that takes the following form:

$$\ln(Gini\_weighted) = \theta_0 + \theta_1 ln(Mono - /Polycentricity) + \sum_{j=2}^{j} \theta_j lnX_j + \varepsilon \quad (5)$$

Our dependent and focal independent variables are regional economic disparity (*Gini_weighted*) and poly-/monocentricity respectively, and their measures are shown in the previous sections. To minimize a possible omitted-variable bias, several controls (X_j) found in the literature are included in our regression. These controls include the level of economic development (*GDP/POP*) which is measured by GDP per capita; urban population (*Urban population*) to capture the agglomeration economics; human capital (*Education*) measured by years of schooling; ratio of government expenditure to GDP (*Gov_exp/GDP*) to reflect the internal intervention of local government; ratio of foreign direct investment to GDP (*FDI/GDP*) to reflect the external intervention of foreign countries or the influence of economic globalization; capital-population ratio (*Capital/POP*) defined as total investment in fixed assets per person; industrial structure (*Sec_ind/GDP* and *Ter_ind/GDP*) measured by the ratio of second industry output to GDP and the third industry output to GDP; urban infrastructure (*Road/POP*) measured by mileage highways per capita; dummy variables (*Dum_hier*), which are based on the administrative hierarchy to capture the intervention from the central government; dummy variables (*Dum_year*) to capture the time fixed effects; and dummy variables (*Dum_pro*) to capture the regional fixed effects.

All the data for these control variables are from the *China Statistical Yearbook for Cities* and the *China Statistical Yearbook for Regional Economy*, which are recognized as the two main sources for data at the Chinese prefectural level. In addition, the data for these control variables are gathered at the prefectural level in 2000 and 2010. Specifically, there are 257 prefectural-level city-regions in 2000 and 282 prefectural regions in 2010. Descriptive statistics are presented in Table 1.

As for the estimation strategy, we use a pooled cross-sectional approach rather than panel regression analysis in our estimations. There are at least two reasons for this. First, there is an essential difference in identifying the sources of variation between these two methods. Panel-data estimators are based on "within" variation, i.e., the time difference of the same sample, while pooled regression can take full advantage of the "between" variation, i.e., the difference coming from different samples (Wooldridge, 2013). According to Table 2, most of the standard deviation comes from different prefectures, and there is not much variation in spatial structure over time. In addition, if we use panel regression in the analysis, we risk having too small of a sample size. Along with China's spectacular economic growth, the administrative boundaries have experienced significant changes in the last twenty years. If we limit qualified samples to those cities that have changed their administration area by less than 10% from 2000 to 2010, we obtain only 377 samples and lose almost half the sample information. Thus, pooled cross-sectional analysis is an appropriate approach for the data at hand.

It should be noted that the changes in administrative units between 2000 and 2010 do not affect the accuracy of our empirical results, for the pooled cross-sectional approach treats every prefectural region as a unique and independent one to capture the between variation, i.e., the difference coming from different prefectural cities. The pooled cross-sectional approach has no special requirement on the consistent set of population data. Furthermore, we have set the year dummy variable to capture the time fixed effect in our regression models.

Moreover, as mentioned in the introduction, basic approaches to exploring the causal relationship between polycentricity and regional disparities may lead to biased estimates because of endogeneity. To address this potentially serious issue and confirm the hypothesized causal relationship, we apply a two-stage least squares (TSLS) regression approach by using a historical instrumental variable. Inspired by Combes, Duranton, and Gobillon (2010) and Meijers and Burger (2010), we use the level of polycentricity in 1953, which comes from the first census conducted in China, as our instrument.

This instrument can meet both the requirement of relevance and exogeneity. Spatial structure in 1953 is the foundation of today's structure. In other words, the more polycentric the region was in 1953, the more likely the region is to have been polycentric in 2000 and 2010. In addition, the weak identification test in Table 3 confirms the relevance of our instrument.

The exogeneity of the level of polycentricity in 1953 depends on the basic fact that the spatial pattern of population in China has evolved over time. Since the economic reforms introduced by the Chinese government in 1978, the urban floating population has increased continuously. According to the latest population census data (2010), there are 221 million people in China who live outside their place of registry. Some may argue that the historical spatial structure is likely to work through the current population, but we control for this variable in all of our models.

Table 1
Descriptive statistics of variables.

