

**HEALTHCARE BEDS EQUITY 2000-2017, THE 2009 REFORM,
AND COVID-19 IN CHINA**

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Healthcare beds equity 2000-2017, the 2009 reform, and COVID-19 in China

Abstract

This study aims to map the trends and patterns of healthcare beds equity in China from 2000 to 2017, and to assess the impact of the 2009 reform. In 2009, China launched a huge and complex health system reform, injecting massive funding to the healthcare sector. However, it is a challenge to ensure the reform can improve equity. Previous literature focused on demand-side equity analyses, but the supply-side evidence is lacking. Using a panel of county-level healthcare beds data (2000-2017), this study mainly adopts interrupted time series to evaluate the impacts, with spatiotemporal indicators including β -convergence and Moran's I used to depict the patterns. Through the trend break test, 2006 is selected as the main analysis year. The results show that the reform to some extent improved the resources allocation equity in China. However, different level equities presented different patterns. Specifically, at the city level, the equity was strengthened, with the annual rate decreased by 0.004 after the reform, as the governments enhanced its roles in the healthcare sector. But at the province level, the reform witnessed widening inequity trends with an annual rate increase by 0.003 compared to the pre-trend, indicating the equity concerns of the decentralization. Also, disparities among regions exist. The study concludes that governments are essential to promote healthcare equity, but the governance structure also matters. Countries should carefully design their healthcare system to strike a balance between government and market roles, as well as the central and local financing arrangements.

Introduction

Since 1978, China transited from the government planned economy to the market economy, with dramatic economic growths achieved. The healthcare system was also transformed, with a *laissez-faire* approach adopted by the government. The privatization of healthcare system in China gave rise to huge problems that "constitute a major potential threat to China's domestic tranquility" (Blumenthal & Hsiao, 2005).

Health inequity was one of the daunting challenges, with wider gaps between rural and urban areas and across income quartiles (Tang et al., 2008). For instance, the Gini coefficients of infant mortality rate (IMR) increased from 0.27 in 1981, to 0.296 in 1990, and 0.367 in 2000. IMR in rural areas was significantly higher than that in cities and the gap widened from 1.5 in 1981 to 2.1 in 2000 (Zhang & Kanbur, 2005). Similarly, in 2003, under-five mortality was 33 per 1000 in rural areas, while the mortality was only 15 in urban locales. In 1996, under-5 mortality ranges from 10.6 per 1000 livebirths to 345.1 (Wang et al., 2016). The situation of maternal mortality was alike, with 65 and 28 per 100,000 livebirths in rural and urban areas in 2002, respectively, giving a rural-to-urban ratio of 2.3. In 1996, the subnational-level maternal mortality ratio ranged from 16.8 per 100 000 livebirths to 3510.3, with a Gini coefficient of 0.63 (Liang et al., 2019). The growing disparities along different dimensions (rural-urban, inland-coastal, etc.) are cited as reasons for the growing social unrests.

It is widely accepted that the substantial health inequities are caused by the unequal distributions of power, income, goods and services, and the circumstances of people's lives (WHO, 2008). The socioeconomic imbalance among regions can partly explain the substantial health outcomes inequities, and the government has the imperatives to reduce disparities. However, many systemic factors in China widen the gaps further.

One factor is the market failure and the insufficient government stewardship (Tang et al., 2008). From 2000 to 2008, government health expenditure only accounted for 18.23% of total health expenditure on average, with out-of-pocket accounted for 52.46%. In 2008, only 7.8% of public hospital revenues were from government subsidies. The other plausible systemic arrangement is the heavy reliance on local public finance to fund health care (Yip & Hsiao, 2009). It is estimated that more than 90 percent of public resources for healthcare is allocated at the provincial and sub-provincial levels (Brixi et al., 2011; Pan & Liu, 2012). Though China's governance system, featured as "Federalism, Chinese style", can boost economic development (Montinola et al., 1995; Qian & Roland, 1998; Xu, 2011), it to some extent undermines public services provision (Zhou, 2016), as health and other public services are not always being evaluated. Under such an incentive design, so-called "promotion tournament" for economic growths (Bo, 1996; Maskin et al., 2000; Li & Zhou, 2005; Chen et al., 2005), local authorities are not motivated to provide public services, especially in poor and rural areas. In 2003, public spending was 48 times higher in the richest than the poorest counties, with the richest province spending over 8 times more per head on public services than the poorest (Dollar, 2007).

The comparative low level of the government funding, with huge disparities of local public finance to healthcare, tremendously reduce equity, and increase dissatisfactions. In the demand side, there was a huge gap in social insurance coverage. In 2003, 45% of the urban population and 79% of the rural population were not covered by social health insurance schemes. Among those who were covered, the benefit packages differed as well. In the supply side, the distribution of healthcare resources was also unequal. In 1980, healthcare beds and healthcare personnel per 1000 people in cities were 4.57 and 7.82, respectively, compared to 1.48 and 1.81 in rural areas (Zhang & Kanbur, 2005). Moreover, the gaps between rural and urban areas have been growing.

Seeing this, in 2009, China launched a huge and complex health system reform, aiming to build a universal essential health-care system and provide all citizens with safe, effective, convenient and cheap healthcare. To achieve this goal, Chinese Government injected massive funding to the healthcare sector (Yip et al., 2012). Between 2008 and 2011, government health expenditure doubled (Figure 2), with half funding demand-side premiums to expand social health insurance coverage, and the rest for supply-side subsidies (Yip et al., 2019).

However, it is a challenge to ensure the injection of financial resources can improve equity, as local finance still accounts for more than 70% of total government healthcare expenditures. Recent years witness a slow growth of studies analyzing the impact of healthcare reform on intermediate equity, but most focus on demand-side, using indicators such as healthcare utilization and financial protection. For example, Meng and his colleagues used data from National Health Services Survey (2003-2011), who found advances have been made in achieving equal access to services and insurance coverage across regions, though gaps remain (Meng et al., 2012). Using data from the China

Family Panel Studies (2010-2016), Ta et al. found income inequity in healthcare utilization was shrinking, but a high degree of inequity in financial protection between rural and urban residents still exists (Ta et al., 2020). It is worth noting that utilization, though widely adopted, is not a good indicator to reflect health access, as overutilization or unnecessary utilization is prevalent in China (Yip et al., 2010).

The principle of equity begins with ensuring people equal access opportunity to needed healthcare resources (Braveman, 2006). Healthcare resources are essential components of service delivery, as well as important determinants of health outcomes. So, optimizing the allocation of healthcare resources should be considered as the primary purpose of the planning. However, this supply-side evidence in China is lacking. To fill in this gap, this study aims to evaluate the impact of the 2009 health care reform on healthcare resources equity across counties in China, using 2000-2017 county level data.

Healthcare institutions, beds and personnel are the main indicators of healthcare resources, among which the bed is the key index connecting institutions and personnel. It can reflect the ability of medical service provision, and the number of beds per 1,000 people is widely used for governments to optimize the allocation of healthcare resources (Horev et al., 2004). So, similar with previous studies (Horev et al., 2004; Pan & Shallcross, 2016), healthcare beds are used as a proxy of resources in the study.

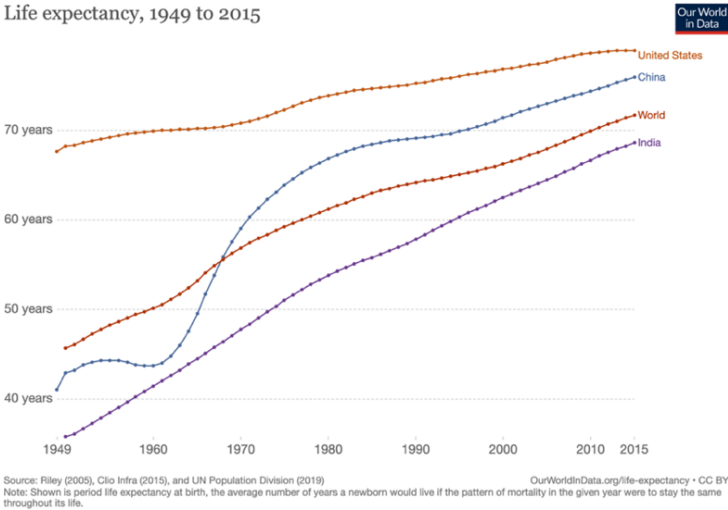
Institutional Background

The Chinese healthcare system has experienced several fundamental changes since the establishment of the People's Republic of China (Yip & Hsiao, 2015). After the revolution in 1949, the government adopted a communist public health system model, with government playing the central role in healthcare financing and delivery. All healthcare facilities were owned and operated by governments. The private sectors disappeared through a publicization movement in the 1950s.

The system attached greatest importance to equity. In rural areas, the Cooperative Medical System was established, with a network of primary healthcare facilities organized. These facilities were staffed by the "barefoot doctors", who received some intensive training in medical care, able to diagnose and treat some common diseases in rural areas. This system was financed through the communes – the economic production unit – within which each rural resident contributed a certain proportion. If referrals to higher level hospitals were needed, a minimal out-of-pocket would be paid. In urban regions, the state-owned enterprises organized and financed the system, which also provided services to the workers and their family members. Residents who did not belong to any state-owned enterprises could seek healthcare services in public-financed neighborhood clinics or hospitals.

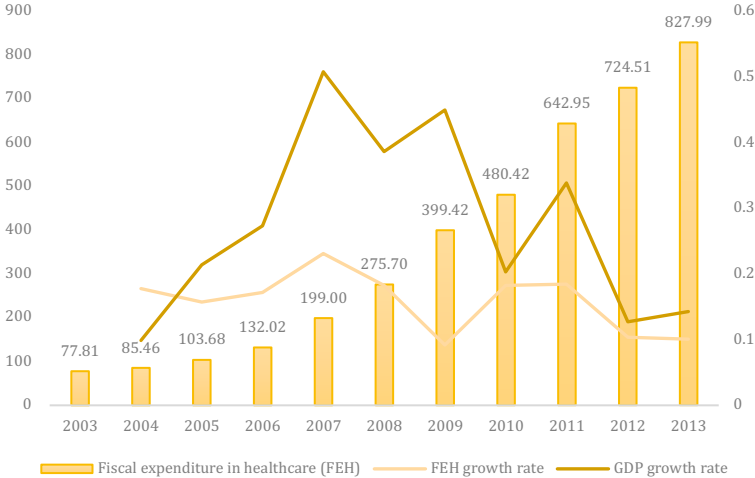
These institutional settings, with some health movements conducted, such as the Patriotic Health Campaign, accomplished great health gains. In this period, infant mortality fell from 200 to 57 per 1,000 live births, and life expectancy increased from about 45 to 68 years (Figure 1).

Figure 1 Life expectancy, 1949 to 2015 in China, India, US, and the world (Source: our world in data)



In 1978, China began the reform and opening up policy. The healthcare system was also transformed. Due to the economic liberalization, China experienced a fiscal crisis, with government revenue accounted for 30% of GDP in 1978, to 10% in 1993 (Naughton, 2014). Under this circumstance, the government funding to the healthcare sector dropped tremendously. At the same time, the communes in rural areas were dismissed, and the Cooperative Medical System collapsed. In urban areas, the state-owned enterprises no longer funded the health services. The healthcare facilities had to rely on themselves, as the government subsidies of facilities' total revenues dropped from 50-60% to merely 10% by the early 1990s (Yip & Hsiao, 2008). Clinics and hospitals generated the revenue through selling drugs, ordering imaging and laboratory tests and other charges. The so-called public facilities became for-profit entities. Social health insurance also shrunk, with 45% of the urban population and 79% of the rural population not covered in 2003. Out-of-pocket payments were as high as 60% of the total health expenditure. A large proportion of the populations could not afford the health services they need.

