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Research article

Unraveling the drivers of inequality in primary health-care resource distribution: Evidence from Guangzhou, China

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ABSTRACT

Background: Primary health-care (PHC) resource plays a critical role in addressing challenges related to healthcare accessibility and costs, as well as implementing a graded diagnosis and treatment system. This study aims to analyze the extent and components of inequality in PHC resource allocation in Guangzhou.
Methods: By utilizing data from the Annual Report on Healthcare Institutions for community and township health centers in Guangzhou from 2012 to 2020, this paper analyses the distribution of human, material and financial resources. It examines inequities in health resource allocation using the Gini coefficient. Additionally, it investigates the internal structure of overall inequality through the two-stage nested Theil decomposition method and explores the influencing mechanisms of inequality using the concentration index decomposition method.
Results: The findings indicate that between 2012 and 2020, except for beds in 2018 and 2019, the Gini coefficients for resource allocation relative to population size remained below 0.3. Moreover, the Gini coefficient for geographical area ranged from 0.1228 to 0.3481. The two-stage nested Theil decomposition results reveal that within-district disparity contributes the most to the overall inequality, exceeding 46 %. The Concentration indexes show negative values, and the decomposition analysis highlights the significant contribution of the number of individuals served (over 72 %) to the inequality in health resource allocation.
Conclusion: At the administrative district level, the allocation of PHC resources in Guangzhou demonstrates overall equity, with within-district inequality identified as the primary contributor to the overall inequality. The distribution of PHC resources in Guangzhou follows a pro-poor pattern. The key factors influencing equity enhancement in PHC resource allocation in Guangzhou include the number of individuals served, the presence of township health centers among institution types, the number of hospital admissions per capita, and the proportion of children aged 0–3.

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1. Background

Primary health-care (PHC) institutions play a crucial role in providing essential health-care services and acting as “gatekeepers” for residents’ well-being. The outbreak of COVID-19 has brought to the forefront the critical importance of primary health care in responding to public health emergencies and ensuring the overall health of communities. Governments worldwide have recognized the urgent need to strengthen and prioritize their primary health-care systems in light of the challenges posed by the pandemic. In China, the government has consistently emphasized the significance of primary health care, prioritizing its strategic development to improve public health. The “Healthy China 2030″ planning framework sets forth a three-step goal for achieving a healthy China by 2020, 2030, and 2050. By 2020, the objective was to establish a PHC system with distinct Chinese characteristics, ensuring universal access to PHC services for both urban and rural populations [1]. Furthermore, the guidelines for health and wellness in China’s new era underscore the importance of primary health care and highlight the pivotal role of the PHC system in the “Basic Health Care Promotion Law".

Guangzhou, the capital of Guangdong Province, serves as the political, economic, cultural, and educational hub of South China and is recognized as one of China’s three major medical centers. By the end of 2020, Guangzhou had a total of 5550 healthcare institutions, including 289 hospitals, 5070 primary healthcare facilities, 101 specialized public health institutions, and 90 other medical entities. However, the distribution of healthcare resources in Guangzhou reveals significant imbalances. The disparity in resource allocation among districts and county-level cities is closely associated with their economic and social development levels. Generally, regions with higher healthcare funding, more advanced economic development, faster urbanization, and better social security levels experience greater disparities in resource allocation. The overall hospital distribution exhibits a “reverse triangle” pattern, with tertiary hospitals predominantly concentrated in Yuexiu District, leading to an overconcentration of high-level hospitals in this area [2]. This results in residents with minor ailments tending to seek care at large hospitals, which strains primary healthcare facilities and diminishes their effectiveness. Additionally, the total number of healthcare professionals in community health service institutions is insufficient and does not meet requirements. Addressing these issues is crucial for optimizing the allocation of limited healthcare resources and enhancing the equity of healthcare services to meet residents’ needs and promote health equity.