Variable	Obs	Mean	SD	Min	Max
Gini_weighted (ln)	510	−1.837	0.630	−7.036	−0.571
Theil_weighted (ln)	509	−2.981	1.069	−9.115	−0.381
Atkinson_weighted (ln)	509	−3.679	1.059	−9.903	−1.211
CV_weighted (ln)	510	−1.029	0.580	−5.896	0.363
Gini (ln)	510	−1.754	0.547	−6.831	−0.439
Theil (ln)	509	−2.895	1.016	−9.115	−0.070
Atkinson (ln)	509	−3.609	0.998	−9.721	−0.904
CV (ln)	510	−0.967	0.566	−5.794	0.573
Pareto (ln)	510	0.075	0.464	−1.606	2.958
HHI (ln)	539	−1.144	0.598	−2.496	0
Primacy (ln)	539	−0.754	0.444	−2.004	0
Pareto_6 (ln)	513	0.132	0.502	−1.606	2.958
HHI_6 (ln)	539	−1.025	0.493	−1.783	0
Primacy_6 (ln)	539	−0.684	0.386	−1.662	0
Pareto_light (ln)	503	−0.508	0.405	−1.811	1.796
HHI_light (ln)	538	−0.891	0.604	−2.655	0
Primacy_light (ln)	538	−0.546	0.406	−1.853	0
GDP/POP (ln)	539	9.386	0.786	7.677	11.711
Urban population (ln)	539	14.144	0.695	11.824	16.180
Capital/POP (ln)	539	9.428	1.263	6.820	12.041
Education (ln)	539	−3.594	0.934	−6.295	−1.272
Gov_exp/GDP (ln)	539	−2.543	0.652	−8.729	−0.407
FDI/GDP (ln)	539	0.020	0.028	0	0.244
Sec_ind/GDP (ln)	539	−0.773	0.257	−1.819	−0.108
Ter_ind/GDP (ln)	539	−1.065	0.235	−2.459	−0.333
Road/POP (ln)	539	1.223	0.793	−1.536	3.417
Dum_hier	539	0.174	0.380	0	1

Note: (1) the observations of Gini, Theil, Atkinson, CV, and Pareto are smaller than others control variables, for the calculation formula of these variables needs more than one sub-unites. There are 29 prefectural regions in our samples with only a core city, such as *Wuhan*, *Xiamen*, and *Dongguan* and so on. (2) the difference of GDP per capita in the sub-unites of *Huainan* prefecture in 2010 is quite small and is regarded as 0 in the measure of Theil and Atkinson. And we lost this sample by taking the log-transformation (ln). (3) we also lost a few samples with the satellite-derived data, for some less developed prefectures, such as *Liupanshui*, cannot extract any contiguous active lighted areas.

Table 2
The decomposition of poly-/monocentricity's standard deviation.

	Overall	Between	Within
Pareto (ln)	0.467	0.431	0.166
HHI (ln)	0.599	0.582	0.141
Primacy (ln)	0.440	0.427	0.117

Table 3
Ordinary least squares (OLS) and two-stage least square (TSLS) estimations on regional economic disparities.

	(1)	(2)	(3)	(4)	(5)	(6)
	OLS			TSLS		
	Pareto	HHI	Primacy	Pareto	HHI	Primacy
Poly-/Monocentricity (ln)	0.235*	−0.452***	−0.378***	1.314*	−1.098***	−1.997***
	(1.86)	(−4.56)	(−3.27)	(1.83)	(−8.09)	(−6.34)
GDP/POP (ln)	0.083	0.095	0.094	0.179	0.143	0.231
	(0.62)	(0.72)	(0.70)	(1.19)	(1.21)	(1.61)
Urban population (ln)	0.292***	0.057	0.173**	0.160	−0.322***	−0.460***
	(4.22)	(0.73)	(2.43)	(1.36)	(−3.09)	(−3.13)
Capital/POP (ln)	0.059	0.041	0.039	0.059	0.015	−0.046
	(0.58)	(0.40)	(0.39)	(0.57)	(0.17)	(−0.43)
Education (ln)	0.079	0.196***	0.134*	0.370*	0.453***	0.640***
	(1.17)	(2.72)	(1.86)	(1.76)	(5.06)	(4.92)
Gov_exp/GDP (ln)	0.137	0.047	0.082	0.259*	−0.042	−0.037
	(1.23)	(0.45)	(0.76)	(1.77)	(−0.39)	(−0.29)
FDI/GDP (ln)	−2.801**	−2.333*	−2.523*	−3.484*	−1.877	−1.970
	(−2.04)	(−1.65)	(−1.81)	(−1.95)	(−1.24)	(−1.09)
Sec_ind/GDP (ln)	0.620***	0.673***	0.641***	0.863***	0.824***	0.959***
	(3.01)	(3.43)	(3.20)	(3.23)	(4.37)	(4.17)
Ter_ind/GDP (ln)	0.273	0.353*	0.306	0.495*	0.536***	0.656***
	(1.32)	(1.70)	(1.49)	(1.87)	(2.74)	(2.75)
Road/POP (ln)	0.166*	0.048	0.115	0.053	−0.157*	−0.211**
	(1.84)	(0.54)	(1.27)	(0.50)	(−1.96)	(−2.07)
Dum_hier	YES	YES	YES	YES	YES	YES
Dum_year	YES	YES	YES	YES	YES	YES
Dum_pro	YES	YES	YES	YES	YES	YES
Constant	−4.811**	−1.712	−3.295*	−2.263	3.558*	6.124**
	(−2.52)	(−0.93)	(−1.80)	(−0.79)	(1.72)	(2.20)
Obs	510	510	510	510	510	510
Adj R^2	0.210	0.245	0.218	−0.124	0.141	−0.217
F	7.202	7.558	7.245	3.242	5.814	3.951
CDF	–	–	–	7.161	274.3	80.33