Figure 2 Fiscal expenditure in healthcare from 2003 to 2013



In response to the widespread dissatisfaction of the citizens, the Chinese government launched a major reform in 2009 and pledged to provide all citizens with equal access to basic healthcare, with

reasonable quality and financial risk protection (Yip et al., 2019). Four priorities were put forward, which were public health, care delivery, drug supply and health security.

The greatest achievement in this reform was the expansion of the social health insurance. Three schemes were strengthened, including Urban Employee Basic Medical Insurance (UEBMI), Urban Resident Basic Medical Insurance (URBMI), and New Cooperative Medical Scheme (NCMS). The government heavily subsidized the residents to enroll these schemes. A complementary Medical Assistance program was also established, to support poor populations. By 2011, these three insurance programs covered more than 92% of the population. In 2016, the URBMI and NCMS were integrated, to promote equity between urban and rural areas. In 2018, the National Health Security Administration was established, to act as a giant single purchaser to manage these insurance schemes, as well as the medical assistance program.

Meanwhile, the government provided funding for primary healthcare providers to deliver a package of basic public health services to populations in a defined region (e.g. village doctors were responsible for populations in their own villages). The package included chronic diseases, maternal and child health, mental health management, etc. The infrastructures of primary care were also improved greatly. Meanwhile, an essential medicine program was implemented, to reduce irrational drug use, and improve accessibility of the drugs for some common diseases.

The last ten years witnessed substantial progress of the reform in improving equal access to care and enhancing financial protection, especially for people of a lower socioeconomic status (Yip et al., 2019). However, the supply-side equity has not been carefully addressed.

Conceptual framework

The reform, along with its massive government investments, has two main channels to impact the healthcare resources equity. On the one hand, the governments at all levels play more important roles in the healthcare sectors. On the other hand, as the central government increased its financial transfer to poor areas, the equity concerns of decentralization are mitigated. The framework can be shown in Figure 3.

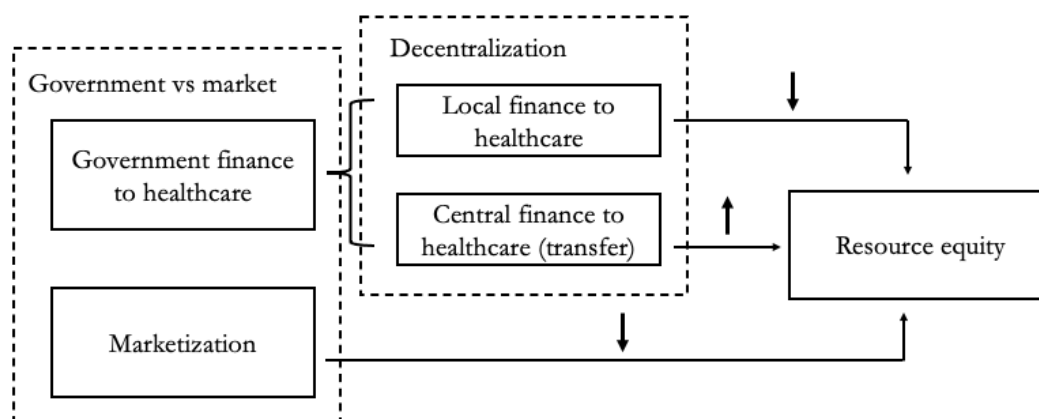


Figure 3 Flowchart of the conceptual framework

The relationship between government investments and equity can be vividly shown through international comparisons. In the United Kingdom, where the healthcare system is mainly financed by the government, both the equity indexes and health outcomes are much higher than that in the United States, where the government adopts marketization as the tool to operate healthcare system.

The government has several approaches to ensure resources equity. On the one hand, it can set priorities and allocate resources to the rural poor regions. On the other hand, it can directly provide public goods. Take China as an example. The government proposed that one of the goals of this reform is that the PHC will be more equitable and accessible, and efficiency of PHC institutions will be significantly improved by 2015. Specifically, the number of beds per thousand would be 1.2 and the number of health workers per thousand people would be 3.5 in PHC institutions by 2020 (General Office of the State Council, 2015). To achieve this goal, the government had invested an additional \$127 billion to enhance the infrastructures of PHC institutions, particularly those in rural areas (Liu et al., 2011). According to a survey covering 6 provinces in China (Zhang et al., 2013), government finance proportion for primary care facilities increased from 18.2% in 2008 to 38.84% in 2011, with the per capita financial input at 20.92 yuan in 2010 and 31.10 yuan in 2011.

However, in the hospital sector, the role of the government is still limited. The theory of market failure has been well researched in the healthcare sector. Even though “free market competition” can yield efficient resource allocation and getting the most maximum output, market failures exist, especially in the healthcare sector (Arrow, 1963; Hsiao, 1995). Moreover, free market competition does not produce equity. On the one hand, the market does not deliver public goods, which are both non-rival and non-exclusive. Free riders may be a huge problem, as no one is willing to pay. So, no private sector, which are profit driven, will supply the public goods. Research has also shown that private sectors may mainly dominate in regions with high economic statuses and population density, while rural poor regions solely rely on public healthcare institutions (Pan et al., 2016). In this case, excessive marketization may widen the inequities, without improvements in efficiency. On the other hand, the market may not redistribute resources. Economic theory assumes that income is fairly distributed, so market competition can produce the goods with the most efficiencies. However, this assumption does not hold in reality, and producers only sells to those who are able to pay. Under these circumstances, equity is undermined.

In China, as the public finance for healthcare increased since 2009, the healthcare resources distributions are not merely driven by the marketization. So, it is reasonable to hypothesize that the increasing role of government in healthcare sector in China can increase the resources equity.

On the other hand, the share of investments from the central government expanded, so the drawbacks of decentralization were to some extent remedied. Even though decentralization can improve governance, through participatory democracy and tailor-made policies (Bardhan & Mookherjee, 2006), it may undermine equity from many perspectives (Qiao et al., 2008; Sumah et al., 2016). A number of studies report negative or ambiguous effects of decentralization on health care, with inequity as a major concern (Collins & Green, 1994; Koivusalo, 1999). The biggest reason is that decentralized decision making may lead to disparities in approaches to healthcare, and further, gaps in health outcomes between autonomous units (Koivusalo, Wyss & Santana P, 2007; Redwood, 1999).

A recent systematic review concluded that the impact of decentralization on healthcare inequities depends on pre-existing socio-economic disparities and financial barriers to access, which also stated that “while decentralization can lead to inequities in health financing between sub-national jurisdictions, this is minimized with substantial central government transfers and cross subsidization” (Sumah et al., 2016). In China’s case, before the reform, declined central transfers to provinces, with a high off-budget funding led to inequity in health finance between jurisdictions. Inter-jurisdictional disparity was also high in China because of the insignificant effect of the replica of an equalization fund (West & Wong, 1995). After 2009, the central government transferred huge resources to poor rural regions in middle and west China, which may help to decrease disparities among regions.

Literature review

Previous research has used several measures to assess the healthcare resources equity, which include beds and personnel. For example, Horev et al. (2004) evaluated the Gini coefficient of hospital beds by population in the United States from 1970 to 1998 and found huge regional disparities. The Gini coefficient varies greatly, though on average it gradually decreased. Nishiura et al. (2004) demonstrated that there were uneven distributions in medical personnel, especially physicians (Gini index = 0.433), by province. For physicians, nurses, and patient beds, approximately 39.6%, 25.8% and 20.6% are concentrated in the Bangkok Metropolis. Similarly, Ramandi et al. (2016) analyzed the physicians, paramedics, and healthcare beds distribution in Iran from 2006 to 2013, Erdenee et al. (2017) evaluated the situation in Mongolia in 2014, and Woldemichael et al. (2019) assessed Ethiopia from 2000 to 2015, who found high inequities of healthcare resources in these countries.

Much research has also been done to measure the status quo and the trend of healthcare resource allocation in China, as well as the regional disparities among eastern, central, and western China.

For example, Qin & Hsieh (2014) analyzed the number of healthcare beds and physician per million people in each province of China from 1949 to 2010. They found that year by year, the coefficients of variation among provinces per million people decreased, and the distribution of healthcare resources among provinces was dispersed. It was also found that from 1949 to 2010, the healthcare resources distribution showed a dynamic convergence phenomenon among provinces in China. In other words, the provinces with fewer healthcare resources have a catch-up growth phenomenon, compared with the provinces with more resources. Chen et al. (2014) revealed the equity of health workforce distribution in urban community health services of China, which showed that the Gini coefficients for health workers, doctors and nurses per 10,000 population ratios were 0.39, 0.44, and 0.48, respectively. Wang et al. (2020) also found disequilibrium in the distribution of the primary health workforce among eight economic regions and between rural and urban areas in China. Pan & Shallcross (2016) analyzed the healthcare beds at the county level in 2011, who calculated the Gini coefficient of the number of beds in each province according to population allocation. It was found that the allocation of resources in western provinces was more unfair than other provinces. Healthcare beds were spatially clustered. County fiscal revenue and income of residents are positively correlated with the bed density. Zhang et al. (2018) found that from 2012 to 2016, the Gini coefficients by population size of primary healthcare resources were below 0.2 and that by geographical area were

between 0.6 and 0.7. Theil index had the same trend, and intra-regional contribution rates were higher than inter-regional contribution rates, which were all beyond 60%. Research on healthcare equipment, such as computed tomography and magnetic resonance imaging also found similar trends (He et al., 2018). Besides, some studies distinguish primary care and hospitals. For example, Zhang et al. (2017) analyzed the evaluate the equality of the distribution of health resources between hospitals and primary care institutions in China from 2010 to 2014. They found that inequality was evident in the geographic distribution of health resources. The Gini coefficients exceeded 0.7 in the geographic distribution of institutions, health workers and beds in both the hospital and the primary care sectors. The eastern developed region also had a high internal inequality compared with the other less developed regions. Hung et al. (2012) argued that a big gap in resources and services between hospitals and primary care institutions exists and it continues to be increase despite the government's favorable investment policies for the primary care sector.

To conclude, even though healthcare resources in China are increasing in recent years, it is characterized by uneven geographical distributions. The pattern is shown both between and within provinces. However, some research gaps exist. First, the longitudinal analyses on healthcare resource allocation in China were mainly at the province level, which may not present fully the current picture. Meanwhile, county-level research adopted the cross-sectional design for analyses, which failed to draw conclusions on patterns and trends of healthcare resources.

Moreover, the rigorous evaluation on the impact of the 2009 reform is rare, with most research only mapping the patterns of healthcare resources equity in China. Most studies used data after the reform, which failed to analyze the pre-reform trends of the equity. Meanwhile, the time spans of the previous research are usually short.

For example, Liu et al. (2016) analyzed the healthcare institutions, beds, technical personnel, and investments in China from 2009 to 2013. It was showed that the healthcare resources in China was increasing, but the geographical distribution was disparate. Specifically, Theil index in healthcare institutions, beds, technical personnel, and investments were 0.050, 0.004, 0.011, and 0.123 respectively in 2009, and 0.057, 0.003, 0.007, and 0.011 in 2013. After further decomposing the Theil index to analyze the unfairness in the eastern, central, and western regions of China, it was found that the contribution rate of the Theil index in the eastern region (40%) are greater than the western region (15%) and the central region (15%). Meanwhile, the between-regional Theil index also contributed much (30%). Ding et al. (2018) compared the inequities in inputs and outputs of the provincial medical service systems from 2009 to 2014, which found that inequities in health resources allocation and service provision existed across the regions, but not all the gaps have begun to narrow since 2009.