For foreign studies, the results of the study show that inequitable healthcare resource allocation is common in countries around the world, and that inequality is mainly reflected in inter-regional and intra-regional differences, as well as differences in human, material and financial resources [3,4]. In China, Wu Xueling [5], using the Gini coefficient, Theil index, and Concentration index analysis, found that the population-based allocation of healthcare resources in Taiyuan was better than the region-based allocation. Other studies also highlighted that China’s healthcare resources are significantly regionally skewed, with high-quality resources concentrated in major cities and central areas, while underdeveloped regions lack resources and investment [6,7]. Additionally, Zhang Tao [8] used the Concentration index and found that due to disparities in resource allocation and service capacity, higher-income groups prefer hospital outpatient services, while lower-income groups are more inclined to use inpatient services at PHC institutions.

Regarding factors affecting the equity of healthcare resource allocation, Shinjo et al. [9]found a positive relationship between the number of local resources and equity in Japan’s 350 medical institutions, indicating that fewer local resources lead to lower equity. Du Fengjiao [10] established a regression model of influencing factors and found a close relationship between resource allocation and regional development levels. Wu Xueling [11] used grey relational analysis to study the factors affecting resource allocation in Taiyuan, showing that population had the greatest impact, followed by social and economic factors. Fu Xianzhi [12] used the Concentration index decomposition method to identify per capita GDP as the main factor of inequity in China’s resource allocation. Other studies showed that healthcare service demand is a major driver of resource allocation, attracting resources to specific areas [13].

In summary, existing research predominantly focuses on provincial and municipal levels, with relatively few studies examining sub-municipal levels [13–15]. Resource allocation varies significantly across regions due to differences in economic, demographic, social, and policy factors. Analyzing the impact and extent of these factors on resource allocation equity can aid in the formulation of localized resource allocation strategies. Building on existing research, this study introduces the following innovations. Firstly, analytical unit innovation. While most research on healthcare resource allocation uses municipal or district levels as the minimum analytical unit, this study further disaggregates administrative regions to the street or township level. It employs a two-stage nested Theil index decomposition method to understand the internal structure of overall resource allocation inequality. Secondly, methodological innovation. Current studies on the factors influencing the equity of healthcare resource allocation in China largely utilize linear regression, panel data regression, and spatial autocorrelation methods to analyze the relationships between healthcare resource allocation and influencing factors. This study, however, employs the Concentration index decomposition method in addition to regression models to decompose the factors, thereby elucidating the contribution of allocation disparities to inequities in healthcare resource distribution.

2. Methods

2.1. Study site

Guangzhou, the capital city of Guangdong Province in China, serves as the economic center of South China. It is composed of 11 districts: Tianhe District (TH), Yuexiu District (YX), Liwan District (LW), Haizhu District (HZ), Baiyun District (BY), Huangpu District (HP), Panyu District (PY), Nansha District (NS), Huadu District (HD), Zengcheng District (ZC), and Conghua District (CH). Among these, TH is considered the central district of Guangzhou.

2.2. Data sources

The health resource data were obtained from the Annual Report on Healthcare Institutions for community and township health centers in Guangzhou from 2012 to 2020. Designed by the National Health Commission of the PRC, the report collects information from all healthcare institutions via a unified internal reporting system. Each organization is legally responsible for reporting accurate data. The dataset includes 11 administrative districts, 165 streets/towns, and 186 institutions, covering all 155 community health centers and 31 township health centers.

2.3. Main indicators

Primary healthcare resources refer to various resources required to provide basic medical and public health services at the community or township level. These include human resources, material resources, financial resources, information resources, and service resources。

In this study, community health centers and town health centers were equipped as research subjects for two reasons. Firstly, these institutions serve as the primary channels for providing PHC services and carrying out important public health tasks. They are also the focal points of national and local government policy support. The development of these institutions directly reflects the effectiveness of policy implementation, ensuring the representativeness and practicality of the research data. Secondly, these institutions are typically uniformly planned in policy documents, with similar resource allocation standards and operational models, thereby making the research conclusions more convincing and relevant for policy guidance.

This study considers three categories of health resources: material resources, human resources, and financial resources. Material resources are represented by the number of institutions, beds, and medical equipment (measured in terms of the number of equipment units valued over 10,000 yuan) [16]. Human resources are represented by health technicians, practicing (assistant) physicians, and registered nurses [17,18]. Financial resources are indicated by financial assistance income [16,19]. The definitions of the indicators are given in Table 7.