Note: (1) the HHI and Primacy are expected to have the opposite sign of the Pareto exponent, for the smaller the value of the HHI and Primacy, the more likely the prefecture region is to be polycentric. (2) robust t-statistics in parentheses; ***p < 0.01, **p < 0.05, *p < 0.1.

4. Empirical results

4.1. Baseline results

Table 3 reports the estimation results, with different econometric approaches, of whether or not a polycentric spatial structure accounts for fewer regional disparities. Columns (1) through (3) assess it with ordinary least squares (OLS) estimation, while columns (4) to (6) use the two-stage least squares (TSLS) estimation.

In columns (5) and (6) the Cragg-Donald Wald F-statistics (CDF) is larger than 16.38, which is the 10% critical value in the Stock-Yogo weak instrument test and is an empirical confirmation of the relevance of our instrument. Unfortunately, the Pareto exponent cannot pass this relevance test. This is also the reason why we remove all the TSLS regression on the Pareto in the following sections. We believe this exception may be caused by the frequent changes in administrative boundaries after 1953. Even though we have manually recorded the 1953 census data based on the administrative boundaries in 2010, the population of some sub-cities remains biased if the restructuring of the jurisdiction is not along the original administrative boundaries. Calculating the Pareto exponent requires complete information for every subcity in the prefectural level city-region. This is also the reason why we do not keep the measures of Pareto in the following analysis.

Turning to our focal variable, we find that the more polycentric the prefectural region, the more the regional disparities in terms of GDP per capita in all the columns. In other words, regions with a relatively monocentric spatial structure are characterized by fewer regional economic disparities. This finding is robust in both the OLS and TSLS estimations and is confirmed in our next section, suggesting that the polycentric-oriented spatial strategy is not an appropriate policy with which to reduce regional economic disparities in China. The results of other controls are consistent with previous findings in similar studies. While the FDI-GDP ratio can significantly diminish regional disparities, human capital and industrial structure are likely to increase regional disparities.

4.2. Robustness check

In this section, we double-check our main finding by using different measures of poly-/monocentricity and regional economic disparities. When interpreting the relationship between polycentricity levels and intra-regional disparities, one must take into account the measures of poly-/monocentricity, the chosen method for measuring disparities, and the specific indicator of intra-regional disparities (Malý, 2016a). It is worth noting that we do not keep the measures of Pareto, as its IV (i.e., the corresponding Pareto in 1953) cannot satisfy the requirement of relevance.

First, we re-measure the variable of interest: poly-/monocentricity. One may argue that poly-/monocentricity is not comparable for the different number of secondary cities in prefectures. Thus it is necessary to reconsider the choice of secondary cities sample size. There are three common criteria to define sample size: a fixed number of cities, a specified threshold of the population, and a given fraction of the total population (Rosen & Resnick, 1980; Wheaton & Shishido, 1981). All of these standards have advantages and weaknesses; we favor the choice of Meijers (2008) on the fixed number of cities. He believes that a city's rank is valuable in assessing the importance of cities and that a top rank is crucial in spite of the city's possible small size. Therefore, we re-measure poly-/monocentricity by adopting sample sizes at the 50th quantiles (the first six subunits) of the subunits distribution. Table 4 (columns (1) and (2)) shows the TSLS estimation results of the new measure of monocentricity, which are broadly in line with our baseline

Table 4
TSLS estimations on regional disparities with different measures of monocentricity.

	(1)	(2)	(3)	(4)
	Fixed number for 6		Based on DMSP-OLS	
	HHI	Primacy	HHI	Primacy
Monocentricity (ln)	−1.785***	−3.216***	−2.344***	−3.588***
	(−7.29)	(−5.08)	(−4.21)	(−3.67)
Control variables	YES	YES	YES	YES
Dum_hier	YES	YES	YES	YES
Dum_year	YES	YES	YES	YES
Dum_pro	YES	YES	YES	YES
Obs	508	508	507	507
Adj R^2	−0.054	−0.891	−2.165	−2.612
CDF	119.4	35.30	21.99	15.97

Note: (1) we do not include the new measures of Pareto, for its IV (i.e., the corresponding Pareto in 1953) cannot satisfy the requirement of relevance. (2) robust t-statistics in parentheses; ***p < 0.01, **p < 0.05, *p < 0.1.

finding. In other words, the number of secondary cities does not make much difference in our study.