Methods

Variables and Data

Data of healthcare facilities (the treated group) and adopting social welfare institutions (the control group) beds at the county level are obtained from China County/City Statistical Yearbook, 2001-2018.

These datasets are made available by the National Bureau of Statistics of China, which cover almost all 2 862 county administration units in mainland China. Data of control variables, including population, industry production, saving deposit, and public revenue are also from the same data sources (Table 1).

Table 1 Description of variables

Variables	Unit	Notes	Data source
Outcome variables			
Healthcare institutions beds	Per thousand population	Health care institutions include hospital, primary care facilities, and other healthcare institutions	China County/City Statistical Yearbook, 2001-2018
Social welfare institutions beds	Per thousand population	Institutions established by the government to help people in difficulties, including orphans and the elder. The institutions will provide them with food, clothing, accommodation etc.	
Controls			
Population	10 thousand	The total population live in the administrative area	
Industry production	10 thou RMB	The total production of industry, in the form of money	
Saving deposit	10 thou RMB	The total amount of money deposited as well as the interests gained by residents in banks or other credit institutions at the end of each year.	
Public revenue	10 thou RMB	The government revenue include tax, public enterprise revenue etc.	
Land size	Km ²	The size of the administrative region	

Notes: 1 RMB = approx. 0.15 USD

Empirical design

Objective 1 Trends and patterns of healthcare beds allocations

This study will evaluate both temporal and spatial patterns of beds distribution. The β -convergence are used to verify the changing tendency of disparities; global and local Moran's I indexes are adopted to identify spatial clusters; the Kulldorff space-time scan statistics analyses are conducted to analyze the spatiotemporal pattern.

Specifically, Baumol's Conditional Convergence Model was adopted to test β -convergence (Baumol, 1986):

$$\ln\left(\frac{bed_{i,t+k}}{bed_{i,t}}\right) = \alpha + \beta \ln (bed_{i,t}) + \mathbf{X}_{it}\gamma + \varepsilon_{i,t}$$

where bed_{it} is the healthcare beds per 1,000 population of county i in year t . $\ln\left(\frac{bed_{i,t+k}}{bed_{i,t}}\right)$ is the change rate of logarithm of healthcare beds per 1,000 population at county i within time interval $k = 1$ (Short term convergence). \mathbf{X}_{it} denotes a vector of explanatory variables. Without adjusting the controls, the convergence is absolute. Otherwise, the convergence is conditional.

Spatial autocorrelation is evaluated by the global and local Moran's I. While global tests evaluate the presence of spatial autocorrelation, local tests indicate where it is (Getis, 2010). False discovery rate is used to identify meaningful clusters (Castro & Singer, 2006). The neighborhood structure was defined as the k nearest neighbors (k = 4) based on the centroid distance ($1/d_{ij}$, where d_{ij} represents the Euclidean distances between the i^{th} and j^{th} points).

$$I = \frac{\sum_{i=1}^n \sum_{j=1}^n w_{ij} (y_i - \bar{y})(y_j - \bar{y})}{s^2 \sum_{i=1}^n \sum_{j=1}^n w_{ij}}; I_i(d) = \frac{(y_i - \bar{y})}{s^2} \sum_j w_{ij}(d)(y_j - \bar{y}); s^2 = \frac{\sum_{i=1}^n (y_i - \bar{y})^2}{n}$$

where n refers to number of counties. y_i are beds in county i , while j indicates neighboring county, and \bar{y} is the national mean. w_{ij} represents spatial weights matrix.

Objective 2 Spatiotemporal patterns of equity

Both city- and provincial-level equities are measured using the Gini index, which was one of the most widely used indicators of social and economic conditions (Isabel & Paula, 2010; Modarres & Gastwirth, 2006; Xu, 2003). In this study, I employed the geometric approach to calculate this coefficient, using the formula below:

$$Gini = \frac{n+1}{n} - \frac{2}{n^2 \mu_y} \sum_{i=1}^n (n+1-i)y_i$$

where n is the total number of counties within a city, μ_y is the mean of bed density among all counties, and y_i refers to the county i 's beds. When calculated, counties should be ranked in ascending order of y_i at first and corresponding population numbers are considered as survey weights in the equation.

Descriptive temporal and spatial analyses will also be conducted, at national, regional, provincial and city levels.

Objective 3 The impact of 2009 healthcare reform on equity

Following Jayachandran et al. (2010), a formal test of trend breaks in healthcare beds equity time series is conducted, using the following model:

$$Gini_t - Gini_{t-1} = \pi + \rho_0 D_t(\tau) + \eta_t$$

The dependent variable, $Gini_t - Gini_{t-1}$ is the first difference between Gini index, while $D_t(\tau)$ is a binary variable, equal to 0 for all years before τ and 1 for all subsequent years. The reason why I use first difference is that I do not expect a drastic change in equity levels but a break in trend. Newey-West standard errors are computed, and the error structure is correlated up to two lags to adjust serial correlation. I test for possible trend break in the interval 2006-2012 for two reasons. Theoretically, the healthcare reform was first announced by President Hu Jintao in 2006, so it can be seen as a watershed. Premier Wen Jiabao declared an RMB 850 billion allocation (2.8% of 2008 GDP) to support healthcare reform during 2009-2011, which stimulates the beds equity change. Empirically, though a common approach is to trim 15% for both ends, due to a small sample size, six data points seem to be appropriate in this study. For each estimate, $\rho_0 = 0$ is tested, and the resulting t-statistics is used to

determine the significance, with the largest taken as the best possible break point. Other breaks will also be analyzed as robust checks.

Interrupted time series (ITS) analyses will first be conducted to evaluate the trend changes in healthcare beds equity. I fit a trend-break model that allows for a change in the slope after 2009.

$$Gini_t = \alpha_0 + \alpha_1 Year_t + \delta_0 Post_t + \delta_1 Post_t \times Year_t + \mathbf{X}'_t \lambda + \varepsilon_t$$

where $Gini_t$ is the Gini index of cities in year t . $Year_t$ is a continuous year variable, and $Post_t$ is a dummy variable, equal to 1 when t is 2009 or after. \mathbf{X}'_t denotes a vector of city characteristics, including industry production, saving, and public revenue. In this model, I am interested in δ_1 (the slope change) to test whether it is significant and negative. I also compute Newey-West standard errors that allow the error structure to be correlated up to two lags to account for serial correlation.

However, the time period is relatively short, so the post-intervention counterfactual may not be reflected precisely by the pre-trend. In this case, I estimate difference-in-difference (DID) models to assess the effect of the healthcare reform, comparing healthcare beds equity and adopting social welfare institutions beds equity. It is noteworthy that in China, healthcare institutions are regulated by the National Health Commission, while adopting social welfare institutions are managed by the Ministry of Civil Affairs. So, it is reasonable to assume that the social welfare institutions beds equities were not impacted by the 2009 healthcare reform. In other words, any pre- versus post-2009 changes in beds equity caused by factors besides the reform are the same for the control and treated institutions, and that the reform is the only factor differentially affecting the treated institutions beginning in 2009. Pre-trends are assessed, to test whether the control selection is valid.

$$Gini_{it} = \beta_0 + \beta_1 Healthcare_i + \beta_2 Post_t + \beta_3 Year_t + \beta_4 Post_t \times Year_t \times Healthcare_i + \beta_5 Post_t \times Healthcare_i + \beta_6 Year_t \times Healthcare_i + \mathbf{X}'_t \theta + \zeta_{it} + \varphi_{it} \times Year_t + \zeta_{it}$$

where $Healthcare_i$ is a dummy variable, equal to 1 for healthcare institutions beds equity and 0 for adopting social welfare institutions. The equations now include city/province fixed effects $City/Province \times Post$, denoted by ζ_{it} , which control the main effect of $Post$ and absorb city/province variation in equity change, and $City/Province \times Post$ fixed effects interact with $Year_t$. Standard errors are clustered by year, since the variables of interest only vary at this level.

Subgroup analyses will be conducted by regions to understand the mechanisms of the equity change. China can be divided into three regions based on economic development. Specifically, the east region is the most developed, while the west region is the least developed. Government revenues will also be classified for subgroup analyses.

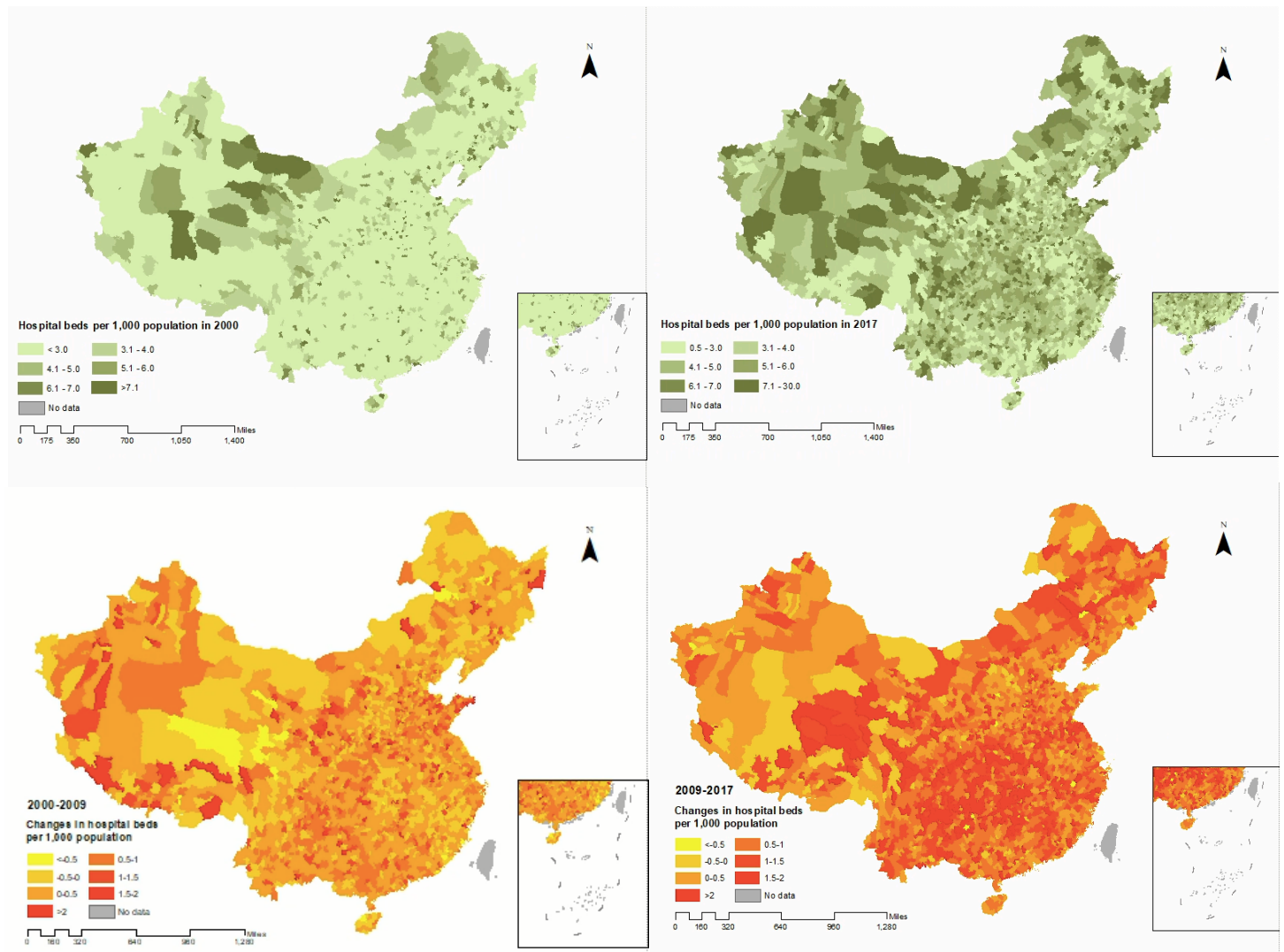
Results

Trends and patterns of healthcare beds distributions

Figure 4 and Figure 5 depict the beds distribution and change in China (2000-2017). When adjusting the beds by populations, western regions have more abundant healthcare resources than the eastern

regions, which are not aligned with common sense. In this case, I consider the land area of county in Figure 5, which shows vividly the disparities of beds allocation among counties of China.