2.4. Measurements of inequity

In this study, the DASP module in STATA16 is primarily utilized to calculate the inequality index. Specifically.

2.4.1. Gini coefficient

The Gini coefficient is calculated based on the Lorenz curve [20]. The x-axis of the Lorenz curve represents the cumulative percentage of the population or geographical area, while the y-axis represents the cumulative percentage of the health resources corresponding to a certain population or geographical area [21]. The 45-degree line represents absolute equality. The area between the Lorenz curve and the absolute equality line reflects the degree of inequality. Therefore, the farther the Lorenz curve is from the absolute equality line, the higher the degree of injustice. Gini coefficient values range from 0 to 1, where 0 indicates an absolute equality state, 1 indicates absolute inequality, <0.3 indicates perfect equality, 0.3–0.4 indicates normal conditions, <0.4 indicates alert conditions, 0.5–0.6 indicates inequality, and >0.6 indicates high inequality [20,22]. The Gini coefficient is calculated using the following

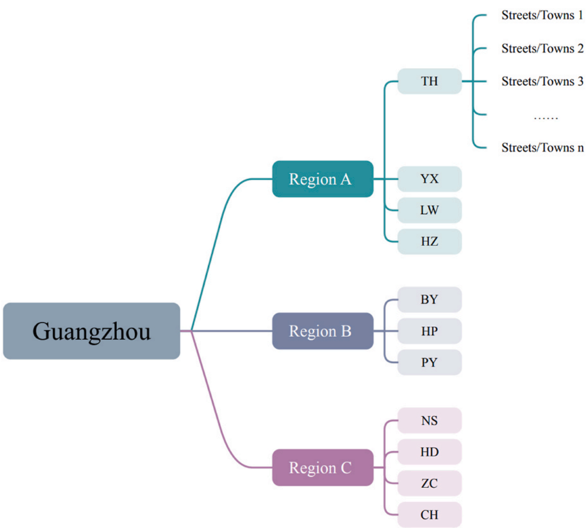

Fig. 1. Three-level hierarchical structure.
Note: Tianhe District (TH), Yuexiu District (YX), Liwan District (LW), Haizhu District (HZ), Baiyun District (BY), Huangpu District (HP), Panyu District (PY), Nansha District (NS), Huadu District (HD), Zengcheng District (ZC) and Conghua District (CH).

formula:

$$G = 1 - \sum_{i=1}^{n} (Y_i + Y_{i-1})(X_i - X_{i-1}) \tag{1}$$

In Eq. (1), X_i For district i according to a certain type of health resource variable from low to high arrangement of the cumulative population (area) proportion, Y_i for district i corresponding to the health resource variable ownership cumulative percentage, n for the total number of districts, and G is the Gini coefficient.

2.4.2. Two-stage nested Theil decomposition method

The Theil index is a relative index, and there is no specific cordon [23]. When the Theil index is zero, resources are allocated equally. The farther away the Theil index is from zero, the more equality there will be. The Theil index is divided into the Theil T index and Theil L index. The Theil T index used the proportion of health resources as the weight and was more sensitive to regional changes with a higher proportion of health resources. The Theil L index, which uses the population share as the weight, is more sensitive to regional changes with a lower proportion of health resources [13]. In this paper, the Theil L index is used.

The Theil index is decomposable [24]. Takahiro Akita [25] proposed a two-stage nested Theil decomposition method, which is an extension of the common one-stage Theil decomposition and is similar to the two-stage nested design in the analysis of variance (ANOVA). This paper uses a two-stage nested Theil decomposition method to explore the internal structure of the overall inequality in the allocation of PHC resources in Guangzhou. It breaks down Guangzhou into three-level hierarchical structures: regions-districts-streets/towns (as shown in Fig. 1). On the first level, according to the economic level and geographical location, the 11 districts of Guangzhou are divided into three types of regions: region A (TH, YX, LW, HZ), region B (BY, HP, PY) and region C (NS, HD, ZC, CH). In the second level, there are 11 districts. The third floor has a total of 165 streets/towns. We breakdown total inequality into three parts: between-region, between-district, and within-district inequality. In this study, the streets/towns were taken as the basic units, so the contributions of within-district inequality, between-district inequality and between-region inequality to the overall health resource inequality could be analyzed.