Another potential issue in measuring poly-/monocentricity is that we may break up the urban population by administrative borders and then divide the factual co-location population into different subunits. This approach can generate arbitrary border effects, an issue related to what the literature calls the Modifiable Areal Unit Problem (MAUP). Therefore, we turn to "stable night lights" from NOAA as a complement to our traditional data sources. The crucial advantage of light data is that we can employ the natural thresholds of light intensity to avoid the arbitrary border effect. Specifically, we first overlap the nighttime lights imagery with a polygon shapefile of China prefectures, set a luminosity threshold (40 in our approach) to extract a contiguous lighted area, and then use the areas of extracted contiguous light mosaic images to reconstruct the index of poly-/monocentricity serving as robustness checks. We also obtain a similar result with the light data in Table 4, columns (2) and (3). Therefore, the shape-induced MAUP has little influence on our finding.

Second, we re-measure our dependent variable: regional economic disparity. According to Rodríguez-Pose and Ezcurra (2009), different indexes of disparity have different ways of aggregating the information contained in the distribution. A variety of measurements can supplement the information provided by the Gini coefficient. The Theil, Atkinson, and variation coefficients are also popular measures of inequality and fulfill the basic requirements for measuring this variable (Allison, 1978; Braun, 1988). Nevertheless, we obtain a similar finding by using the new measures of regional economic disparity in Table 5.

Furthermore, though weighing the inequality indexes by population can better capture the spatial inequality perceived by an "average" person, this may also distort the inequality measure by allowing it to be dominated by the characteristics of the largest regions (Lessmann, 2014). To address this argument, we also calculated the unweighted measures of disparity. The results, which also support our general findings, are reported in Table 6.

All of these prove that both the measures of poly-/monocentricity and regional disparity cannot change the basic conclusion of our study; that is to say, monocentric, not polycentric, development is associated with less territorial disparity.

5. Why is monocentricity associated with less regional economic disparity?

In this section, we try to explore the reasons for our counter-intuitive finding by focusing on the three possible channels discussed in the literature section. It should be noted that our sample in this section is entirely reset to the subunits (i.e., *shi xia qu, xian,* and *xian ji shi*) of the prefectural region.

5.1. Labor mobility effect

It is thought that labor mobility can bring in cohesion because the benefits of agglomeration can be shared through migration; hence, the difference between the destination and origin of migration is leveled out during this process. Thus, the next step is to examine whether the core cities, particularly in the monocentric region, can attract more migration than secondary cities. If this is tenable, a monocentric region with a considerably large immigrant population could potentially lead to balanced development despite unbalanced population distribution.

By resetting the explained variable to the amount of floating population (calculated by subtracting permanent resident population from household registration population) in 2010, we try to empirically verify the hypothesis mentioned above. Our key explanatory variable is the value of poly-/monocentricity at the prefecture scale, which is assigned to every sub-unit. To be more specific, the sub-units of a prefectural region are divided into two groups—core cities (population ranking 1st) and secondary cities (population ranking over 1st)—and all the explanatory variables are drawn from the year of 2000 to avoid reverse causality as much as possible. Monocentricity in 1953 is used as IVs to also ensure the reliability of our results.

Table 7 shows that the coefficients of monocentricity are significantly and positively associated with the amount of floating population in the group of core cities, which means there truly is a greater influx of floating population in core cities in monocentric regions. In this sense, the benefits of agglomeration in the core cities are likely to

Table 5
TSLS estimations on regional economic disparities with weighted different measures.

	(1)	(2)	(3)	(4)	(5)	(6)
	Weighted_Theil		Weighted_Atkinson		Weighted_CV	
	HHI	Primacy	HHI	Primacy	HHI	Primacy
Monocentricity (ln)	−1.518***	−2.872***	−1.456***	−2.747***	−0.678***	−1.288***
	(−6.78)	(−5.68)	(−6.58)	(−5.54)	(−5.51)	(−4.84)
Control variables	YES	YES	YES	YES	YES	YES
Dum_hier	YES	YES	YES	YES	YES	YES
Dum_year	YES	YES	YES	YES	YES	YES
Dum_pro	YES	YES	YES	YES	YES	YES
Obs	507	507	507	507	508	508
Adj R^2	0.192	−0.083	0.193	−0.063	0.168	−0.021
CDF	272.4	79.68	272.4	79.68	273.2	79.97

Note: (1) we do not include the measures of Pareto, for its IV (i.e., the corresponding Pareto in 1953) cannot satisfy the requirement of relevance. (2) robust t-statistics in parentheses; ***p < 0.01, **p < 0.05, *p < 0.1.

