Physician distribution across China's cities: Regional variations

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Abstract

Background Distribution of physicians is a key component of access to health care. Although there is extensive research on urban-rural disparities in physician distribution, limited attention has been directed to the heterogeneity across urban areas.This research depicts variations in physician density across over 600 cities in the context of China's rapid urbanization.

Methods Data came from National Census Surveys and China statistical yearbooks, 2000-2003, and 2010-2013. Cities were characterized in terms of not only administrative level but also geographic regions and urban agglomerations. We analyzed variations in physician supply by applying generalized estimating equations with an ordinal logistic linking function.

Results Although overall physician density increased between 2003 and 2013, with population and socioeconomic attributes adjusted, physician density actually declined in urban China. On average, urban districts had a higher physician density than county-level cities, but there were regional variations. Cities in urban agglomerations and those outsides did not differ in physician density.

Conclusion Despite the improved inequality between 2003 and 2013, the growth in physician density did not appear to be commensurate with the changes in population health demand. Assessment in physician distribution needs to take into account heterogeneity in population and socioeconomic characteristics.

Introduction

Equitable distribution of physicians is a key component of access to health care [1, 2]. Prior studies have focused on its social and demographic determinants, including household income [3–5], education [6], population density [7], and racial composition [8]. In addition, some researchers have noted different preferences of physicians for locating urban versus rural areas [5, 9, 10].

However, earlier studies have at least two knowledge gaps that should be addressed comprehensively. First, the vast majority of analytic studies on physician distribution were based on data derived from developed nations. Whether their findings could be generalized to developing countries, such as China, is unknown, since the financing, healthcare delivery, and social contexts differ substantially between developing and developed nations. At the same time, China's experience may provide useful lessons to not only other low and middle-income nations but also high-income nations [11, 12].

Second, current research has focused on the disparities in physician distribution between urban and rural areas, with limited attention to the heterogeneity across cities [13]. This is an important gap, particularly in China, as Anand et al. (2008) noted that, in urban areas, where more than half of Chinese resided, the inequality in the distributions in physicians and nurses was twice as high as that in the rural areas [14]. Since the market reform in 1978, an estimated 262 million people have migrated from rural areas to urban areas because of greater job opportunities, better social welfare, and improved living conditions

[15, 16]. However, prior studies did not examine how cities' attributes were associated with physician distribution in China.

Cities in China can be divided into three categories: provincial-level cities, prefecture-level cities, and county-level cities, reflecting the substantial heterogeneity in economic development, population density, and social welfare [17]. Also, they are hierarchical because provincial/prefecture-level cities encapsulate densely populated urban districts as well as sparsely-populated county-level cities and counties. Urban districts have been traditionally recognized as the narrowly-defined provincial/prefectural-level cities since social welfare in urban districts is better than county-level cities and counties [17, 18].

Furthermore, there exist significant economic disparities across regions in China. Regions close to coastlines, where the market-oriented reform was first initiated, such as the Eastern Region, are economically more developed relative to other regions [19].Thus, Eastern China is recognized as more attractive to physicians in comparison with Western China, which has experienced significant brain drain [20].

As a vehicle of its economic development strategy, China has established a number of urban agglomerations (U.A.s). An U.A. or city cluster consists of several metropolis or large cities, which form a multi-layer group centered on one or two most prosperous cities [21]. Representing a more advanced form of urbanization, each U.A. has its dominant industries, connected transportation networks, and similar social public welfare [22]. Geographic information of regions and U.A.s is presented in Supplemental Materials Fig. 1.

Objectives And Hypotheses

This research aims to analyze China's urban disparities, i.e., urban districts vs. county-level cities, in physician density with particular interests in the roles of regions and U.A.s in 2003 and 2013. We conceptualized the differences in physician distribution as a function of population and socioeconomic attributes, which significantly affected the supply and demand for physician services. As a guide for data analysis and interpretation of findings, we offered four hypotheses.