Figure 4 Beds per thousand population distribution and change in China (2000-2017)



In 2000, the healthcare resources in China were relatively low. The number of beds per 1,000 people was less than 2.28. Since 2006, the resources had a continuous and high-speed growth. As of 2017, the number of beds per thousand nationwide doubled to 4.69. As for beds per thousand per square kilometer, in 2000, the average was 0.002, with the range from $9.71e^{-6}$ to 0.125, while in 2017, the number increased to 0.003 (0.00002-0.13173). The increase in the eastern region was more obvious than that in the western region. From a national perspective, the highest increase was 0.1317 beds per thousand per square kilometers, while the lowest increase was 0.00002.

Figure 5 Beds per thousand per kilometer square distribution and change in China (2000-2017)

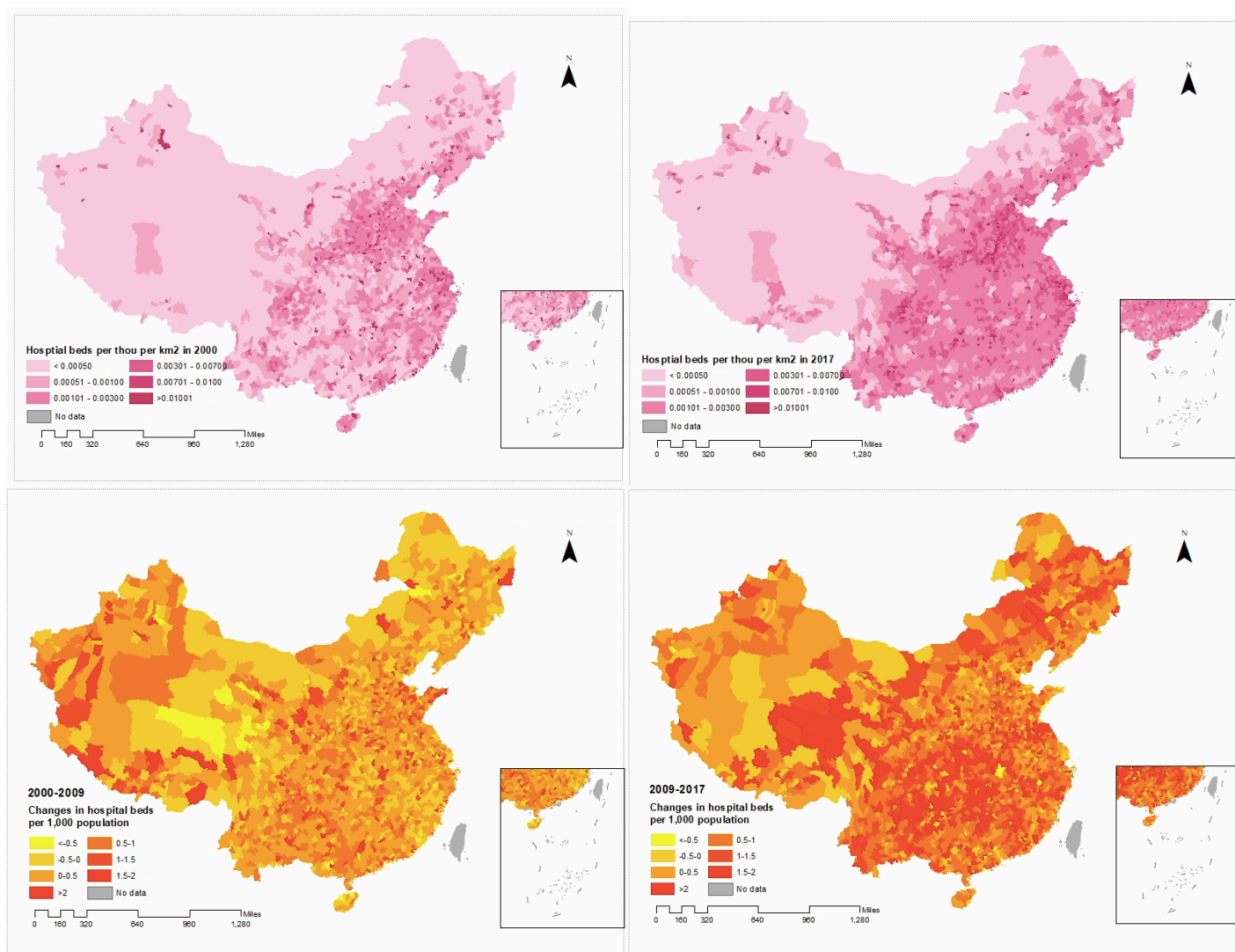


Table 2 Dynamic convergence analyses

Area	Sample size	Absolute convergence		Conditional convergence	
		Ln (beds/pop)	R ²	Ln (beds/pop)	R ²
National	39,894	-0.041*** (0.001)	0.019	-0.046*** (0.002)	0.021

Notes: Robust standard errors in the parenthesis. *** at 1% significance level; ** 5%; * 10%.

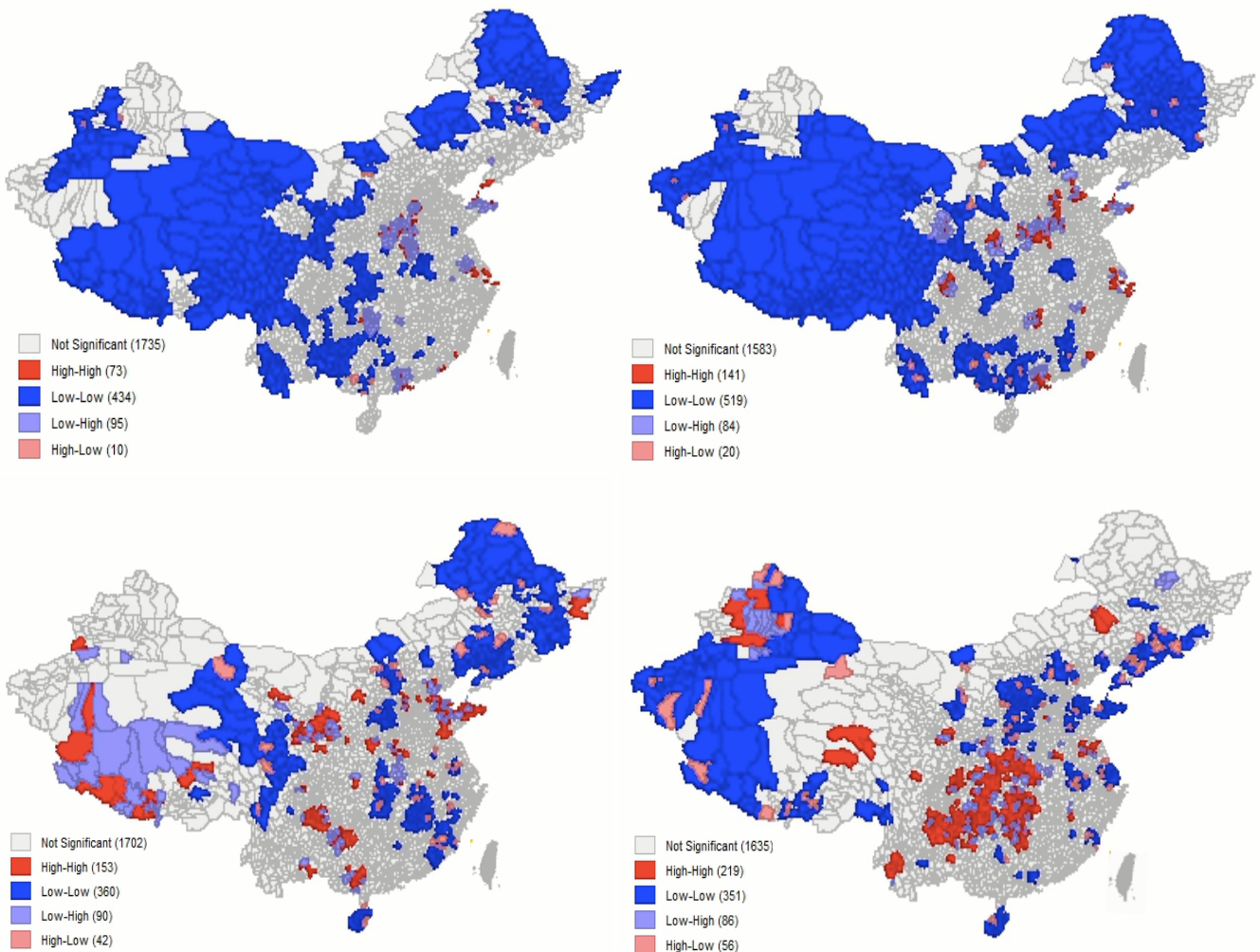
The results for dynamic convergence analyses are presented in Table 2. At the national level, both absolute and conditional convergence coefficients are negative and statistically significant, which indicate that the distribution of China's healthcare resources has dynamic convergence trends from 2000 to 2017. In other words, counties with initially fewer healthcare resources are catching up.

From Table 3, a spatial clustering pattern of healthcare beds distribution can be seen. Moran's I are significantly larger than 0, with positive Z value. It indicates that healthcare beds distribution follows high-high and low-low clustering patterns.

Table 3 Global Moran's I of beds per thousand per kilometer square

Year	Coefficient	Z	P value	Year	Coefficient	Z	P value
2000	0.109	6.2883	0.001	2009	0.125	8.3637	0.001
2001	0.106	5.8677	0.001	2010	0.125	8.2494	0.001
2002	0.113	6.9037	0.001	2011	0.126	8.4312	0.001
2003	0.119	7.7431	0.001	2012	0.126	8.5445	0.001
2004	0.127	8.7982	0.001	2013	0.128	8.8457	0.001
2005	0.117	7.1801	0.001	2014	0.127	8.6503	0.001
2006	0.122	7.8691	0.001	2015	0.130	8.8857	0.001
2007	0.125	8.2342	0.001	2016	0.131	9.1651	0.001
2008	0.126	8.4709	0.001	2017	0.133	9.6551	0.001

Figure 6 Hotspots map of healthcare beds per thousand per km2 distribution (Local Moran's I)



The spatial clustering pattern can be seen in Figure 6. The cold spots mostly distributed in the west, as well as north China. From 2000 to 2017, the cold spots expanded. The changes of beds distribution also showed spatial clustering pattern. From 2000-2009, north China did not have high increases in beds. From 2009-2017, the west China (west Xinjiang and north Tibet) did not have big increases, while the middle China showed dramatic changes in beds per thousand per kilometer square.