Table 6
TSLS estimations on regional economic disparities with different measures.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	GINI		Theil		Atkinson		CV	
	HHI	Primacy	HHI	Primacy	HHI	Primacy	HHI	Primacy
Monocentricity (ln)	−0.565***	−1.032***	−0.925***	−1.803***	−0.864***	−1.689***	−0.383***	−0.745***
	(−4.96)	(−4.34)	(−4.50)	(−4.19)	(−4.29)	(−4.04)	(−3.26)	(−3.12)
Control variables	YES	YES	YES	YES	YES	YES	YES	YES
Dum_hier	YES	YES	YES	YES	YES	YES	YES	YES
Dum_year	YES	YES	YES	YES	YES	YES	YES	YES
Dum_pro	YES	YES	YES	YES	YES	YES	YES	YES
Obs	508	508	507	507	507	507	508	508
Adj R^2	0.198	0.082	0.245	0.132	0.249	0.149	0.204	0.138
CDF	273.2	79.97	272.4	79.68	272.4	79.68	273.2	79.97

Note: (1) we do not include the measures of Pareto, for its IV (i.e., the corresponding Pareto in 1953) cannot satisfy the requirement of relevance. (2) robust t-statistics in parentheses; ***p < 0.01, **p < 0.05, *p < 0.1.

Table 7
TSLS estimations on the number of floating population.

Y: Number of floating population (ln, 2010)	(1)	(2)	(3)	(4)
	Core cities		Secondary cities	
	HHI	Primacy	HHI	Primacy
Monocentricity (ln, 2000)	0.178**	0.277**	0.012	0.038
	(0.072)	(0.108)	(0.014)	(0.027)
GDP/POP (ln, 2000)	0.038	0.032	0.060**	0.057**
	(0.090)	(0.090)	(0.027)	(0.028)
Education (ln, 2000)	0.682*	0.629	0.444	0.452
	(0.409)	(0.396)	(0.277)	(0.279)
Gov_exp/GDP (ln, 2000)	−0.011	−0.019	0.053***	0.054***
	(0.065)	(0.066)	(0.011)	(0.011)
Sec_ind/Ter_ind (ln, 2000)	0.005	0.005	0.027	0.028
	(0.042)	(0.041)	(0.025)	(0.025)
Dum_Pro	Yes	Yes	Yes	Yes
N	260	260	1380	1380
Adj R^2	0.627	0.630	0.028	0.028
CDF	309.363	168.692	910.895	483.793

Note: (1) we do not include the measures of Pareto, for its IV (i.e., the corresponding Pareto in 1953) cannot satisfy the requirement of relevance. (2) the control variables are from the China county statistical yearbook, and the variables of Dum_hier are omitted because of multicollinearity. (3) robust t-statistics clustered at the level of prefecture in parentheses; ***p < 0.01, **p < 0.05, *p < 0.1.

be shared through the mass inflow of population in the monocentric region; thereby, a monocentric region can lead to balanced regional development.

5.2. The potential narrowing effect brought about by agglomeration diseconomies

Due to the diseconomies of agglomeration, economic growth will be constrained with the increase of city size. In other word, as the population grows, the core city in a monocentric region may incur diseconomies and then restrain its economic development. Moreover, compared with polycentric regions, a similarly sized monocentric region is more likely to have a larger core city. Therefore, the disparities within the monocentric region could be narrowed down.

To explore whether this is the case, we again divide the sub-units of a prefectural region into core cities and secondary cities and employ *Density* (measured by the urban population over the built-up area) and the interaction term between *Density* and *Monocentricity* as core explanatory variables. The explained variable is the per capita GDP growth rate of every sub-unit from 2000 to 2010.

We find that all the coefficients of density and the interaction term in the group of central cities are insignificant (Table 8). This means that there is no evidence of agglomeration diseconomies, even in the most likely case, i.e., the central cities in monocentric regions. However, it is worth noting that the absolute values of coefficients of GDP per capita in core cities are robustly larger than those in secondary cities. This

Table 8
OLS estimations on the growth rate of per capita GDP.