First, equality in physician density across cities in China improved significantly between 2003 and 2013 (H_1), given the significant growth of human healthcare resources [23] and substantial economic growth [15]. However, the improvement might vary as a function of demand and supply of physician services as reflected by demographic and socioeconomic characteristics across cities and their changes over time (H_{1a}).

Second, physician density is higher in urban districts than county-level cities, even when demographic and socioeconomic characteristics are controlled (H_2). Disparities in physician distribution across cities are largely driven by the uneven distribution of supply factors that affect physicians' location choices, including opportunities for education, professional prestige, and physician origin [13]. In addition, population growth, particularly population aging, and economic development lead to increased demand for physician services [24].

Third, the urban disparities in physician distribution may exacerbate across regions (H_3) as there are substantial regional differences in socioeconomic development because of structural and long-term factors including education, regional labor supply, and geographic location [25]. For instance, the national government adopted preferential policies such as the Open and Reform, benefiting the coastal area disproportionally, and the Western Development policy, creating favorable conditions for investment in Western provinces [19].

Fourth, recent initiatives of creating urban agglomerations across China to promote economic growth is associated with increased physician density (H_4). China's government has invested substantial resources in new industrial parks to generate spillovers for the local economy. There is some evidence of the geographic spillover effect of parks as an increasing function of overall human capital level, foreign direct investment share, and its "synergy" with nearby incumbent firms [26].

Methods

1. Data source

Data came from China City Statistical Yearbooks and National Census Surveys, 2000–2003, and 2010–2013 [27–30]. We obtained the total numbers of physicians in 2003 and 2013, and the land area and GDP in 2000 and 2010 from the China City Statistical Yearbooks. We derived population attributes (e.g., total population, female-to-male ratio, migrant population) in the year of 2000 and 2010 from the National Census Surveys.

2. Measures

To measure physician density, we calculated the number of physicians per 1,000 population [31]. In our calculation, we included physicians and assistant physicians, who passed the National Physician or Assistant Physician License Examination. Data on population reflected the actual number of residents in each city, including the migrant population but excluding those registered in the Hukou system while seeking jobs and living in other areas. Because physician density was highly skewed to the left, i.e., cities with lower physician density, to characterize its distribution better, we divided it into three groups: low-density (bottom 1/3; 0-1.48 physicians per 1,000 population), medium-density (middle 1/3, 1.49–2.46 physicians per 1,000 population), and high-density (top 1/3; 2.47–9.68 physicians per 1,000 population).

Due to data limitations, we merged urban districts in a given provincial-level or prefecture-level city and treated them as one study unit, whereas each county-level city was treated as a single study unit. The geographic region of each city was categorized as (a) Eastern China, (b) Northeastern China, (c) Central China, and (d) Western China [32]. We identified cities in four major U.A.s, including: (a) Beijing-Tianjin-Hebei U.A. consisting of 13 cities with Beijing, the capital city of China, as the center; (b) the Yangtze River

Delta U.A. including 26 cities with China's most developed city, Shanghai, in the center; (c) the Pearl River Delta U.A. with nine cities that are centered around Shenzhen and Guangzhou; and (d) the Chengdu-Chongqing U.A. consisting of 16 cities with two large cities in Western China, Chengdu and Chongqing, as central cities [33].We combined four U.A.s in one category since it was not feasible to differentiate them because of the small number of cities included in each U.A.

Socioeconomic characteristics included GDP per capita and the proportion of the population with a high school education or above. Demographic attributes including population density (i.e., population per land area), female-to-male ratio (the number of female individuals/the number of male individuals, %), proportion of the migrant population, proportion of minority population, proportion of persons aged under 15, and proportion of persons aged over 65, were introduced as covariates to reflect population health need [24, 34].

Overall, 16 cities in 2000–2003 and 21 cities in 2010–2013 were excluded because of missing data. Two observations were available for 614 cities, whereas 50 cities had only one observation.

3. Data analyses

To gauge the inequality in physician distribution, we first calculated Gini coefficients for 2003 and 2013 [35]. This was supplemented by descriptive analyses of physician density in conjunction with the demographic and socioeconomic characteristics in 2003 and 2013.