Spatial and temporal patterns of equity

Table 4 and Figure 8 show the Gini coefficients changes at the national level, from 2000 to 2017. The Gini coefficients nationwide were as high as 0.7, indicating that the distribution was not very fair. From 2000 to 2005, Gini coefficients increased from 0.7198 to 0.7420, which presented the inequities widened. After 2006, the inequities showed a decreasing trend, indicating a narrowing inequity situation.

Table 4 National level Gini coefficients of healthcare beds in China (2000-2017)

Years	Healthcare beds Gini coefficients at national level
2000	0.7198
2002	0.7417
2005	0.7420
2009	0.7279
2014	0.7071
2016	0.7169
2017	0.7113

Figure 8 National level Gini coefficients of healthcare beds in China (2000-2017)

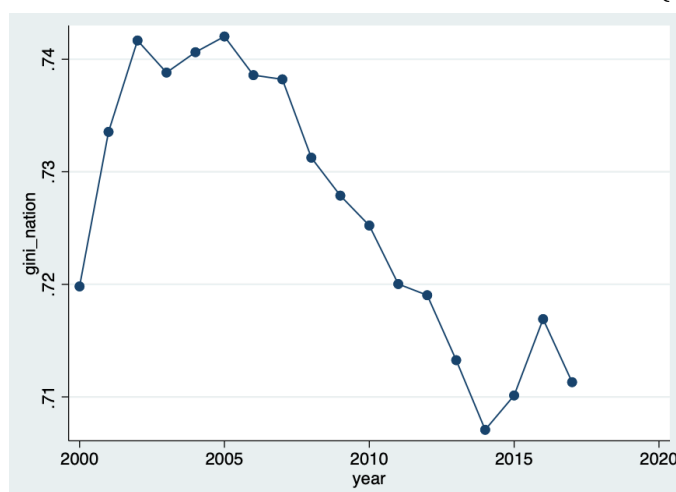


Figure 9 Regional level Gini coefficients of healthcare beds in China (2000-2017)

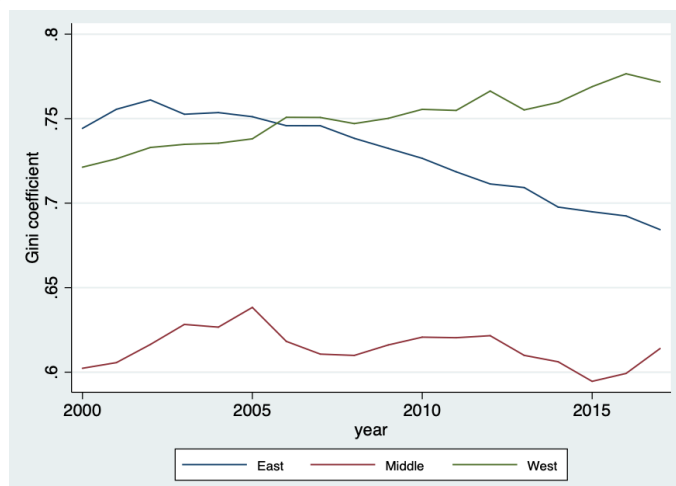


Figure 9 presents the Gini coefficients across regions in China. Different regions shown different patterns of equity change. The east region has the highest Gini coefficients before 2005. However, it has shown an obvious decreasing trend since 2001. The west region, on the contrary, showed increasing Gini coefficients year by year. The middle region has the fairest distribution of healthcare beds, though some fluctuations were witnessed.

Figure 10 Gini Coefficient at province level 2000-2017

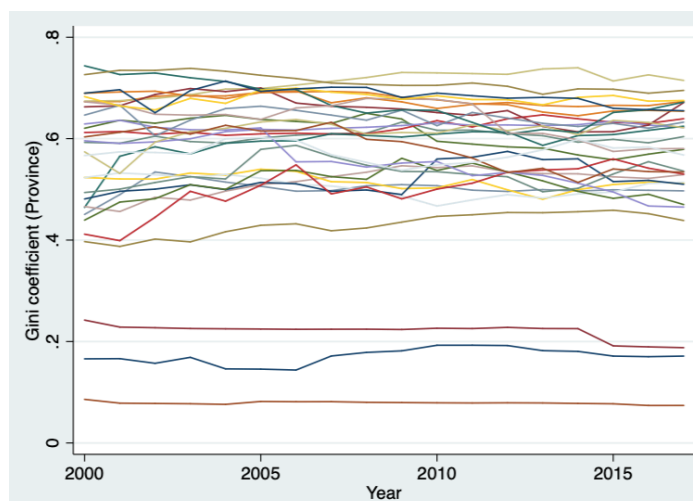


Figure 10 presents the Gini coefficients change from 2000 to 2017 across provinces in China. Specifically, the three province-level municipalities, Beijing, Tianjin, and Shanghai has the lowest Gini coefficients. The other municipality, Chongqing, also has high Gini coefficients at 0.6 or so. It is worth noting that the first three municipalities are much smaller than other provinces, so the regional disparities are relatively smaller.

Table 5 shows city-level Gini coefficients in 2000, 2009 and 2017. It can be seen that from 2000 to 2009, there was an increasing trend in Gini coefficients, following a decrease from 2009 to 2017. The variations decreased from 2000 to 2017 generally.

Table 5 City level Gini coefficients (2000, 2009, 2017)

Year	Mean	Standard deviation	Min	Max
2000	0.299	0.123	0.024	0.666
2009	0.312	0.116	0.010	0.640
2017	0.292	0.110	0.017	0.566

The spatial pattern of city level Gini coefficients in 2000 and 2017 can be seen in Figure 11 and Figure 12. The Gini patterns do not change much in 2000 and 2017. When looking at the local Moran's I, we can see that both high-high and low-low regions shrank.

Figure 11 Gini Coefficient at city level in 2000 and 2017

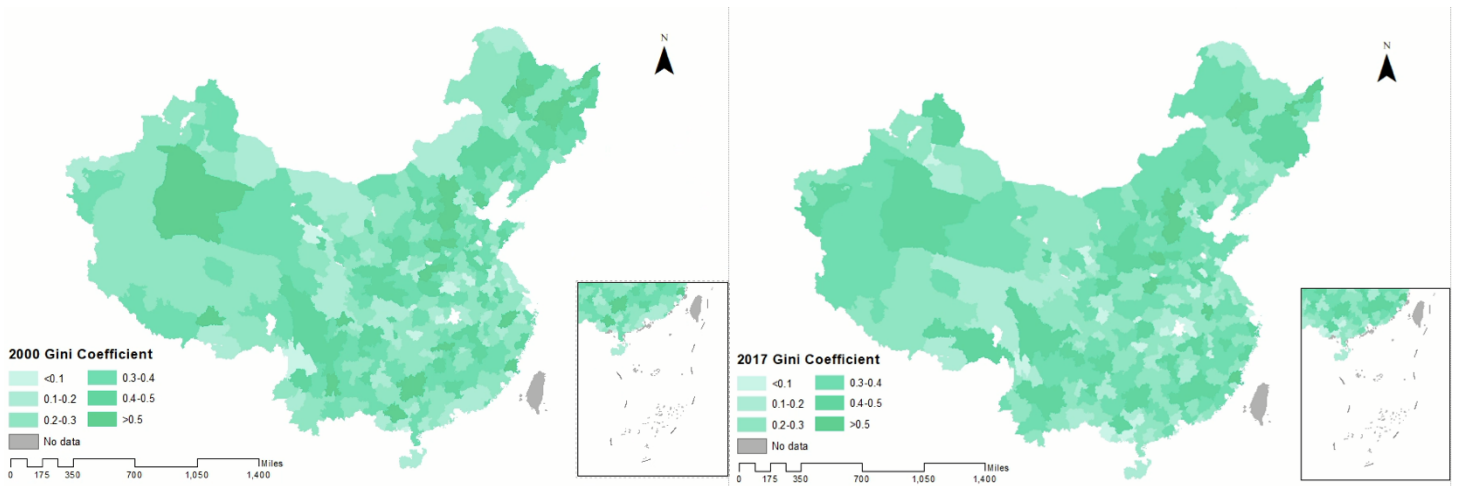
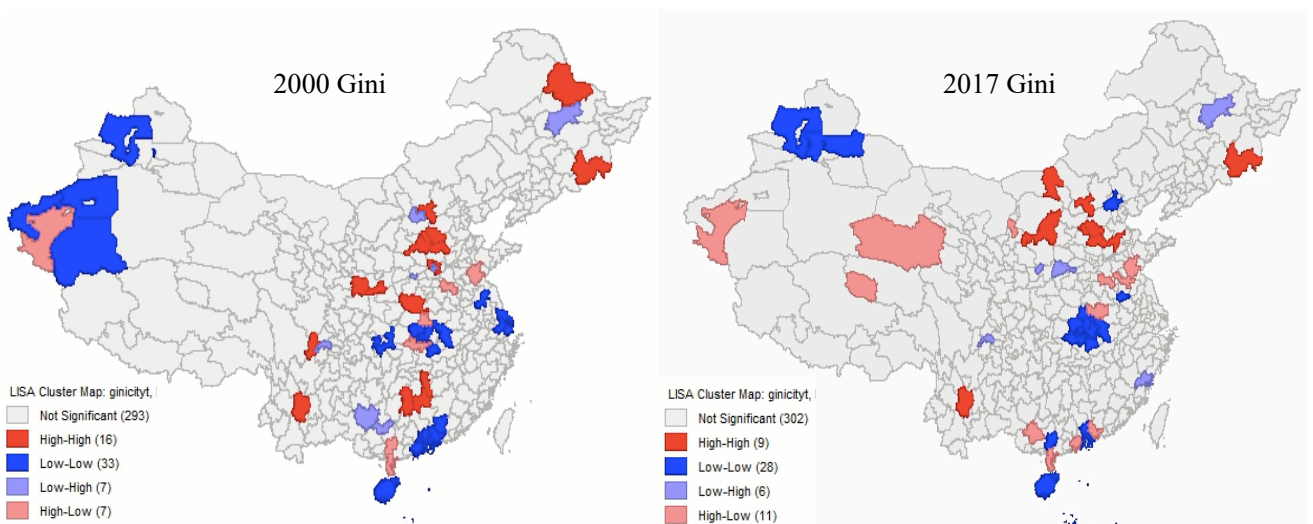


Figure 12 Hotspot map of city level Gini Coefficient 2000 and 2017 (Local Moran's I)



The impact of 2009 healthcare reform on equity

The descriptive results of control variables are shown in Table 6. As presented, the east is the most populous and rich region in China.

Table 6 Descriptive results of control variables by region (2017)

Controls	East	Middle	West	P-value
Population (10 thousand)	85.63 (110.44)	62.63 (58.51)	44.15 (101.21)	<0.001
Industry production (10k RMB)	10 807 019 (25 376 429)	4 040 088 (7 123 490.7)	1 839 277.5 (9 201 862)	<0.001
Government revenue (10k RMB)	743 739.09 (365 5646.3)	223 820.19 (699 906.62)	133 309.65 (586 972.42)	<0.001
Saving deposit (10k RMB)	5 087 995.4 (16 890 089)	2 162 554 (4 432 511.6)	1 516 044 (6 277 170.7)	<0.001

Area (km ²)	1 936.32 (1 455.19)	3 597.16 (7 153.60)	6 877.28 (14 677.04)	<0.001
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Trend Break Analyses

The trend break test results are shown in Table 7. All years in the period 2006 to 2012 are significant, with 2006 has the highest t statistics. In this case, I consider 2006 as the main turning point. Other time periods are included as robust checks.