Y: Growth rate of per capita GDP (ln, 2010–2000)	(1)	(2)	(3)	(4)	(5)	(6)
	Core cities			Secondary cities		
	Pareto	HHI	Primacy	Pareto	HHI	Primacy
Density(ln, 2000)	0.024	0.021	0.020	−0.002	0.002	0.001
	(0.051)	(0.051)	(0.051)	(0.017)	(0.017)	(0.016)
Monocentricity (ln) × Density (ln, 2000)	0.035	0.020	0.030	−0.011	0.017*	0.024*
	(0.042)	(0.020)	(0.031)	(0.021)	(0.009)	(0.014)
GDP/POP(ln, 2000)	−0.300***	−0.360***	−0.355***	−0.158***	−0.161***	−0.158***
	(0.092)	(0.089)	(0.089)	(0.054)	(0.053)	(0.053)
Monocentricity (ln)	−0.248	0.052	0.034	−0.085	0.085	0.088
	(0.236)	(0.116)	(0.176)	(0.126)	(0.058)	(0.089)
Control variable	Yes	Yes	Yes	Yes	Yes	Yes
Dum_Prov	Yes	Yes	Yes	Yes	Yes	Yes
N	248	260	260	1380	1380	1380
Adj R^2	0.324	0.329	0.319	0.324	0.345	0.340

Note: (1) TSLS estimations are not employed because the number of endogenous variables (monocentricity and its interaction term) is increased, and our IVs cannot satisfy the requirement of relevance. (2) the control variables are Education, Gov_exp/GDP and Sec_ind/Ter_ind as in Table 7. (3) robust t-statistics clustered at the level of prefecture in parentheses; ***p < 0.01, **p < 0.05, *p < 0.1.

finding means that central cities face a faster convergence speed than their secondary cities; in other words, the economic gap between large and small cities cannot be widened indefinitely. Overall, we do not find direct evidence of agglomeration diseconomies in monocentric regions, but there is a promising sign of convergence.

5.3. The limited effect of agglomeration shadow

One implication of agglomeration shadow is that proximity to higher-tiered cities may constrain the growth of surrounding secondary cities because of the spatial competition. This could make economic growth positively related to distance from larger core cities (Partridge et al., 2009). Moreover, a large core city, which is more commonly found in monocentric regions, may be more capable of casting a growth shadow to its secondary cities and, hence, generating regional inequality. However, this shadow may be overcome by countervailing positive agglomeration spillovers (or borrowed size). Hence, the landscape of growth in the vicinity of central cities, due to the offsetting effects of positive agglomeration spillovers and potential growth shadows, is inconclusive.

To investigate whether the growth shadow plays a leading role in the development of a region, Table 9 estimates the growth effect of central cities on its surrounding secondary cities. We identify the secondary cities according to the distance to their own core city (population ranking 1st) in every prefectural region. By adopting the distance at the 25th, 50th and 75th quantiles, which would be approximately 50 km, 70 km and 100 km respectively, the sample was divided into three groups. While the explained variable is the per capita GDP growth rate of every secondary city (population ranking over 1st) from 2000 to 2010, the key explanatory variables are the growth rate of their corresponding core cities and the interaction with monocentricity.

We find that all the coefficients of central cities' growth rate and the interaction terms are insignificant. This result implies that the growth shadow does not play a dominant role in regional economic development and that a monocentric region does not introduce an extra agglomeration shadow. In other words, the development of core cities does not occur at the expense of its sub-cities. Furthermore, it should be noted that the coefficients of central cities' growth rate actually become larger, although insignificant, as the distance increases, which is in line with the inference drawn by Partridge et al. (2009); that is, the economic shadow means that economic growth is positively related to the distance from larger central cities. Although this finding suggests a weak sign of agglomeration shadow, we believe it is safe to say that the growth shadow plays a limited role in regional economic development.

Table 9
OLS estimations on growth effect of per capita GDP in secondary cities.

Y: PGDP_Growth in secondary cities	(1)	(2)	(3)	(4)	(5)	(6)
(ln, 2010–2000)	50 Km		70 Km		100 Km	
	HHI	Primacy	HHI	Primacy	HHI	Primacy
PGDP_Growth in core cities	−0.100	−0.118	0.028	0.006	0.093	0.086
	(0.137)	(0.123)	(0.139)	(0.130)	(0.153)	(0.138)
PGDP_Growth in core cities× Monocentricity (ln)	−0.101	−0.181	−0.073	−0.140	−0.056	−0.098
	(0.086)	(0.114)	(0.100)	(0.144)	(0.117)	(0.156)
Monocentricity (ln)	0.308***	0.454***	0.246**	0.361**	0.226*	0.316*
	(0.097)	(0.123)	(0.105)	(0.146)	(0.123)	(0.162)
Control variables	YES	YES	YES	YES	YES	YES
Dum_Prov	Yes	Yes	Yes	Yes	Yes	Yes
N	443	443	791	791	1107	1107
Adj R^2	0.380	0.378	0.370	0.366	0.370	0.365

Note: (1) in order to save space, we do not show the regression results of Pareto, which are consistent with HHI and Primacy. (2) the control variables are Education, Gov_exp/GDP and Sec_ind/Ter_ind as in Table 7. (3) robust t-statistics clustered at the level of prefecture in parentheses; ***p < 0.01, **p < 0.05, *p < 0.1.

