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Spatial inequality in the city-regions in the Yangtze River Valley, China

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Abstract

The city-region has emerged as an important scale of state spatial strategy in China to promote equitable and sustainable development. This study investigates the spatial inequality of city-regions in the Yangtze River Valley (YRV) in terms of population, land, GDP and productivity, and examines changing patterns and factors of GDP per capita. We find that the spatial form of the YRV is typical of city-regions in China, where population density and productivity around mega-cities are much higher and decline from the low to the middle and upper reaches of the YRV. We also find that inequality across city-regions is high, and that most inequality is due to differences within city-regions. We find that the YRV is driven by capital-intensive and labour-intensive growth, with an emerging significance of productivity. Our analysis reveals the significance of institutional factors, including the processes of marketisation, globalisation, decentralisation and urbanisation in regional development. Moreover, the importance of the non-state sector in economic growth has been increasing, while the role of globalisation has been declining.

Keywords

China, city-region, spatial inequality, Yangtze River Valley

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摘要

为了促进公平和可持续发展，城市区域已经成为了中国国家空间战略的一个重要尺度。本研究调查了长江流域城市区域在人口、土地、国内生产总值和生产力方面的空间不平等，并考察了人均国内生产总值的变化规律和因素。我们发现，长江流域的空间形态是中国城市区域的典型代表。在长江流域，大城市周围的人口密度和生产力要比其他地区高得多，并且从长江流域的下游到中上游呈下降趋势。我们还发现，城市区域之间的不平等程度很高，大多数不平等是由于城市区域之间的差异造成的。我们发现，长江流域是由资本密集型和劳动密集型增长驱动的，而生产率的重要性正在显现。我们的分析揭示了制度因素的重要性，包括区域发展中的市场化、全球化、去中心化和城市化进程。此外，非国有部门在经济增长中的重要性一直在上升，而全球化的作用一直在下降。

关键词

中国、城市区域、空间不平等、长江流域

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Introduction

In China, interregional competition for economic growth has intensified since the mid-1990s due to the deepening of the reform process resulting from fiscal decentralisation (Lin and Liu, 2000; Zhang, 1999) and urban entrepreneurialism (Chien and Gordon, 2008; Walder, 1995), which have impelled local governments into a 'race to the bottom'. Mega-cities in coastal regions such as Shanghai and Beijing have been experiencing rapid growth (Li et al., 2016), while many rural areas in the hinterland have been lagging behind (Liu and Li, 2017). Regional inequality and polarisation have threatened social stability and equitable development, which has caused considerable concern (Wei, 2011, 2015).

The city-region is an emerging urban form, arising through the process of decentralisation from big central cities to adjacent smaller ones (Hall and Pain, 2006). In Western countries, the city-region emerged in the context of globalisation and the effort to enhance regional competitiveness (McCann, 2007; Scott, 2001). In China, regional competition occurs at a scale greater than in mega-cities and metropolitan areas (Fang et al., 2010; Wu and Zhang, 2007), and the extensive high-speed railway system has facilitated the creation of polycentric mega-city-regions (Hou and Li, 2011). Furthermore, the development plan in China is a key driver of rapid urbanisation and economic growth (Wu, 2015). The Chinese government has launched city-region development plans as the state spatial strategy to boost economic growth and enhance competitiveness (Wu, 2017). Several state city-region plans have been promulgated, including the Middle Reach of Yangtze River Valley City-region Plan and the Yangtze River Delta (YRD) City-region Plan. In 2014, the Chinese government approved the outline of the Yangtze River Valley (YRV) Collaborative Development Plan for reducing regional inequality and fostering economic growth in the whole YRV.

Studies of regional inequality in China have focused on provinces and groups of provinces (e.g. Fan and Sun, 2008; Li and Hogan, 2015; Li and Wei, 2010; Wei, 2002), as well as intra-provincial inequality (e.g. Li et al., 2014; Liao and Wei, 2015; Wei and Ye, 2009; Yu and Wei, 2008). In recent years, spatial inequality in city-regions has drawn considerable scholarly interest (Fang and Yu, 2017; Li and Wu, 2013; Wu, 2017;

Wu and Zhang, 2007). However, the concept of the city-region in China is vaguely defined (Wu, 2017), and studies of the spatial-temporal evolution of inequality in city-regions are still insufficient. Although GIS spatial analysis has been used to visualise the space and scale of urban systems, most of the research has concerned provinces, especially developed provinces such as Zhejiang, Jiangsu and Guangdong (Liao and Wei, 2015; Wei and Ye, 2009; Wei et al., 2011). Recent research has employed GIS techniques to study the form and function of China's city-regions, such as the Shanghai mega-city-region (Sun et al., 2010), the capital metropolitan area (Zhang et al., 2017) and the Pearl River Delta (PRD) (Yeh et al., 2015).

This research on spatial inequality in the city-regions in the YRV attempts to answer the following questions: (1) How has the spatial structure of city-regions in the YRV been evolving? (2) How have the spatial patterns of population, GDP and landscape changed? (3) How has inequality in the YRD been evolving and what are its related factors? This study investigates the inequality of city-regions with respect to population, productivity, wages and economic activity, and the association between inequality and various factors such as TFP, investment, labour cost and institutional policy factors. The study may help both scholars and policy makers form a better understanding of the spatial structure and inequality of the YRV, which should contribute to the implementation and future assessment of the Yangtze River Valley Collaborative Development Plan.