Table 7 Trend Break Test Results

Years	Estimate	Newey-West Standard errors	T statistics	P-value
2006	-0.00573	0.00097	-5.8880	<0.001
2007	-0.00488	0.00094	-5.1935	<0.001
2008	-0.00387	0.00093	-4.1664	<0.001
2009	-0.00423	0.00093	-4.5706	<0.001
2010	-0.00395	0.00094	-4.1903	<0.001
2011	-0.00429	0.00098	-4.3760	<0.001
2012	-0.00383	0.00100	-3.8310	<0.001

Interrupted time series

In Figure 13-15, we can see that the reform changed the trend of healthcare beds equity. From 2000 to 2005, the Gini coefficients at all levels increased to some extent. After 2006, the Gini coefficients showed a decreasing trend. The results provide some evidence that the reform promoted the equity in healthcare resources. Meanwhile, the figures also show wide variations of Gini coefficients at both provincial and city level, indicating that the equities between provinces and cities still exist.

Figure 13 National level healthcare beds Gini Coefficient (2000-2017)

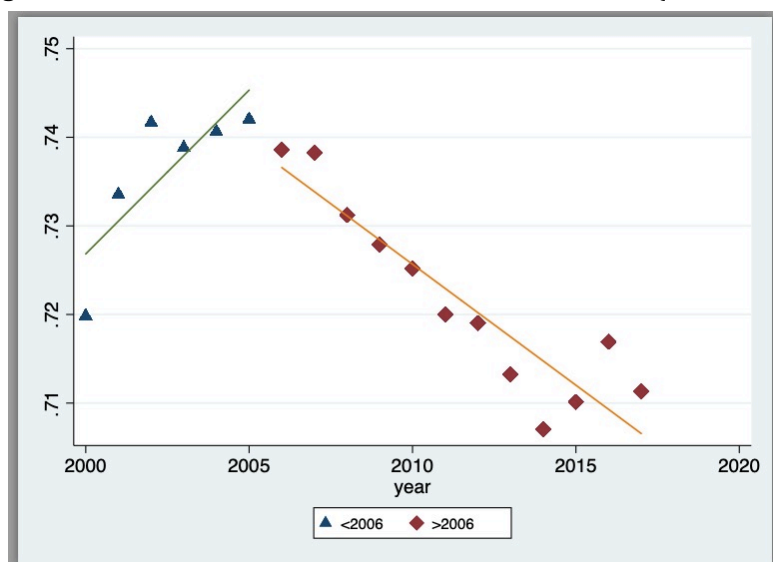


Figure 14 Province level healthcare beds Gini Coefficient (2000-2017)

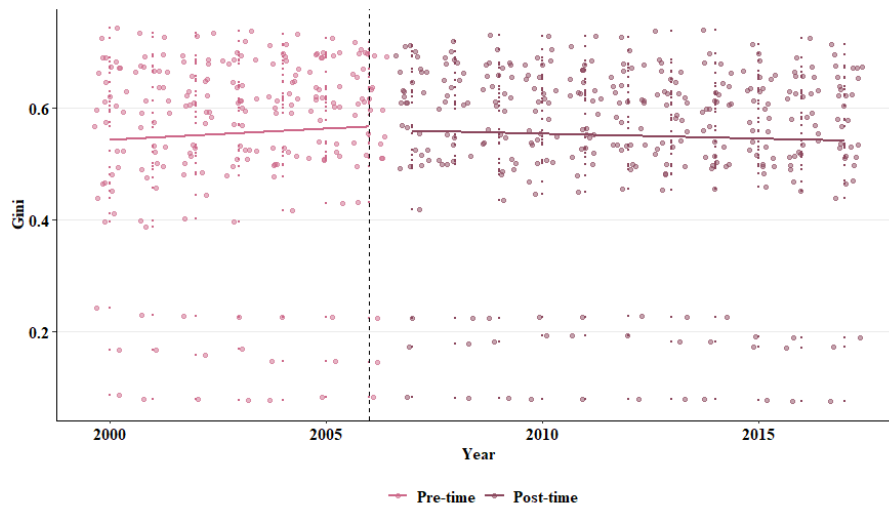


Figure 15 City level healthcare beds Gini Coefficient (2000-2017)

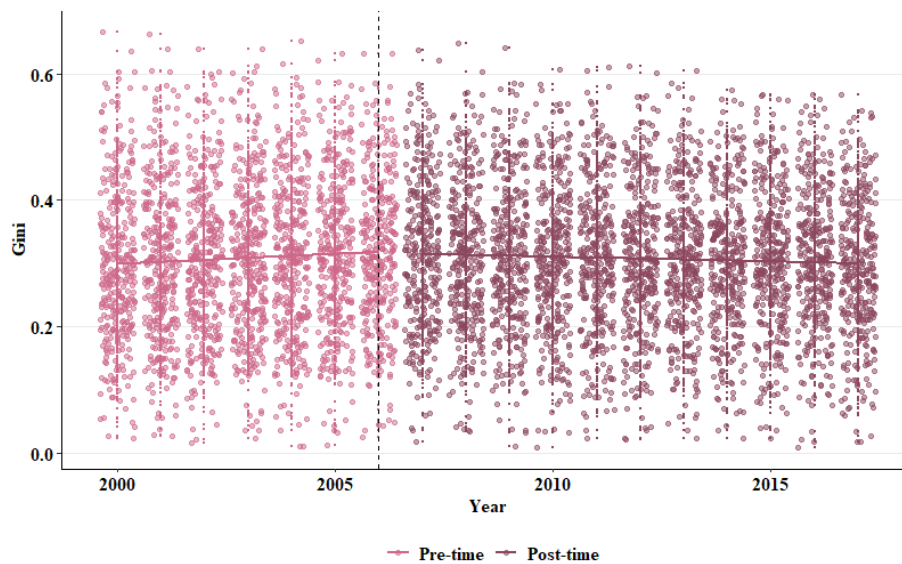


Table 8 presents interrupted time series results for Gini coefficients at the city level. In 2006, with and without adjusting controls, the results show that the reform significantly changed the trend of Gini coefficients. As the coefficients for Post and Year interactions are negative, we can conclude that the reform increased equity situations at the city level. Specifically, before 2006, the Gini coefficients increased at an annual rate of 0.003. After 2006, the rate decreased by 0.004, adjusting for controls. Analyses for 2007, 2008, and 2009 also showed similar results.

Table 8 ITS results for city-level Gini coefficients

	2006		2007		2008		2009	
	Crude	Adjusted	Crude	Adjusted	Crude	Adjusted	Crude	Adjusted
Year	0.003 (0.001)*	0.003 (0.001)*	0.003 (0.001)*	0.002 (0.001)*	0.002 (0.001)*	0.001 (0.001)*	0.002 (0.001)*	0.001 (0.001)*
Post	9.321 (3.173)**	8.337 (3.144)**	8.287 (2.811)**	7.358 (2.782)**	7.298 (2.677)**	6.375 (2.639)*	6.751 (2.750)*	5.860 (2.701)*

Post*Year	-0.005 (0.002)**	-0.004 (0.002)**	-0.004 (0.001)**	-0.004 (0.001)**	-0.004 (0.001)**	-0.003 (0.001)*	-0.003 (0.001)*	-0.003 (0.001)*
Saving		0.000 (0.000)*		0.000 (0.000)*		0.000 (0.000)*		0.000 (0.000)*
Revenue		0.000 (0.000)***		0.000 (0.000)***		0.000 (0.000)***		0.000 (0.000)***
Industry		0.000 (0.000)***		0.000 (0.000)***		0.000 (0.000)***		0.000 (0.000)***
Population		0.000 (0.000)***		0.000 (0.000)***		0.000 (0.000)***		0.000 (0.000)***
Area		0.000 (0.000)***		0.000 (0.000)***		0.000 (0.000)***		0.000 (0.000)***

Notes: Newey-West standard errors that allow the error structure to be correlated up to two lags in parentheses. *** P< 0.001, ** P<0.01, * P<0.05

Subgroups analyses by region (Table 9) show that all regions have been significantly impacted by the reform, with decreasing Gini coefficients. Specifically, the annual rate in middle region decreased the most by 0.013, with the east region decreased the least by 0.002 in 2006, adjusting for controls.

Table 9 ITS Subgroup analyses by regions (city-level Gini coefficients)

	2006			2007		
	East	West	Middle	East	West	Middle
Year	0.002 (0.003)*	0.003 (0.002)*	0.001 (0.002)*	0.002 (0.002)*	0.002 (0.002)*	0.000 (0.002)*
Post	4.503 (5.607)*	8.685 (4.551)*	25.475 (5.018)***	3.551 (4.957)*	7.386 (4.062)*	25.307 (4.454)***
Post*Year	-0.002 (0.003)*	-0.004 (0.002)*	-0.013 (0.003)***	-0.002 (0.002)*	-0.004 (0.002)*	-0.013 (0.002)***
Controls	Yes	Yes	Yes	Yes	Yes	Yes
	2008			2009		
	East	West	Middle	East	West	Middle
Year	0.001 (0.002)*	0.001 (0.001)*	-0.001 (0.002)*	0.001 (0.001)*	0.000 (0.001)*	-0.001 (0.001)*
Post	2.466 (4.613)*	6.168 (3.890)*	24.875 (4.253)***	1.544 (4.602)*	6.245 (4.028)*	24.247 (4.379)***
Post*Year	-0.001 (0.002)*	-0.003 (0.002)*	-0.012 (0.002)***	-0.001 (0.002)*	-0.003 (0.002)*	-0.012 (0.002)***
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Newey-West standard errors that allow the error structure to be correlated up to two lags in parentheses. *** P< 0.001, ** P<0.01, * P<0.05

Subgroup analyses by government revenue tertiles show that the middle class has the biggest annual rate decrease for Gini coefficients after the reform, by 0.012 in 2006, adjusting for controls.

Table 10 ITS Subgroup analyses by government revenue (city-level Gini coefficients)

	2006			2007		
	Tertile 1	Tertile 2	Tertile 3	Tertile 1	Tertile 2	Tertile 3
Year	-0.004 (0.002)**	-0.001 (0.003)*	0.002 (0.005)*	-0.004 (0.001)***	-0.002 (0.002)*	0.001 (0.004)*
Post	9.691 (4.298)*	24.382 (6.101)***	11.612 (9.848)*	7.696 (4.356)*	20.765 (4.953)***	11.053 (8.045)*
Post*Year	-0.005 (0.002)*	-0.012 (0.003)***	-0.006 (0.005)*	-0.004 (0.002)*	-0.010 (0.002)***	-0.006 (0.004)*
Controls	Yes	Yes	Yes	Yes	Yes	Yes
	2008			2009		
	Tertile 1	Tertile 2	Tertile 3	Tertile 1	Tertile 2	Tertile 3
Year	-0.005 (0.001)***	-0.004 (0.002)*	0.002 (0.003)*	-0.006 (0.001)***	-0.006 (0.002)***	0.002 (0.003)*
Post	6.003 (4.754)*	15.393 (4.435)***	12.209 (6.871)*	6.307 (5.604)*	10.715 (4.368)*	12.591 (5.907)*
Post*Year	-0.003 (0.002)*	-0.008 (0.002)***	-0.006 (0.003)*	-0.003 (0.003)*	-0.005 (0.002)*	-0.006 (0.003)*
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Newey-West standard errors that allow the error structure to be correlated up to two lags in parentheses. *** P< 0.001, ** P<0.01, * P<0.05

Unlike results at the city level, the reform witnessed increased trend of inequities at the provincial level, with adjusting for controls (Table 11). Specifically, before 2006, the Gini coefficients at province level increased at an annual rate of 0.001, while after 2006, the rate further increased by 0.003, adjusting for controls. Results for 2007, 2008, 2009 also showed similar results.