6. Why does polycentricity fail?

This section tries to explain why polycentricity fails to reduce regional disparities in our study from the perspective of "borrowed size." As an organizing principle of polycentricity (Hesse, 2016), borrowed size is beneficial for small cities in overcoming their lack of critical mass and boosting their growth and, hence, can bring cohesion to the entire region. Moreover, Meijers and Burger (2017) find empirical support for borrowed size occurring more frequently in polycentric areas in Europe. We now examine whether the idea of borrowed size holds true in China's prefectural regions.

According to Meijers and Burger (2017), size borrowing occurs when a city exhibits more urban functions and higher performance levels than expected given its size. Following their pioneering empirical strategy, we regress size on service functions ("borrowed function") and economic performance ("borrowed performance") in sub-units of a prefectural region and obtain the residuals to serve as a sign of borrowed function or performance. Specifically, the explained variables are the ratios of the employed populations for different occupations (including finance, education, public administration and social/international organizations, culture/sports/entertainment) to population and GDP per capita, and the core explanatory variable is the population. We also include province and year dummies to control for spatial and time differences.

The following three points should be noted. First, in calculating service function, instead of the number of service facilities, we could only obtain the data on the employed population with different occupations. Second, the choice of four occupations is based on studies by Malý (2016b) and Meijers and Burger (2017) and on the availability of our data. In addition, we pay more attention to the higher-ranked services, which are more sensitive to size borrowing. Third, the data, gathered from the population census of the People's Republic of China by county, are only from the year of 2010. Because the classifications of occupations in the census differ considerably between 2000 and 2010, we select only the year of 2010 to trace the latest situation of borrowed function and performance.

After conducting the abovementioned regressions, we obtain the residuals of different occupations and GDPs of various sub-units and sum these residuals within the same prefecture to offset the internal borrowed size and agglomeration shadow effect. The summed residuals can indicate whether the prefecture is dominated by borrowed size or agglomeration shadow. As shown in Fig. 2, the red dots are prefectures with a positive sum of residuals, which means that this prefecture is leading by borrowed size, whereas the blue dots are prefectures with a summed residual lower than 0, which suggests the agglomeration shadow prevails. We then plot the summed residuals with poly-/monocentricity to illustrate the relationship between the spatial structure and borrowed function/performance of a prefectural region.

We can find that there is a clear positive relationship between monocentricity and residuals for the noticeable steep slopes. In other words, cities within polycentric regions do not "borrow" as much function or performance from each other as expected. This might be because our morphological polycentricity or a balance in the size distribution of centers does not necessarily imply that there are functional linkages between them, as stated in Burger and Meijers (2012). Consequently, polycentricity fails to reduce regional disparities.

7. Conclusions

One of the main assumptions about polycentric development is that it can effectively level out regional disparities and thus bring cohesion to the region. However, both the theoretical foundations and empirical