To evaluate differences in physician distribution over time, we applied generalized estimating equations (GEE) with an ordinal link function. Population and socioeconomic attributes were introduced as covariates. We also employed GEE with log-linear analyses and GEE with multinomial link function as supplemental analyses, which yielded similar results. Variance inflation factors indicated moderate but acceptable multicollinearity.

4. Supplemental analyses

To evaluate the robustness of our results, several supplemental analyses were performed (results not presented here). As county-level cities could be promoted to prefectural-level cities between 2003 and 2013, we excluded such cities and reanalyzed variations in physician density. The results remained unchanged. As county-level cities and urban districts were nested within the given provincial/prefectural-level city, multilevel ordinal logistic analyses were performed to adjust for the clustering. Lastly, the four provincial-level municipalities or top-tier cities (i.e., Beijing, Tianjin, Shanghai, and Chongqing) may differ significantly from other prefecture-level cities in their socioeconomic development. Hence, we reanalyzed the data by excluding these four municipalities, and the results were similar.

Results

1. Descriptive analyses

Overall, physician distribution across cities improved between 2003 and 2013, as suggested by the decline in Gini Coefficient from 0.31 to 0.25 (Supplemental Materials Figure 2). Results from the descriptive analysis offer additional support for the hypothesized improvement in physician distribution from 2003 to 2013 (H_1). The physician density in China's cities increased from 1.80 in 2003 to 2.48 in 2013. County-level cities experienced a greater proportional increase (41%; from 1.36 in 2003 to 1.92 in 2013) than urban districts (30%; from 2.47 in 2003 to 3.20 in 2013) (Table 1).

Table 1 Physician supply and socioeconomic characteristics of study area (mean values)

Region	Variable	2003		2013	
		Urban district	County-level city	Urban district	County-level city
Overall		N=272	N=368	N=281	N=357
	Physician density	2.47	1.36	3.20	1.92
	High school education or above (%)	21.13	11.50	34.12	21.51
	GDP per capita (10,000 CNY)	1.46	0.95	3.76	3.43
	Migrant (%)	21.25	10.43	27.97	16.38
Central		N=79	N=88	N=80	N=84
	Physician density	2.62	1.33	3.57	1.85
	High school education or above (%)	21.97	10.84	36.92	22.10
	GDP per capita (10,000 CNY)	1.14	0.67	3.26	3.25
	Migrant (%)	19.29	6.66	24.7	10.76
Northeastern		N=34	N=56	N=34	N=55
	Physician density	2.73	1.61	2.87	1.68
	High school education or above (%)	24.77	13.09	36.88	19.67
	GDP per capita (10,000 CNY)	1.38	0.81	4.08	3.29
	Migrant (%)	19.74	9.43	24.00	12.79
Western		N=72	N=80	N=84	N=80
	Physician density	2.17	1.63	2.91	2.36
	High school education or above (%)	17.63	12.84	29.45	23.78
	GDP per capita (10,000 CNY)	1.08	0.90	3.21	3.31
	Migrant (%)	17.20	15.15	27.27	21.51
Eastern		N=87	N=144	N=83	N=138
	Physician density	2.48	1.13	3.28	1.81
	High school education or above (%)	21.84	10.53	35.01	20.57
	GDP per capita (10,000 CNY)	2.11	1.20	4.59	3.67
	Migrant (%)	26.97	10.51	33.46	18.24

Note: All demographic attributes are available from Supplemental Material Table 1 and 2. GDP was adjusted by Consumer Price Index.

Furthermore, there appeared to be some regional variations across urban districts and county-level cities. For instance, urban districts in Western China had a lower physician density (2.17 in 2003 and 2.91 in 2013) than other regions. In contrast, county-level cities in Western China had the highest physician density (1.63 in 2003 and 2.36 in 2013) of their kinds among all regions.

Finally, physician density varied substantially across U.A.s (Table 2). Specifically, Beijing-Tianjin-Hebei U.A., Yangtze River Delta U.A., and Pearl River Delta U.A. had a higher physician density than Chengdu-Chongqing U.A. and cities which were not part of any U.A.