Table 11 ITS results for province-level Gini coefficient

	2006		2007		2008		2009	
	Crude	Adjusted	Crude	Adjusted	Crude	Adjusted	Crude	Adjusted
Year	0.004 (0.006)*	0.001 (0.005)*	0.003 (0.005)*	0.002 (0.004)*	0.002 (0.004)*	0.001 (0.003)*	0.002 (0.003)*	0.000 (0.003)*
Post	11.600 (13.063)*	-5.925 (10.445)*	9.626 (11.390)*	-7.397 (8.913)*	8.293 (10.735)*	-8.877 (8.308)*	7.363 (10.984)*	-9.120 (8.155)*
Post*Year	-0.006 (0.007)*	0.003 (0.005)*	-0.005 (0.006)*	0.004 (0.004)*	-0.004 (0.005)*	0.004 (0.004)*	-0.004 (0.005)*	0.005 (0.004)*
Saving		0.000 (0.000)***		0.000 (0.000)***		0.000 (0.000)***		0.000 (0.000)***
Revenue		0.000 (0.000)***		0.000 (0.000)***		0.000 (0.000)***		0.000 (0.000)***
Industry		0.000 (0.000)***		0.000 (0.000)***		0.000 (0.000)***		0.000 (0.000)***

Population	0.000 (0.000)*	0.000 (0.000)*	0.000 (0.000)*	0.000 (0.000)*
Area	0.000 (0.000)***	0.000 (0.000)***	0.000 (0.000)***	0.000 (0.000)***

Notes: Newey-West standard errors that allow the error structure to be correlated up to two lags in parentheses. *** P< 0.001, ** P<0.01, * P<0.05

Subgroup analyses by region showed that in the east region, the increased inequities trend after the reform is significant (0.002). In both west and middle regions, the reform still witnessed a decreasing trend of Gini coefficients.

Table 12 ITS Subgroup analyses by regions (province-level Gini coefficients)

	2006			2007		
	East	West	Middle	East	West	Middle
Year	0.002 (0.004)*	0.000 (0.003)*	0.001 (0.003)*	0.002 (0.003)*	0.000 (0.002)*	0.000 (0.003)*
Post	-3.867 (9.774)*	10.351 (6.845)*	27.364 (8.561)**	-4.613 (9.035)*	9.606 (6.098)*	30.317 (7.628)***
Post*Year	0.002 (0.005)*	-0.005 (0.003)*	-0.014 (0.004)**	0.002 (0.005)*	-0.005 (0.003)*	-0.015 (0.004)***
Controls	Yes	Yes	Yes	Yes	Yes	Yes
	2008			2009		
	East	West	Middle	East	West	Middle
Year	0.002 (0.002)*	-0.001 (0.002)*	0.000 (0.002)*	0.002 (0.002)*	-0.002 (0.002)*	-0.001 (0.002)*
Post	-6.380 (9.259)*	9.114 (5.910)*	32.457 (7.370)***	-7.567 (10.102)*	10.164 (5.738)*	36.019 (7.524)***
Post*Year	0.003 (0.005)*	-0.005 (0.003)*	-0.016 (0.004)***	0.004 (0.005)*	-0.005 (0.003)*	-0.018 (0.004)***
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Newey-West standard errors that allow the error structure to be correlated up to two lags in parentheses. *** P< 0.001, ** P<0.01, * P<0.05

The samples are divided into three subgroups by government revenue. In 2006, the regions with second class government revenue witnessed increased Gini coefficients at the province level after the reform (0.005). Other years do not show similar results.

Table 13 ITS Subgroup analyses by government revenue (province-level Gini coefficients)

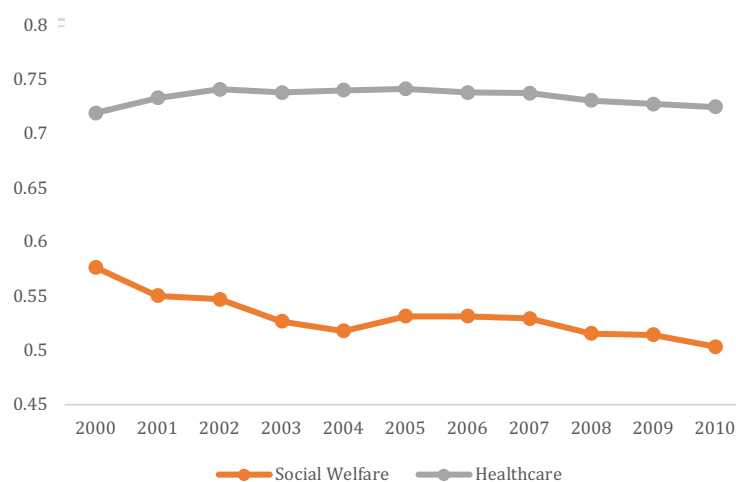
	2006			2007		
	Tertile1	Tertile2	Tertile3	Tertile1	Tertile2	Tertile3
Year	0.008 (0.004)*	0.005 (0.006)*	0.013 (0.052)*	0.009 (0.004)*	0.010 (0.004)*	0.019 (0.027)*
Post	16.996 (8.867)*	-9.617 (15.498)*	11.899 (103.345)*	11.570 (8.366)*	1.602 (13.035)*	23.396 (55.345)*

Post*Year	-0.008 (0.004)*	0.005 (0.008)*	-0.006 (0.052)*	-0.006 (0.004)*	-0.001 (0.006)*	-0.012 (0.028)*
Controls	Yes	Yes	Yes	Yes	Yes	Yes
	2008			2009		
	Tertile1	Tertile2	Tertile3	Tertile1	Tertile2	Tertile3
Year	0.008 (0.004)*	0.010 (0.004)**	0.019 (0.013)*	0.006 (0.003)*	0.010 (0.003)**	0.013 (0.010)*
Post	4.866 (8.685)*	6.102 (12.218)*	23.357 (27.768)*	4.983 (9.236)*	20.009 (10.914)*	13.121 (20.980)*
Post*Year	-0.002 (0.004)*	-0.003 (0.006)*	-0.012 (0.014)*	-0.002 (0.005)*	-0.010 (0.005)*	-0.007 (0.010)*
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Newey-West standard errors that allow the error structure to be correlated up to two lags in parentheses. *** P< 0.001, ** P<0.01, * P<0.05

Difference in difference

Figure 16 Healthcare and adopting institution beds equity in China (2000-2010)



Pre-trends seem not parallel (Figure 16). At first, the healthcare beds equity showed an increasing trend, while the social welfare beds equity was decreasing. So, the difference in difference results may be biased, as the social welfare institution beds equity may not be able to serve as a good counterfactual for healthcare beds equity. In this case, I do not present difference in difference results here.

Discussion

Initially, the healthcare resources in China were at a relatively low level. Since 2006, the resources had a continuous and high-speed growth, which is the result of economic growth. Meanwhile, a dynamic convergence phenomenon of China's county-level healthcare resources was found, with a catch-up

trend presented. On the national level, the healthcare resources equity also witnessed improvements from 2000 to 2017.

However, the uneven geographical distribution persists. The national Gini coefficient is as high as 0.742 in 2005, and 0.7113 in 2017. Healthcare resources are mainly concentrated in the eastern region, and the difference between the eastern and western regions is gradually increasing. Also, the spatial aggregations of the beds and the relative change distributions continue to exist from 2000 to 2017. Meanwhile, within regions, the inequities also exist. The western China has the highest Gini coefficient as of 2017, which also shows an increasing trend. It is well-known that socioeconomic factors play major roles in healthcare resources distributions. Under these circumstances, to achieve the equity, the balance between the government and market should be struck. Even though China has launched some programs, such as the West Development, the Pairing Assistance, and the Rural Revitalization to boost economic and social development in lagged behind regions, the gaps still exist. What extent of inequities is acceptable should be further analyzed.

Results show that after the reform, the equities improved, which proved that the increased government role can promote healthcare equity. Similarly, Zhang et al. (2013) analyzed differences of government investment between different provinces and between urban and rural areas during the first three years of the reform in China. The authors concluded that more governmental investments promoted equity in different regions, narrowing the gap between urban and rural areas. However, differences still exist in per capita government compensation. The government may need to make use of the limited financial resources efficiently, to maximize the gains.

As discussed above, the increased government investments in healthcare may impact resource equity through two channels: the government versus market, and the local versus central government financing. It is worth noting that at different levels, different channels play roles. At the city level, where the local (county) finances are usually similar, the decentralization may not have large negative impacts on equity. Meanwhile, as indicated by the Tiebout model, at the local level by cities and towns, competition will naturally arise because individuals can vote with their feet: if they don't like the level of public goods provision in one county, they can move to the next county over, without much disruption to their lives. In this case, it is reasonable to hypothesize that the city-level inequities are mainly driven by overall government finance in healthcare proportional to the total healthcare expenditure. As expected, this study finds that at the city level, the equities improved after the reform, as the government invested much in the healthcare sector.

However, at the provincial level, the equity concerns of the decentralization may matter. Eastern regions have higher public finance than western regions. If the financial transfers for healthcare from the central government are not sufficient, the total government healthcare expenditure in western regions may be far less than the eastern regions, so resources equity may deteriorate further. The results in this study confirmed this hypothesis.

Different regions also have different results. At the city level, the middle region decreased the most, with the east region decreased the least. At the province level, after 2006, the eastern China also witnessed an increased trend of Gini coefficients. The reason may be because the market and (central versus local) government arrangements differ among regions, especially the extent and development

of privatization in the hospital sector. Even though the Chinese government has invested much to the supply side, the major injection of the resources has been to primary care (PHC) institutions, rather than to the hospital sectors. Specifically, for rural PHC facilities, the share of direct government subsidies in revenue rose from 23% in 2010 to 37% in 2017. For urban PHC facilities, the share increased from 25% in 2010 to 45% in 2017 (Ma et al., 2019). However, the investments in hospitals were not proportional. Even though the government budget allocated to public hospitals increased from ¥5.2bn to ¥23.5bn, its proportion of hospitals' disposable revenue was stable around 12.6% (Xu et al., 2019). The actual arrangement of government subsidies still depended on the local governments that were responsible for the hospitals. Meanwhile, the government introduced policies to open up the hospital sector for private investment, with the target of private hospitals reaching a 20 percent market share by 2015. From 2009 to 2017, the number proportion of private for-profit and non-for-profit hospitals increased from 22.39% and 8.36% to 32.44% and 27.96%, respectively, though public hospital beds still accounted for 75.67% in 2017. In eastern region, where the economics are usually mature, private hospitals are well developed. In this case, the resources in rural and poor areas in eastern regions may not be comparable to urban and abundant areas, with equity undermined.