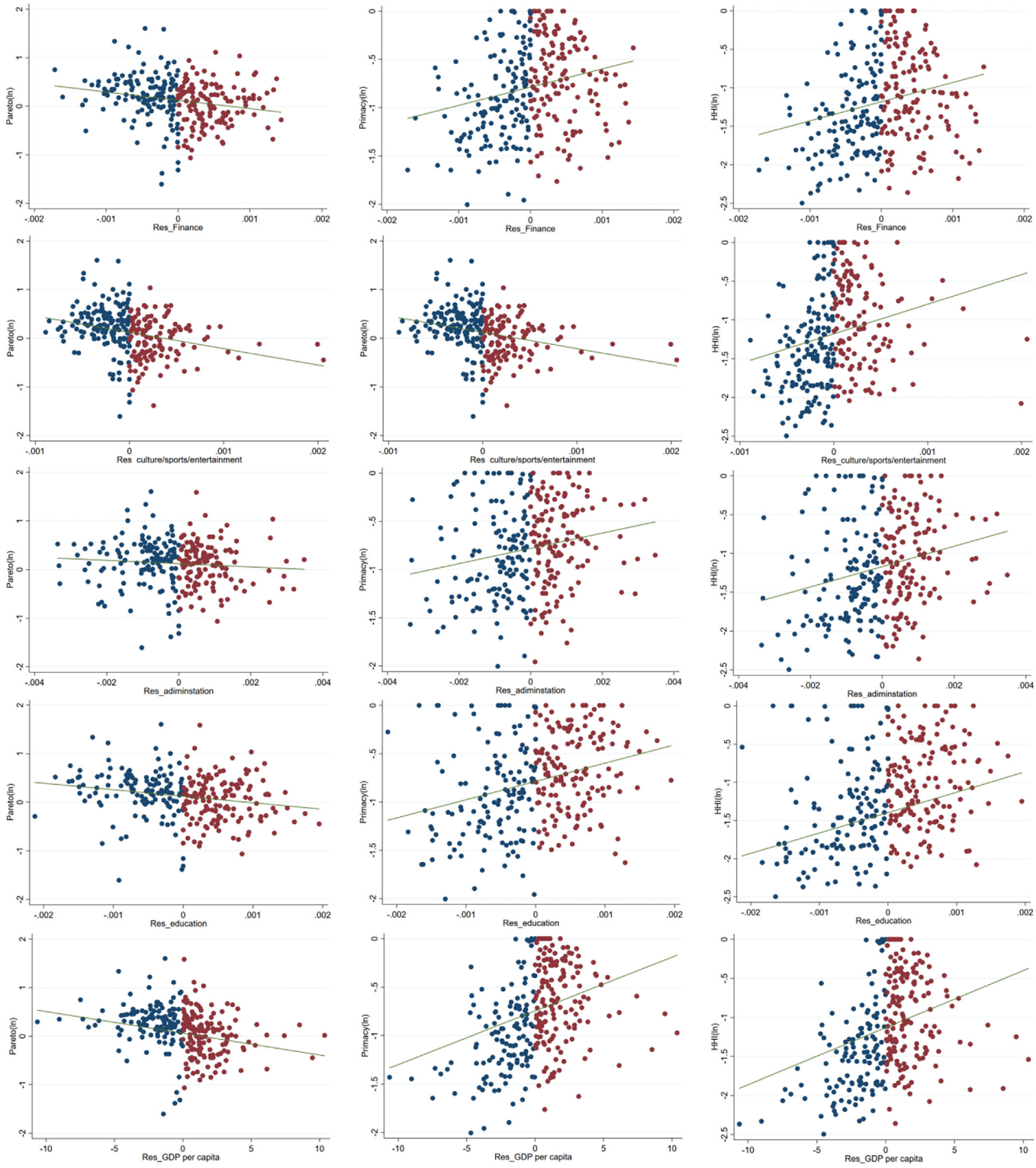

Fig. 2. The correlation plots of monocentricity and residuals. Note: the x-axis is the residuals of different occupations (line 1, Finance; line 2, Culture/sports/entertainment; line 3, Public administration and social/international organizations; line 4, Education) and GDP per capita (line 5), and the y-axis is the value of poly-/monocentricity.

evidence regarding the connection between polycentricity and regional disparity are weak and scarce. Drawing on theoretical achievements from related fields, this study tries to provide an empirical assessment of this relationship in terms of Chinese prefectural regions. By using reliable TSLS estimation, we reach a counter-intuitive result: monocentricity, rather than polycentricity, is associated with less territorial economic disparity. This conclusion is robust to different morphological measures of poly-/monocentricity and regional disparities. Further analyses illustrate that the core cities in monocentric regions can share the benefits of agglomeration through labor mobility; monocentricity does not introduce an extra agglomeration shadow. At the same time, cities within polycentric regions may not "borrow" as much function or

performance from each other as expected.

Our findings, on the one hand, can be taken as an important warning for urban planners and policymakers. Regional disparities in regions with a monocentric urban system are less pronounced than regions with a polycentric urban system in China, which is entirely the reverse of what is generally expected. Hence, polycentric development in terms of population distribution cannot be considered as a reliable tool for diminishing regional economic disparities, at least for Chinese prefectural regions. On the other hand, or on the positive side, this research result promises a new possibility: monocentric development can increase equality in an efficient economy. Though monocentricity is well recognized as an efficient way to organize economic activities, a common worry is that it may also bring about inequality. However, we find that the core cities in the monocentric region can share the benefits of agglomeration through labor mobility and that the economic shadow in monocentric regions, which may fuel an increase in regional disparities, plays a limited role. In addition, we find a promising sign of convergence between core cities and secondary cities. Future research is required to carefully validate whether monocentricity can achieve the dual goals of efficiency and balance.

Moreover, although we have conducted a series of robustness checks by using different measures of poly-/monocentricity, all of these measures are quantified from the perspective of morphology. This morphological approach may exert considerable influence on our finding. In addition, this paper deals only with economic disparities and omits other social, cultural, or environmental aspects of uneven development. Further research should be undertaken in this regard; therefore, we cannot generally invalidate the utility of polycentric development.

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