Regional development and inequality in China: Theories and practices

Regional inequality in China is a critical issue for both scholars and governments. China launched its economic reform in the late 1970s to restructure the socialist economy and promote economic growth. The reform process is spatially uneven; preferential policies have been provided to the more developed coastal region to make reform more effective in speeding up economic growth. The government hoped that the benefits would trickle down to the lagging regions in the interior (Wei and Ye, 2009), influenced by growth pole theory (Fan, 1997). However, the gaps between rich and poor regions, including the coast–interior divide, were intensified, threatening social equity and sustainable development (Li and Hogan, 2015; Liao and Wei, 2015). To cope with this problem, the Chinese government has devoted more resources to the development of poorer regions, for example its 'western development strategy' (in 2000), 'central area rise strategy' (in 2004) and 'north-east area revitalisation strategy' (in 2009). The effect of these policies is debatable, since population and investment have still been flowing into coastal metropolitan areas. Besides interregional/interprovincial inequality, rural–urban inequality and intercity inequality have also become challenging issues in post-reform China in the context of rapid urbanisation. Population inflow towards coastal mega-cities such as Beijing and Shanghai has made urban problems more serious, such as spatial polarisation, traffic congestion and environmental degradation, while many small towns and cities have been experiencing recession, even being labelled ghost towns (Yang et al., 2014).

Two developments in China have made reducing regional inequality a challenging issue. The first is the fiscal decentralisation enacted in 1994, which has stimulated Chinese municipal governments to focus on GDP growth and investment, and also intensified interregional competition and chaotic development (Wu and Zhang, 2010). The other is the development of an extensive

high-speed rail system (Hou and Li, 2011), which has led to regional competition occurring at a scale greater than in mega-cities and metropolitan areas (Fang et al., 2010; Wu and Zhang, 2007). In recent years, China has adopted a new spatial strategy of state-orchestrated rescaling (Wu, 2017), and seven state city-region plans have been launched, in which city-regions include several cities or whole metropolitan areas.

Existing studies on regional inequality, especially in China, can be summarised as follows. (1) Researchers have measured levels and patterns of inequality at various scales to assess the extent of inequality (Bourguignon and Morrisson, 2002; Breau, 2015; Sala-i-Martin, 2006; Wei and Fan, 2000). (2) Scholars have investigated the determinants of inequality from a neoclassical perspective focusing on capital and labour, while more recent work examines the effects of globalisation and institutional change (Li and Fang, 2014; Liao and Wei, 2015; Wei, 2002; Wei et al., 2010). (3) Some study the enduring debate between 'convergence' and 'divergence' theories with different epistemological foundations, including neoclassical, structural, institutional and political economy perspectives (Barro and Sala-i-Martin, 1992; Li, 2013; Pritchett, 1997; Quah, 1996). These theories have had a profound impact on studies of regional inequality in China. (4) The majority of existing studies have been focused on regional inequality between provinces and groups of provinces (Fan and Sun, 2008; Li and Hogan, 2015; Li and Wei, 2010; Yu and Wei, 2008), as well as intra-provincial inequality, especially in developed coastal regions such as Zhejiang province (Wei and Ye, 2009; Ye and Wei, 2005), Guangdong province (Liao and Wei, 2015) and Jiangsu province (Wei et al., 2010).

In recent years, with the rise of city-regions in China, research on regional inequality in China has extended to the study of city-regions. Some investigate the inter-regional inequality at the city-region scale. For example, Long et al. (2018) analysed 23 urban agglomerations in China and observed a tendency of homogenisation and fragmentation. Xu et al. (2018) emphasise the effect of market growth, which is closely linked to global economic restructuring, on the increasing earnings gap in coastal city-regions. Li and Miao (2017) highlight the impact of population flow on regional inequality in the YRV. Meanwhile, others focus on intra-regional inequality. Chen et al. (2019) reveal that economically, the YRD urban agglomeration is experiencing greater polycentricity, but in terms of social welfare, the region manifests growing monocentricity. Li (2012) studies regional inequality in the capital metropolitan region, and points out the polarising trend between mega-cities and counties in terms of resource flow.

GIS techniques have been used to analyse the spatial-temporal evolution of these urban systems. For example, Wang et al. (2014) studied the spatial pattern of the central plain city-region by assessing the radiation effect of the central city of Zhengzhou, and found marked spatial imbalances in Zhengzhou's interactions with cities and regions on its periphery. Sun et al. (2017) studied the structural change of 13 metropolitan areas in China. Yeh et al. (2015) examined the producer service linkages and connectivity of the PRD. Given the significance of the YRV, more studies are needed to understand spatial inequality in the city-regions in the YRV. This study investigates the space and the scale of population, economic activities and productivity, as well as analysing the inequality between city-regions in the YRV, in order to gain a better understanding of the uneven development of the YRV.

This study also examines the association between inequality and various factors. Various theories have been developed to explain influencing factors of regional

Table 1. Status and structure of the YRV.