Table 2 Physician supply and socioeconomic characteristics of urban agglomerations (mean values)

UA	Variable	2003	2013
Beijing-Tianjin-Hebei U.A.		N=11	N=13
	Physician density	3.30	4.15
	High school education or above (%)	26.08	45.68
	GDP per capita (10,000 CNY)	1.61	4.62
	Migrant (%)	23.45	32.18
Yangtze River Delta U.A.		N=26	N=24
	Physician density	2.54	3.04
	High school education or above (%)	23.50	33.55
	GDP per capita (10,000 CNY)	2.97	5.37
	Migrant (%)	26.25	33.62
Pearl River Delta U.A.		N=8	N=8
	Physician density	2.45	2.64
	High school education or above (%)	24.43	38.05
	GDP per capita (10,000 CNY)	2.44	5.99
	Migrant (%)	55.73	55.51
Chengdu-Chongqing U.A.		N=14	N=15
	Physician density	1.68	2.44
	High school education or above (%)	12.06	25.45
	GDP per capita (10,000 CNY)	0.69	2.77
	Migrant (%)	11.93	20.45
Areas not in any U.A.		N=581	N=578
	Physician density	1.77	2.42
	High school education or above (%)	15.00	26.27
	GDP per capita (10,000 CNY)	1.07	3.47
	Migrant (%)	13.88	20.29

Note: U.A. represents urban agglomeration

2. Multivariate analyses

Table 3 presents the results from the GEE regression analysis of physician density in 2003 and 2013. In sharp contrast with the results from our descriptive analysis, odds of having a higher physician density were significantly greater in 2003 than in 2013 (OR = 0.17, 95% CI = 0.07 - 0.38), suggesting a possible deterioration in access over time (H_{1a}), when heterogeneity in population and socioeconomic characteristics were adjusted (Model 1in Table 3).

Table 3 GEE regression analysis of physician density, OR(95% CI)

Variable	Model 1	Model 2
Intercept2	0.01 (0.01 to 0.03)***	0.02 (0.01 to 0.04) ***
Intercept1	0.17 (0.07 to 0.38) ***	0.21 (0.09 to 0.48) ***
Year 2013 (vs. year 2003)	0.49 (0.34 to 0.72) ***	0.50 (0.33 to 0.75) ***
Urban district (vs. county-level city)	2.62 (1.84 to 3.73) ***	
Geographic location		
Eastern (vs. Western)	0.52 (0.36 to 0.77) **	
Northeastern (vs. Western)	0.73 (0.45 to 1.21)	
Central (vs. Western)	0.65 (0.44 to 0.95) *	
Geographic location & Administrative level		
County-level city x Western	Ref.	
Urban district x Eastern	1.49 (0.81 to 2.74)	
County-level city x Eastern	0.32 (0.20 to 0.52) ***	
Urban district x Northeastern	1.09 (0.49 to 2.38)	
County-level city x Northeastern	0.62 (0.33 to1.15)	
Urban district x Central	1.47 (0.80 to 2.71)	
County-level city x Central	0.42 (0.25 to 0.70) ***	
Urban district x Western	1.53 (0.93 to2.52)	
U.A. (vs. non-U.A.)	0.87 (0.51 to 1.49)	0.75 (0.44 to 1.29)
High school education or above (%)	1.21 (1.17 to 1.25) ***	1.21 (1.17 to 1.25) ***
GDP per capita (10,000 CNY)	1.15 (0.83 to 1.59)	1.02 (0.96 to 1.08)
Population density (/1000 km^2)	0.99 (0.78 to 1.25)	0.96 (0.76 to 1.22)
Female-to-male ratio (in a unit of 10%)	0.84 (0.70 to 0.99) *	0.86 (0.73 to 1.01)
Migrant (in a unit of 10%)	1.08 (0.91 to 1.28)	1.07 (0.90 to 1.26)
Minority (in a unit of 10%)	1.02 (0.93 to 1.12)	0.99 (0.91 to 1.09)
Aged under 15 (in a unit of 10%)	0.93 (0.81 to 1.07)	0.94 (0.83 to 1.07)
Aged over 65 (in a unit of 10%)	1.57 (0.66 to 3.72)	1.78 (0.70 to 4.54)

Note: *** $P < .001$; ** $P < .01$; * $P < .05$. UA represents urban agglomeration. County-level city x Western represents county-level cities in Western China. GDP was adjusted by Consumer Price Index.