The core of healthcare system arrangement is the roles of government and market. In 2009, China made the right decisions to strengthen government functions in the healthcare settings. In the past ten years, major achievements were accomplished (Yip et al., 2019). Recently, the pendulum had the trend to shift back to the marketization, which may have strikingly negative impacts, including the suffering population health outcomes, escalating healthcare expenditures, less financial protections, and a two-tiered system in which access and quality of care are decided by the ability to pay (Yip and Hsiao, 2014). The government should carefully consider the balance between equity and efficiency, as well as the role of government and market in the healthcare sector. However, the government's financing is limited, and requiring the government to fully fund the healthcare system is neither plausible, nor efficient. A plausible way to enable the sustainable development is benchmark competition proposed by Yip & Hsiao (2014). Specifically, the government can consider building and finance benchmark public healthcare facilities in each county, with other institutions competing with the benchmark. The social insurance schemes only cover basic healthcare services, with high reimbursement rates. Both public and private hospitals can be reimbursed by the social health insurance schemes for basic services, as long as they accept the price schedule set by the government. For non-basic healthcare services, the prices in public hospitals are regulated, while the private sectors can set their own prices. Evidence from Singapore has shown the success of this model, though the integration between primary healthcare and hospitals needs to be strengthened (Hsiao, 2019). So, the priority is to define what are the basic services, and provide all citizens with equal access and high quality. China is on the right track to define "health insurance benefit package list", in order to standardize the benefits. For drugs, local governments are not authorized to add or drop items, while for medical services and equipment, they have some flexibilities. However, it is only a start in the demand-side reform. There is still a long way to go for China to accomplish equity from both demand and supply sides.

This study contributes to the existing literatures in several ways. First, it is the first study to systematically examine the patterns of healthcare resources equity at the city and province levels in

China, from 2000 to 2017. Both temporal and spatial aspects are evaluated. Second, using an interrupted time series design, it can assess the causal impact of China's 2009 healthcare reform on the supply-side equity, which is missing in the previous literature. Third, given the crucial role of healthcare resources distribution to health outcomes equity, this study has important policy implications to optimize the resources allocation, and promote health equity in China.

The major threat to the internal validity in this study is the timing selection. As mentioned above, even though the reform was officially initiated in 2009, the Chinese top leaders announced the reform in 2006. It is also hard to determine precisely when the reform worked, as the injection of the funding may not impact immediately on the healthcare beds equity. In this case, I conduct a formal test to see whether a trend break is present, and use several different cutoffs to simulate the lagged impacts.

Meanwhile, the counties may adopt the policy in different manners, which may influence the validity. But it is noteworthy that the main argument of this study is that the increased government investments promote health equity, so the variations in payment and delivery policies in this reform would not have large impacts. Also, in China's context, the central government is in a strong position to require its local branches to take actions as desired. So, it is reasonable to assume the local governments implement the reform almost at the same time, with almost same movements.

Third, the measurement error can be a concern. However, it is reasonable to argue that the error in the measurement for the outcome, the Gini coefficients, is uncorrelated with the key variable, the implementation year of the reform. In this case, the results are still unbiased and consistent. The measurement errors in the intervention year can be a concern. But as discussed above, I conduct several robust checks, to mitigate the biases.

Fifth, the equity trends may be impacted by other reforms during this period. But the payment or delivery change would not have large impacts as the government direct investment since the 2009 reform, as healthcare resources are fixed assets. Another possibility is that the government investment is not immediate, so after the cutoff selected, there are still increases in government financing. However, it is worth noting that the reform can be seen as a watershed for the increased role of the government. In other words, even though the injection of money did not happen suddenly in the cutoff selected, we can expect the post-trend differ from the pre-trend due to the ongoing government funding, which is not contrary to the results obtained above.

Meanwhile, this study has some limitations. First, due to data availability, this study fails to evaluate the accessibility equity, considering the distance and time for population to access healthcare services, which is more precise estimate of supply side equity. Meanwhile, other healthcare facilities characteristics, such as quality, human resources are unknown, which may influence our estimates of resource allocation. The time series is relatively short in this study, which may influence the statistical power and validity of the ITS. Besides, the study fails to distinguish primary care and hospital beds, due to the data limits. Also, the mechanism is not tested empirically, as data is not available (Appendix 2).

Conclusions

This study confirms that the increased role of government in the healthcare sector can promote equity, using China as an example. However, the study also finds that the governance structure matters. Specifically, if the government finance for health is mainly at the local level, the equity concerns of decentralization should be considered. Countries should think carefully about how to strike a balance between government and market roles, the central and local government financing, as well as the equity and efficiency considerations in the healthcare sector.

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Appendix 1 The impact of allocation equity on COVID-19 mortality

Background

As the COVID-19 crisis changes nearly every aspect of our lives, inequities are exacerbating (Williams & Cooper, 2020; Z. Wang & Tang, 2020). Though it is without any doubts that COVID-19 affects vulnerable populations disproportionately, the impact of equity issues on COVID-19 crisis severity is unknown. Among them, the resource allocation equity deserves further evaluation.

Similar with literatures on income inequity (Subramanian & Kawachi, 2004), the conceptual foundation of allocation inequity and health is the economic law of diminishing marginal utility (Figure A1).

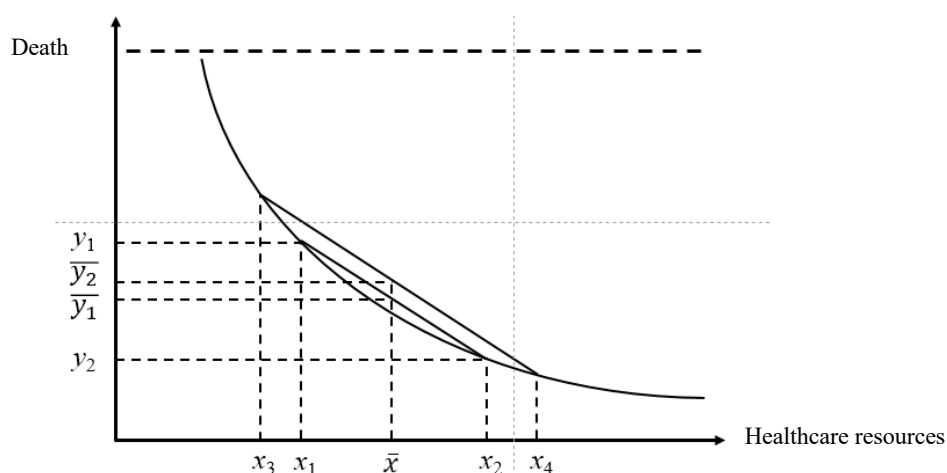


Figure A1 Convex relationship between healthcare resources and COVID-19 case fatality rate

Suppose region A with fewer healthcare resources (x_1) has more deaths of COVID-19 (y_1), while region B with more healthcare resources (x_2) has less deaths (y_2). The average healthcare resource of A and B is \bar{x} and corresponding average death is \bar{y}_1 . Compared to another two regions C (x_3, y_3) and D (x_4, y_4), even these two groups (A and B, C and D) have on average same amount of resources (\bar{x}), the average death of C and D (\bar{y}_2) is higher than that of A and B (\bar{y}_1), as the resources disparity between C and D is larger than that of A and B. It demonstrates that the average death in a specific area (e.g. A and B, or C and D) is not only influenced by the average healthcare resources, but by the equity in healthcare resources allocation as well. However, little is known on the association of resources equity and COVID-19 deaths.

To fill in this gap, this study aims to quantify the impact of allocation equity on COVID-19 deaths.

Methods

Variables and Data

City-level COVID-19 death data are from 32 Provincial Health Commission of China. Several environmental, demographic and social factors are thought to be associated with COVID-19 mortality (Guan et al., 2020; Ioannidis et al., 2020; Jordan et al., 2020; Ma et al., 2020; Ogen, 2020; Onder et al., 2020; Perone, 2020; Yao et al., 2020). Based on a preliminary review, this study will include following variables:

Table A1 Framework for COVID-19 mortality

Dimensions	Description	Data sources
<i>Environmental</i>		
Temperature	Average temperature of the first epidemic wave	National Oceanic and Atmospheric Administration
Precipitation	Average precipitation of the first epidemic wave	National Oceanic and Atmospheric Administration
<i>Demographic</i>		
Population	Population size	China County/City Statistical Yearbook
Area	Administrative land square kilometer	China County/City Statistical Yearbook
<i>Social</i>		
Healthcare resources equity	Healthcare beds allocation Gini index	China County/City Statistical Yearbook
Population movement	Average inflow/outflow index from Jan 10 to first case	Fan et al. (2020)

Empirical design

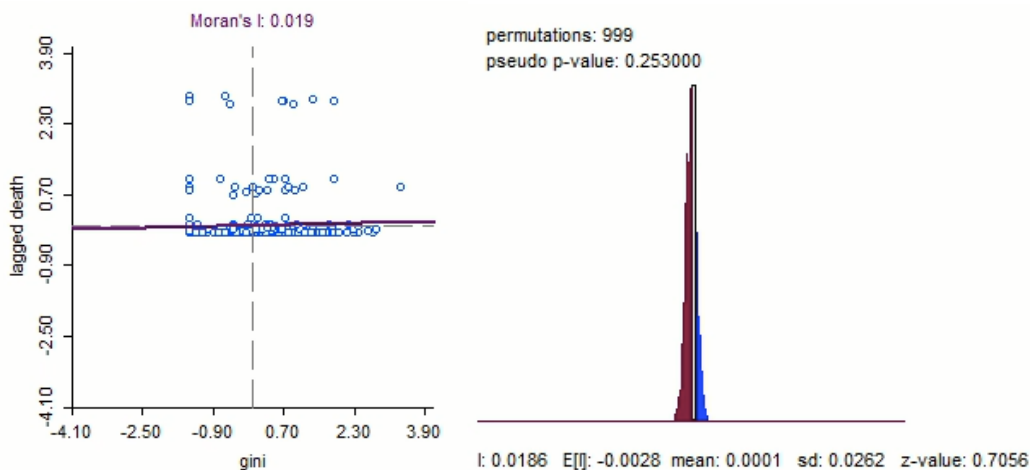
A cross sectional design is adopted, as healthcare beds equity changes little in the short term. Spatial error model will be conducted to evaluate the association, if spatial autocorrelation is present. This choice is mainly because COVID-19 deaths results from a complex mix of environment, demographic and social factors, of which only a small number is possible to measure and be included into the regression model.

$$Death = \beta equity + \mathbf{X}'\lambda + \varepsilon; \varepsilon = \rho W\varepsilon + \xi$$

Death denotes the total death of COVID-19 in each city. *equity* is the Gini index of healthcare beds allocation. \mathbf{X}' is a matrix of covariates. ε is the vector of error terms with covariance structure given by $\varepsilon = \rho W\varepsilon + \xi$, where W is a weights matrix, ρ is the spatial lag parameter to be estimated, and ξ is the vector of uncorrelated errors.

Results

Figure A1 Global Moran's I for Gini and death



As Moran's I does not show spatial clustering, I decide to use OLS to conduct the analyses. However, I do not find significant results of Gini impact.

Table A2 Results of OLS and spatial error model

Variable	OLS
Gini	-3.058 (5.227)
Control	Yes
R square	0.022
Log likelihood	-1346.98
AIC	2715.95

Discussion

The insignificant results may be due to statistic power of the model used. Furthermore, healthcare beds are static measures of healthcare resources, which may not impact largely on the sudden crises. Research has found that public health measures such as travel restrictions can play more important roles on deaths (Chinazzi et al., 2020; Fang et al., 2020; Kraemer et al., 2020; Lai et al., 2020; A. Pan et al., 2020; Qiu et al., 2020; Tian et al., 2020).

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