	YRV		As percentage of total in 2013		
	2000	2013	YRD	Middle reach	Upper reach
Population (million)	50.8	55.9	39.1	30.5	30.4
GDP (billion yuan)	3,962.5	25,463.2	53.9	24.9	21.1
Land area (km^2)	1,283,786	1,283,756	27.2	40.1	32.7
Fixed asset investment (billion yuan)	913.7	17,264.5	46.4	27.8	25.8
FDI (US$ billion)	14.7	117.8	64.6	21.3	14.1

inequality, including neoclassical (Barro and Sala-i-Martin, 1992; Borts and Stein, 1964), divergence (Myrdal, 1957; Storper, 2018), structural (Smith, 1984) and institutional (Rodréguez-Pose, 2013) theories or perspectives. Differences in economic growth rates practically explain the sources of inequality (Barro and Sala-i-Martin, 2004; Bourguignon and Morrison, 2002). We follow the conceptual framework that regional development in post-reform China is influenced by the triple processes of marketisation, decentralisation and globalisation, which are the major drivers of spatial inequality (Wei, 2000). This conceptual framework attempts to integrate Western theories and the economic transition in China. We have also extended the framework to include the process of urbanisation, which has been proved to significantly influence spatial development and inequality in China (Gao et al., 2015; Long et al., 2018). We also examine factors studied conventionally as sources of regional inequality in the YRV, such as wages, investment and factor productivity.

In summary, the city-region development plan in China is a state spatial strategy to overcome spatial polarisation and achieve coordinated development (Wu, 2017). Research to date has focused on inter-regional inequality between the coastal region and the hinterland in China, as well as on intra-provincial inequalities. Inequality in city-regions in the YRV needs further investigation in light of the political context of the YRV development plan. This article seeks to contribute to the literature by using spatial and statistical analysis to better understand inequalities between city-regions in the YRV.

Study area and methodology

Study area

The study area for this research is the YRV, through which flows the longest river of Asia, an area consisting of 110 prefectural-level cities in 11 provinces. With a land area of 2,050,000 km^2, the region is home to more than 40% of the national GDP and population.

As Table 1 shows, regional development in the YRV was clearly characterised by a spatially uneven pattern from 2000 to 2013. In 2013, the YRD produced 53.9% of the YRV's GDP on 27.2% of the land area. It also attracts 64.6% of FDI and 46.4% of fixed asset investment. In contrast, the middle and the upper reaches produce 24.9% and 21.1% of GDP on 40.1% and 32.7% of the land area, respectively. The ratio of GDP per capita of the YRD to the middle and upper reaches is 2 : 1.2 : 1. This gap is the object of growing concern. In 2014, the Chinese government approved the outline of the Yangtze River Valley Collaborative Development Plan, which aims to reduce regional inequality and foster economic growth. Three out of seven state city-region

Table 2. Variables used in the regression model.

Category	Definition	Abbreviation	Unit
Dependent variable			
Economic development	GDP per capita	GDPPC	Yuan
Independent variables			
Productivity	Total factor productivity	TFP	—
Capital	Fixed asset investment per capita	FAIPC	Yuan
Labour	Average wage per year	WAGE	Yuan
Marketisation	Non-state-owned sector to the state-owned sector	NSOE	%
Globalisation	FDI per capita	FDIPC	US$
Urbanisation	Population in urban area to the total	URB	%
Fiscal decentralisation	Electricity supply per capita	ESPC	kwh
	Number of doctors per 10,000 persons	DOCPC	person

plans have been implemented in the YRV to date, including the Middle Reach of Yangtze River Valley City-Region Plan (in 2015), the Yangtze River Delta City-Region Plan (in 2016) and the Chengyu City-Region Plan (in 2016).

Methods and indicators

To measure the extent and agglomeration of city-regions in the YRV, the GIS spatial smoothing method is used to visualise the structural change of population distribution. To measure the scale of efficiency and technical efficiency, input and output panel data are employed to estimate total-factor productivity (TFP) on the non-parametric frontier method, and the clustering characteristic of productivity is also described. To measure the spatial correlation of economic activity, the LISA (Local Indicators of Spatial Association) map is employed. Then the regression model is used to further investigate the related factors for inequality in economic growth.

The difference in economic growth rate underlies the source and trend of regional inequality (Wei et al., 2010). Regional inequality is usually represented by an output concept such as GDP per capita (Liao and Wei, 2015; Yu and Wei, 2008). We use GDP per capita (GDPPC) as the independent variable. Economic growth can be explained by means of the Cobb–Douglas production function used in macroeconomic modelling of technology, capital and labour. The indicators of total-factor productivity (TFP), fixed asset investment per capita (FAIPC) and average wage cost (WAGE) are selected as explanatory variables in the basic regression model. Institutional and policy factors are fundamental to economic growth in post-reform China, and therefore we view regional development in China as a process of marketisation, globalisation, urbanisation and decentralisation (Wei, 2015; Wei et al., 2010). The variables (NSOE, FDIPC, UBR, DOCPC and ESPC – explained below) are selected for the extended regression model to examine the impacts of institutional factors on regional development. All indicators in the regression model are reported in Table 2. The explanation of key variables is as follows.

Marketisation: Since the late 1970s, the Chinese government has been stimulating market forces by encouraging non-state-owned enterprises (Wu, 1993). The non-state sector employment rate (NSOE) is used as an indicator to reflect the degree of marketisation in the economy.

Globalisation: In post-reform China, the 'opening up' policy has allowed the coastal

region to attract foreign direct investment (FDI) inflow. Foreign direct investment per capita (FDIPC) is used as the indicator to measure globalisation (Liao and Wei, 2015; Shen and Wei, 2017).

Urbanisation: The high rate of internal mobility from the rural to the urban areas is one of the most significant demographic features of post-reform China (Li et al., 2016). The ratio of population in urban area to the total (UBR) is used to represent the degree of urbanisation.