Per our hypothesis, urban districts were more likely to have a higher physician density (OR = 2.62, 95% CI = 1.84 - 3.73), relative to county-level cities. This association remained robust even with population and socioeconomic attributes controlled (H_2).

Regions mattered but in an unexpected direction (Model 1). Specifically, in comparison with Western China, economically more developed Eastern China (OR = 0.52, 95% CI = 0.36 - 0.77) and Central China (OR = 0.65, 95% CI = 0.44 - 0.95) were significantly less likely to have a higher physician density. There were no significant differences in physician density between Northeastern China and Western China. These findings provide some evidence that the difference between urban districts and county-level cities in physician density varied across regions, as we hypothesized (H_3).

According to results pertaining to Model 2, regional differences existed among county-level cities but not urban districts. Relative to county-level cities in the less developed Western China, county-level cities in Eastern China had lower odds of being in a higher physician-density group (OR = 0.32, 95% CI = 0.20 - 0.52). Likewise, county-level cities in Central China (OR = 0.42, 95% CI = 0.25 - 0.70) were at a substantial disadvantage in comparison with their counterparts in Western China.

Finally, contrary to our hypothesis (H_4), urban districts in the four urban agglomerations did not differ from areas not included in the U.A.s (Model 2 in Table 3). Because the Chengdu-Chongqing U.A. had a lower physician density and was less developed socioeconomically relative to the other three U.A.s, it appeared to be more like cities outside any U.A. (Table 2). Hence, we conducted an additional analysis by grouping the Chengdu-Chongqing U.A. with areas that were not in any U.A., which yielded similar results.

3. Predicted probabilities

The magnitude of the odds ratio is difficult to interpret because of the arbitrary scaling factor [36]. Consequently, based on the models in Table 3, we derived the predicted probabilities for high, medium, and low physician density by urban districts/county-level cities, regions, and urban agglomeration (Table 4), while controlling for socioeconomic and demographic covariates by constraining them at their mean values.

Table 4 Predicted probabilities for physician density after controlling for population and socioeconomic covariates

Region	2003			2013		
	Low density [0.00 -1.48]	Medium density [1.49 - 2.46]	High density [2.47 - 9.68]	Low density [0.00 -1.48]	Medium density [1.49 - 2.46]	High density [2.47 - 9.68]
Model 1						
Urban district	0.17	0.55	0.28	0.29	0.55	0.16
County-level city	0.34	0.53	0.13	0.52	0.42	0.07
Eastern China	0.17	0.55	0.28	0.29	0.55	0.16
Northeastern China	0.13	0.52	0.35	0.23	0.56	0.21
Central China	0.14	0.54	0.32	0.25	0.56	0.19
Western China	0.09	0.48	0.43	0.18	0.56	0.27
Non - U.A.	0.29	0.43	0.28	0.29	0.55	0.16
U.A.	0.32	0.43	0.25	0.32	0.54	0.14
Model 2						
Urban district x Eastern	0.14	0.54	0.33	0.24	0.57	0.19
County-level city x Eastern	0.42	0.49	0.09	0.59	0.36	0.05
Urban district x Northeastern	0.18	0.56	0.26	0.30	0.55	0.15
County-level city x Northeastern	0.27	0.56	0.17	0.43	0.48	0.09
Urban district x Central	0.14	0.54	0.32	0.24	0.57	0.19
County-level city x Central	0.36	0.52	0.12	0.53	0.41	0.06
Urban district x Western	0.13	0.54	0.33	0.23	0.57	0.20
County-level city x Western	0.19	0.57	0.25	0.32	0.54	0.14

Note: Low, medium, and high density respectively represent physician density ranging from 0.00 to 1.48, 1.49 to 2.46, and 2.47 to 9.68 per 1,000 population. Probabilities were derived on the basis of the models in Table 3 with covariates conditioned at the following values: High school education or above = 21.32%, GDP per capita = 2.89, population density = 779.80 (/km^2), female-to-male ratio = 96.81%, migrant = 18.25%, minority = 7.88%, aged under 15 = 18.77%, aged over 65 = 7.94%. UA represents urban agglomeration. County-level city x Western represents county-level cities in Western China.