Fiscal decentralisation: Fiscal decentralisation stimulates Chinese local governments to improve infrastructure and social development for capital and labour (He et al., 2008). Electricity supply per capita (ESPC) is used as an indicator to measure the development of municipal infrastructure. The number of doctors per 10,000 persons (DOCPC) is used as an indicator of the level of public services.

Regression model specification

A regression model is used to reveal the impacts of determining factors on GDP per capita. The basic model is built on the Cobb–Douglas production function, which explains the output of an economy as determined by variables of technology, capital and labour. The factors of marketisation, globalisation, urbanisation and decentralisation are also included in the extended model (Equation 1) as determining variables. The data used for the study comes from the China City Statistical Yearbook, a database administered by the National Bureau of Statistics of China that contains information on demographic and economic aspects of prefectural-level cities in 2000 and 2013.

$$Y_{it}^{'} = f(A_{it}, L_{it}, K_{it}, M_{it}, F_{it}, U_{it}, D_{it}) \quad (1)$$

We represent the regression equation as follows:

$$\begin{aligned} \ln(GDPPC_{i,t}) &= c_i + \delta_1 \cdot \ln(TFP_{i,t}) \\ &+ \delta_2 \cdot \ln(FAIPC_{i,t}) + \delta_3 \cdot \ln(WAGE_{i,t}) \\ &+ \delta_4 \cdot \ln(NSOE_{i,t}) + \delta_5 \cdot \ln(UBR_{i,t}) \\ &+ \delta_6 \cdot \ln(FDIPC_{i,t}) + \delta_7 \cdot \ln(DOCPC_{i,t}) \\ &+ \delta_8 \cdot \ln(ESPC_{i,t}) + u_{i,t} \end{aligned} \quad (2)$$

where $GDPPC_{i,t}$ is GDP per capita; $TFP_{i,t}$ is total-factor productivity of city i at time t; $FAIPC_{i,t}$ is investment; $WAGE_{i,t}$ is labour cost; $NSOE_{i,t}$ represents marketisation; $UBR_{i,t}$ represents urbanisation; $FDIPC_{i,t}$ represents globalisation; $DOCPC_{i,t}$ and $ESPC_{i,t}$ represent decentralisation; and δ represents the regression coefficient.

The evolution of the spatial structure and inequality of city-regions

The structure of city-regions

Figure 1 distinguishes and compares the formation and expansion of city-regions in the YRV from 2000 to 2013. Population distribution in the YRV is very typical of city-regions; population density is highest around mega-cities and declines with distance. To be specific, population density in the YRD is the highest, especially around mega-cities such as Shanghai, Nanjing and Suzhou, while sub-city-regions became more tightly organised between 2000 and 2013. The city-region in the middle reach has expanded substantially since 2000, where the Wuhan metropolitan area has grown the fastest, with an expansionary trend towards connecting with the Poyang metropolitan area. The expansion rate of the city-region in the upper reach is also very fast, where the core area is expanding rapidly and a new sub-city-region (Chengdu-Yibin-Zigong metropolitan area) is forming. In contrast, population density in Guizhou and Yunnan provinces remains

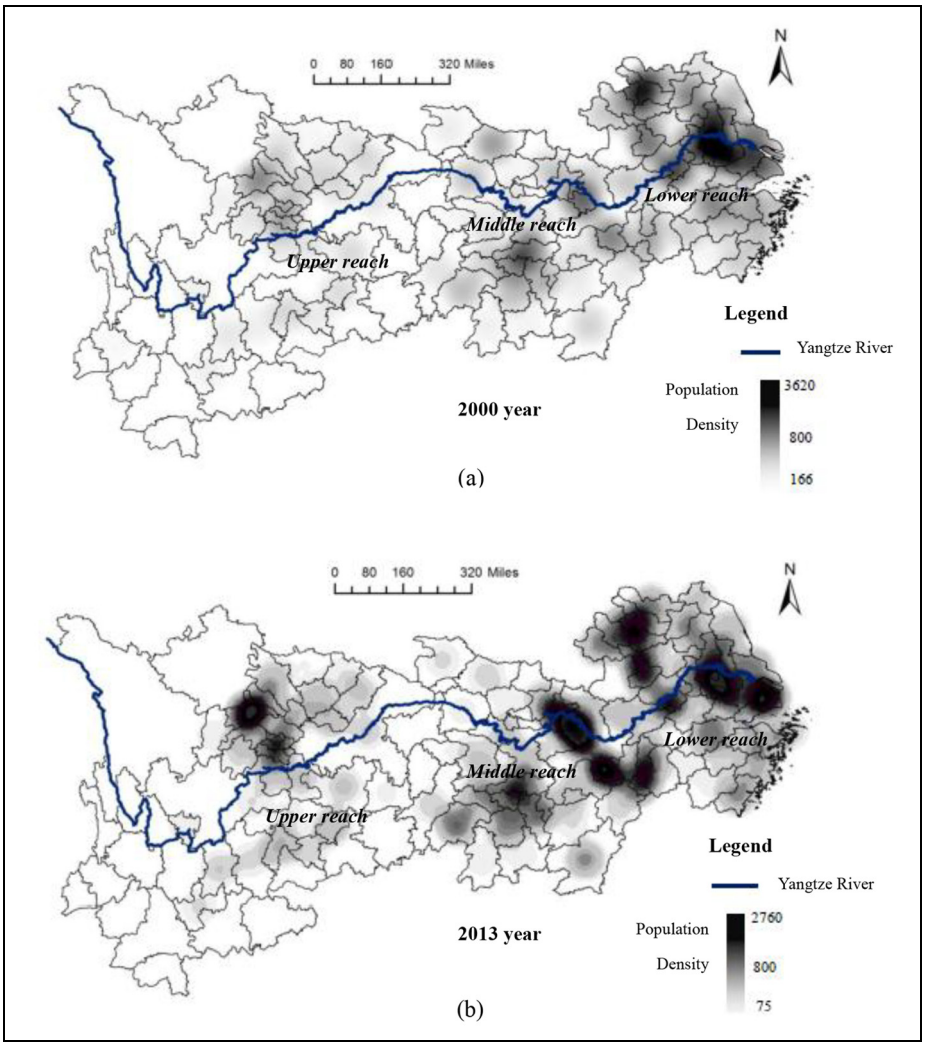

Figure 1. Population clustering and evolution in the YRV: 2000 versus 2013.
Note: The population clustering is computed on the population density of all 110 prefectural-level cities in the YRV.

quite low, and population concentration is not as great as in other provinces.

Inequality of city-regions

Table 3 presents the inequality of city-regions in the YRV in terms of population, land area and GDP per capita. First, with respect to population distribution, a gradient descending from the YRD to the middle reach and then to the upper reach can be observed. In 2000, the population of city-regions in the YRD was almost three times and 13 times higher than those in the middle and upper reaches, respectively. In 2013, the gap narrowed to 2.3 times and five times, respectively. Second, with respect to the total city land area of city-regions, the expansion rates in the middle and

Table 3. The stylised facts of inequality of city-regions in the YRV: 2000 versus 2013.

City-region	Land area		Population		GDP per capita	
	Total city (km^2)	Urban district (km^2)	Total city (10,000)	Urban district (10,000)	Total city (yuan)	Urban district (yuan)
2000						
YRD	167,467	15,755	11,384	3048	14,719	26,580
Middle reach	78,659	15,339	3799	1519	9151	15,442
Upper reach	25,573	3445	889	246	4903	7644
Total	271,699	34,539	16,073	4813	12,859	22,097
2013						
YRD	171,626	50,990	12,650	6099	83,495	116,658
Middle reach	119,917	12,658	5638	1702	54,624	107,626
Upper reach	35,695	6047	2460	912	52,233	88,817
Total	327,238	69,695	20,748	8713	71,943	111,979

Notes: In China, the total administrative region of a city includes the urban district, suburban district and counties under the jurisdiction of the municipality. Here we report stylised facts (land area, population and GDP per capita) of the total city and urban district of city-regions in the lower, middle and upper reaches in the Yangtze River Valley separately.

Table 4. Inequality decomposition in the YRV.

Year	Estimates of Theil index			Percentage	
	Inequality within city-regions	Inequality between city-regions	Total inequality	Inequality within city-regions (%)	Inequality between city-regions (%)
2000	0.091	0.030	0.121	75	25
2013	0.095	0.022	0.118	81	19

upper reaches were 52% and 40%, respectively, for the period, much faster than those of the YRD. In 2013, about half of the land area in the YRD city-region had a population density over 800 people/km^2, which decreased to 30% in the middle reach and 20% in the upper reach. Finally, with respect to GDP per capita, the YRD city-region produced 81.1% of the total GDP of the YRV in 2000 and 70.8% of the total in 2013. Along with the fast growth of the middle and upper reaches, the ratios of GDP per capita of city-regions in the YRD to the middle and upper reaches were 3 : 1.6 : 1 in 2000, decreasing to 1.5 : 1.1 : 1 in 2013.

Table 4 shows the degree and a decomposition of the total inequality of city-regions in the YRV. The estimate of total Theil index is 0.121 in 2000, decreasing to 0.118 in 2013, which indicates that the total inequality in the city-regions has been shrinking. The differential between central and peripheral cities in the city-regions increased; over 75% of the inequality was accounted for by inequality within city-regions in 2000, and the share rose to 81% in 2013. In contrast, the inequality between city-regions decreased; the share was 25% in 2000 and decreased to 19% in 2013.

Migrants respond to wage differentials for benefit gain (Long, 2005). Table 5 reports and compares average wages in the city-regions in the YRV. The results show that wages rose across the board from 2000 to

Table 5. Average wage of city-regions in the YRV: 2000 vs. 2013.

2000		2013	
Region	Average wage (yuan)	Region	Average wage (yuan)
YRD	11,622	YRD	58,991
Middle reach	7512	Middle reach	40,263
Upper reach	8126	Upper reach	49,799
Total	9621	Total	51,200

Source: China City Statistical Yearbook.

Table 6. Estimates of TFP of cities in the YRV, in 2013.