First, adjusting for population and socioeconomic attributes, the decline in physician density between 2003 and 2013 is further illustrated by the estimated probabilities (Table 4). For both urban districts and county-level cities, probabilities for low physician density increased from 2003 to 2013. In contrast, probabilities for high physician density declined substantially during the same period.

Regarding the differences between urban districts and county-level cities, urban districts had a greater probability of high physician density (0.28 in 2003 and 0.16 in 2013) relative to county-level cities (0.13 in 2003 and 0.07 in 2013). Western China had a much higher probability for high physician density (0.44 in 2003 and 0.27 in 2013) relative to other regions, which had probabilities for high physician density ranging respectively from 0.28 to 0.35 in 2003 and from 0.16 to 0.21 in 2013 (Table 4).

The disparities among county-level cities across regions are also exhibited by the predicted probabilities. As shown in Table 4, probabilities in high, medium, and low physician density groups are quite similar among urban districts across the four regions. In contrast, county-level cities in East China and Central China had the lowest probabilities for high physician density (0.09 and 0.12 in 2003; 0.05 and 0.06 in 2013) among all county-level cities.

Last, cities in and those outside an urban agglomeration exhibited similar probabilities in terms of low, medium, and high physician density, although probabilities for a high physician density were substantially diminished.

Discussion

Despite being a developing country with approximately 1.4 billion people, China has managed to extend a basic health care safety net for more than 95 percent of its population in 2012 [11]. Nonetheless, stark health disparities remain, for which the distribution of health care human resources is a major cause [37]. o the best of our knowledge, this is the first examination of physician distribution across China's cities in conjunction with regional differences and urban agglomeration, while considering the heterogeneity in population and socioeconomic characteristics over time.

The present research provides further insights regarding inequality in physician density across China's cities by highlighting their regional variations. First, regional differences existed only among county-level cities but not urban districts. Second, Eastern and Central China regions had the lowest probabilities of high physician density relative to other regions. As county-level cities in Central China had lower education and GDP per capita (Table 1), it was not surprising that they were less likely to have high physician density. More surprising was that county-level cities in Eastern China, whose county-level cities had the highest GDP per capita across regions, were disadvantaged in terms of high physician density.

We offered the following hypotheses to account for the lower physician density in county-level cities in Eastern China. First, urban districts in Eastern China may attract physicians from neighboring county-level cities because of the advanced transportation systems, which reduce the time cost of migration of physicians [38]. This possibility was supported by Wang et at. (2008), who noted a positive correlation between the length of highway and health professionals' distribution [44]. Additionally, numerous tertiary hospitals in urban districts in Eastern China may lead to a “Matthew Effect” that attracts an increasing number of physicians from nearby communities. Since career prospect plays an important role for physicians in choosing a workplace [8, 9, 45], physicians may greatly benefit from urban districts in Eastern China, which had 33.52% China's tertiary hospitals (1,399 in total) in 2011, while Central, Northeastern, and Western regions only took up 28.59%, 13.22%, and 24.73%, respectively [46].

Abbreviations

OR, odds ratio

CI, confidence interval

U.A., urban agglomeration

Declarations

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1. China City Statistical Yearbook 2001.
2. China City Statistical Yearbook 2004.
3. China City Statistical Yearbook 2011.
4. China City Statistics Yearbook 2014.
5. National Census Survey 2000.
6. National Census Survey 2010.

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Authorship declaration: X.Y., W.Z., and J.L. designed the study. X.Y. collected data and completed data analysis. X.Y., W.Z., and J.L. interpreted results. X.Y. and J.L. collectively drafted the manuscript.

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