City-region	Mean value	Estimate of TFP
YRD	0.785	Shanghai(1), Nanjing(0.697), Wuxi(1), Xuzhou(0.69), Changzhou(0.971), Suzhou(1), Nantong(0.606), Lianyungang(0.689), Huai'an(0.682), Yancheng(0.724), Yangzhou(0.686), Zhenjiang(1), Taizhou(0.715), Suqian(0.636), Hangzhou(0.697), Ningbo(0.856), Wenzhou(0.708), Jiaxing(0.794), Huzhou(0.789), Shaoxing(0.716), Jinhua (0.794), Chuzhou(0.931), Zhoushan(1), Taizhou(0.758), Lishui(1), Hefei(0.517), Wuhu(0.801), Pangbu(0.678), Huainan(0.739), Ma'anshan(0.897), Huaibei(0.777), Tongling(1), Anqing(0.699), Huangshan(0.861), Chuzhou(0.802), Xingyang(0.789), Suzhou(0.668), Liu'an(0.47), Bozhou(0.78)
Middle reach	0.711	Wuhan(0.811), Huangshan(0.715), Shiyan(0.474), Yichang(0.634), Xiangyang(0.699), E'zhou(1), Jingmen(0.619), Xiaogan(0.457), Jingzhou(0.566), Huanggang(0.529), Xianyang(0.655), Suizhou(0.817), Changsha(0.872), Zhuzhou(0.718), Xiangtan(0.724), Hengyang(0.709), Shaoyang(0.563), Yueyang(0.804), Changde(0.9), Zhangjiajie(1), Yiyang(0.702), Chenzhou(0.759), Yongzhou(0.749), Nanchang(0.541), Jingdezhen (0.785), Pingxiang(0.767), Jiujiang(0.634), Xinyu(1), Yingtan(1), Ganzhou(0.596), Ji'an(0.591), Yichun(0.612), Fuzhou(0.56), Shangrao(0.602)
Upper reach	0.713	Chongqing(0.356), Chengdu(0.446), Zigong(1), Panzhihua(0.79), Luzhou(0.654), Deyang(0.85), Mianyang(0.674), Guangyuan(0.654), Suining(0.707), Neijiang(0.948), Leshan(0.754), Nanchong(0.608), Meishan(0.797), Yibin(0.721), Dazhou(0.661), Ziyang(0.794)

Notes: The estimates of TFP for prefectural-level cities in the YRV are computed by the non-parametric frontier method. The input indicators are land, labour and investment in urban area, and the output indicators are GDP produced in urban area and pollution discharge.

2013, but average wages obviously differed between the three regions. Those in the YRD were the highest, with 11,622 yuan in 2000 and 58,991 yuan in 2013, and the ratios of the average wages of the three city-regions were 1.4 : 1 : 1.2.

Wages vary with productivity (Akerman et al., 2013; Bowlus and Robinson, 2012). In the process of urban-system evolution, cities with high productivity expand, and cities with low productivity decline (Glaeser, 2011). Table 6 displays the estimates of

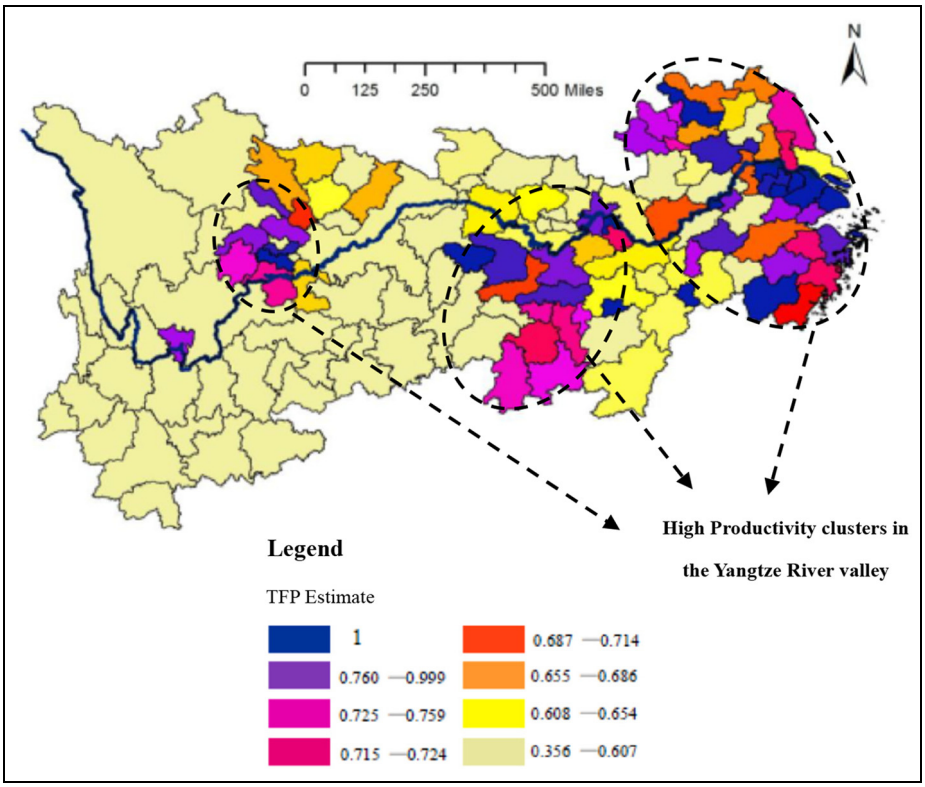

Figure 2. Productivity clustering of TFP estimate in the YRV.

Table 7. Estimates of TFP changes and decomposition.

Period	City-region	Techch	Sech	Tfpch
2000–2013	YRD	1.048	1.064	1.115
	Middle reach	1.010	0.92	0.938
	Upper reach	1.023	0.964	0.986
	Mean value	1.031	0.984	1.014

Notes: The estimates of TFP change for cities in the YRV are computed using the DEA-Malmquist TFP index. Techch represents technical change; Sech represents allocative efficiency change; Tfpch represents total factor productivity change.

total-factor productivity (TFP) of cities in the YRV in 2013. The results show that the productivity of city-regions in the YRV was still low, and the highest estimate of TFP is for the YRD, where seven cities (Shanghai, Wuxi, Suzhou, Zhenjiang, Zhoushan, Tongling and Lishui) are found on the production frontier. Figure 2 describes the productivity clustering in the YRV. It is obvious that the productivity of mega-cities is much higher than that of remote cities. The scope of high productivity clustering in the YRD is much larger than in the middle and upper reaches. Table 7 shows the

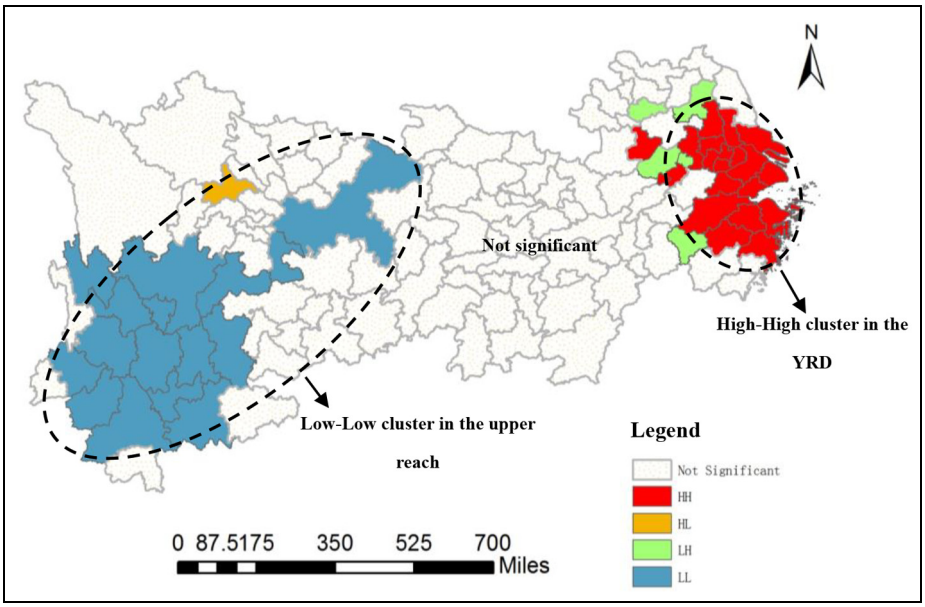

Figure 3. LISA map of prefectural-level GDP per capita in the YRV.

Table 8. Correlation matrix of independent variables.

	Mean	S.D.	1	2	3	4	5	6	7	8
ln (TFP)	4.28	0.21	1.000							
ln (FAIPC)	10.27	0.58	0.097***	1.000						
ln (WAGE)	10.71	0.22	0.456***	0.772***	1.000					
ln (NSOE)	2.39	0.67	0.281***	0.426***	0.467	1.000				
ln (UBR)	3.88	0.50	0.020***	0.423*	0.225**	0.064	1.000			
ln (FDIPC)	4.66	1.36	0.328**	0.623**	0.585***	0.592*	0.202**	1.000		
ln (DOCPC)	7.53	0.39	0.088**	0.676***	0.502***	0.256***	0.539***	0.468***	1.000	
ln (ESPC)	5.32	0.60	0.164***	0.600***	0.597***	0.375***	0.058***	0.482***	0.383***	1.000

Notes: *$p < 0.1$, **$p < 0.05$ and ***$p < 0.01$.

decomposed estimates for TFP of technical efficiency change and scale efficiency change. The average estimate of TFP in the YRV is 1.014, the estimate of technical efficiency change is 1.031, while scale efficiency is at the relatively low level of 0.984.

Figure 3 describes the spatial correlation of prefectural-level GDPPC in the YRV, and the uneven spatial pattern of GDPPC is obvious. Rich cities are markedly clustered in the YRD, while poorer cities cluster in the upper reach.

Factors for inequality in economic growth

Table 8 presents the correlation coefficients of the independent variables. All the coefficients in the matrix are less than 0.8, which

indicates that multi-collinearity is not serious in the model. Table 9 reports the estimate results obtained from OLS multiple regression regarding the effects of explanatory variables. To observe the variation during the study period, a comparison is made between the years 2000 and 2013. Overall, the model has high goodness of fit (R-squared), and more than 80% of the total variance of ln (GDPPC) has been explained by the regression model.

The results show that economic growth in the YRV can be explained with the triple formula of capital, labour and technology, for all the explanatory variables are statistically significant. The coefficients of capital and labour are positive, which means that capital and labour are the main drivers of economic growth in the YRV. This result accords with the view that China's economic growth pattern is typical of capital-intensive and labour-intensive growth (Lim and Spence, 2012). The investment rate has exceeded 45% of GDP and labour cost is only about 7.5% when compared with developed countries. The coefficient of TFP is also positive, which indicates that a new growth pattern based on knowledge accumulation and productivity increase has also become important in the YRV. After we introduced the policy factors to the model, the effects of the explanatory variables were robust.

The effect of the policy factors – marketisation, urbanisation, globalisation and fiscal decentralisation – on economic growth is also significant. The effect of marketisation is positive, with a significantly increasing trend, about 8.1 times greater in 2013 than in 2000, which implies that economic growth in the YRV is mostly attributable to the dynamism of the non-state sector. This result also implies that the SOEs in the YRV are significantly less efficient than in the private sector, and that low productivity in SOEs amounts to a drag on economic growth. The effect of urbanisation was 2.5 times greater at the end of the period, confirming that urbanisation boosts economic development in the YRV, which is in line with the viewpoint that urbanisation is an engine of economic growth (Li, 2014). It is notable that the effect of globalisation decreased by 30%, reflecting that as wages have risen the competitiveness of export-oriented manufacturing in the YRV has been declining. The effect of municipal infrastructure and public services was significant, with an increasing trend of 1.5 times and 2.4 times from 2000 to 2013, respectively. This result indicates that municipal infrastructure raises productivity and boosts growth, and that spending on public services attracts migrants. Both are factors of economic growth in the YRV.

Discussion and conclusion

This study examines the spatial structure of city-regions in the YRV, and investigates the inequality of city-regions in terms of population, land, GDP, wages and productivity, as well as growth of GDP per capita. The YRD located in the lower reach is a populous and prosperous area, which produces more than half of the YRV's GDP with about a quarter of the land area. The ratio of GDP per capita of the YRD to the middle and upper reaches is 2 : 1.2 : 1, and the ratio of average wage is 1.4 : 1 : 1.2.

The study finds that the spatial form of the YRV is typical of city-regions, where the population density around mega-cities is much higher, with a decentralised trend and high productivity clusters centred on mega-cities. Productivity in mega-cities is much higher than in remote cities, and the size of the high productivity cluster in the YRD is much larger than in the middle or upper reaches. The study finds that the level of total inequality in the YRV is high, and that most of the inequality is due to differences within city-regions which are still on the rise,

Table 9. Results of regression models.

Variables	2000				Variables	2013			
	Basic model		Extended model			Basic model		Extended model	
	Coefficient	T-value	Coefficient	T-value		Coefficient	T-value	Coefficient	T-value
Basic variables					***Explanatory variables***				
ln (TFP_i)	0.527***	6.05	0.416***	5.41	ln (TFP_i)	0.341***	3.14	0.459***	4.83
ln ($FAIPC_i$)	0.482***	9.17	0.314***	5.44	ln ($FAIPC_i$)	0.587***	20.56	0.526***	7.28
ln ($WAGE_i$)	0.534***	2.98	0.479***	3.07	ln ($WAGE_i$)	0.615***	5.26	0.206*	1.84
Expanded variables					***Control variables***				
ln ($NSOE_i$)			0.013*	1.74	ln ($NSOE_i$)			0.106***	3.55
ln (UBR_i)			0.023***	3.55	ln (UBR_i)			0.058**	2.23
ln ($FDIPC_i$)			0.085***	5.04	ln ($FDIPC_i$)			0.025	0.96
ln ($DOCPC_i$)			0.16*	1.90	ln ($DOCPC_i$)			0.241***	3.3
ln ($ESPC_i$)			0.080*	1.67	ln ($ESPC_i$)			0.182***	4.22
Statistical characteristics					***Statistical characteristics***				
R-squared		0.87	0.91		R-squared		0.91	0.95	
Log likelihood		8.09	26.74		Log likelihood		16.97	42.48	
S.E. of regression		0.23	0.19		S.E. of regression		0.21	0.16	

Notes: *$p < 0.1$, **$p < 0.05$ and ***$p < 0.01$.

which is consistent with the findings of Li and Miao (2017). In contrast, inequality between city-regions in the YRV has been shrinking, as the ratio of GDP per capita of city-regions in the YRD to the middle and upper reaches is 3 : 1.6 : 1 in 2000, and decreases to 1.5 : 1.1 : 1 in 2013.

The study confirms that the economic growth pattern in the YRV is typical of capital-intensive and labour-intensive growth, for the coefficients of capital and labour are positive and statistically significant. It also confirms an emerging growth pattern based on knowledge accumulation and productivity increases, as argued in the literature emphasising the role of innovation and regional development (Storper, 2018). The study demonstrates that institutional or policy factors boost economic growth in a way that intensifies regional inequality, which concords with Wei (2002) and Wei et al. (2010), and more generally the importance of institutions in regional inequality (Rodríguez-Pose, 2013). A notable finding is the significance of non-state-owned enterprises in regional development, since the effect of marketisation is positive with a significantly increasing trend, which is consistent with Lim and Spence (2012) and Xu et al. (2018). That urbanisation boosts economic development in the YRV is also confirmed, supporting the findings of Gao et al. (2015) and Long et al. (2018) on the significance of urbanisation in China. The study finds that the effects of globalisation are decreasing, reflecting the fact that the YRV has experienced difficulty in maintaining the competitiveness of export-oriented manufacturing, as wages rise and low value-added manufacturing has moved to other regions.

Municipal infrastructure and public services are also confirmed to be drivers of growth. In China, local governments are responsible for spending on municipal public services, and public spending per capita differs greatly between localities. For instance, in 2013, as regards expenditures for municipal public utilities per capita in the three primary cities of the city-regions in the YRV, Shanghai spends 1746 yuan, about three times and 3.5 times higher than is spent in Wuhan and Chongqing, respectively. The study implies that providing more funding for infrastructure in the middle and upper reaches and equalising the public services could be used to balance economic growth in the YRV.

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