Next, we use streets or villages and towns as the basic unit and use the Theil index to decompose the overall inequality of primary health resource allocation in Guangzhou.

$$T = \sum_i \sum_j \sum_k \left(\frac{N_{ijk}}{N}\right) \log\left(\frac{N_{ijk}/N}{Y_{ijk}/Y}\right) \tag{2}$$

In Eq. (2), N_{ijk} is the population of street or township k in district j in region i,

N is the total population of all streets and townships $\left(= \sum_i \sum_j \sum_k N_{ijk}\right)$,

Y_{ijk} is the health resources of street or township k in district j in region i,

Y are the health resources of all streets and townships $\left(= \sum_i \sum_j Y_{ij}\right)$.

If we define T_i to measure within-region health resource inequality for region i by Eq. (3),

$$T_i = \sum_j \sum_k \left(\frac{N_{ijk}}{N_i}\right) \log\left(\frac{N_{ijk}/N_i}{Y_{ijk}/Y_i}\right) \tag{3}$$

then the overall inequality T in Eq. (2) can be decomposed into

$$T = \sum_i \left(\frac{N_i}{N}\right) T_i + \sum_i \left(\frac{N_i}{N}\right) \log\left(\frac{N_i/N}{Y_i/Y}\right) = \sum_i \left(\frac{N_i}{N}\right) T_i + T_{BR} = T_{WR} + T_{BR} \tag{4}$$

In Eq. (4), N_i is the total population of region $\left(= \sum_j \sum_k N_{ijk}\right)$,

Y_i are the total health resources of region i $\left(= \sum_j \sum_k Y_{ijk}\right)$,

$T_{BR} = \sum_i \left(\frac{N_i}{N}\right) \log\left(\frac{N_i/N}{Y_i/Y}\right)$ measures health resource inequality between regions, and

$T_{WR} = \sum_i \left(\frac{N_i}{N}\right) T_i$ measures health resource inequality within regions.

Therefore, the overall health resource inequality T is the sum of the within-region component (T_{WR}) and the between-region component (T_{BR}).

Following this, if we define T_{ij} in Eq. (5) as follows to measure within-district health resource inequality for district j in region i,

$$T_{ij} = \sum_k \left(\frac{N_{ijk}}{N_{ij}}\right) \log\left(\frac{N_{ijk}/N_{ij}}{Y_{ijk}/Y_{ij}}\right) \tag{5}$$

Then, T_i in Eq. (3) can be decomposed into

$$T_i = \sum_j \left(\frac{N_{ij}}{N_i}\right) T_{ij} + \sum_j \left(\frac{N_{ij}}{N_i}\right) \log\left(\frac{N_{ij}/N_i}{Y_{ij}/Y_i}\right) = \sum_j \left(\frac{N_{ij}}{N_i}\right) T_{ij} + T_{di} \tag{6}$$

In Eq. (6), N_{ij} is the total population of district j in region $\left(= \sum_k n_{ijk}\right)$,

Y_{ij} are the total health resources of district j in region i $\left(= \sum_k y_{ijk}\right)$,

$T_{di} = \sum_j \left(\frac{N_{ij}}{N_i}\right) \log\left(\frac{N_{ij}/N_i}{Y_{ij}/Y_i}\right)$ measures health resource inequality between districts in region i.

Finally, we obtain

$$\begin{aligned} T &= \sum_i \left(\frac{N_i}{N}\right)\left[\sum_j \left(\frac{N_{ij}}{N_i}\right) T_{ij} + T_{di}\right] + T_{BR} \\ &= \sum_i \sum_j \left(\frac{N_{ij}}{N}\right) T_{ij} + \sum_i \left(\frac{N_i}{N}\right) T_{di} + T_{BR} = T_{wD} + T_{BD} + T_{BR} \end{aligned} \tag{7}$$

Equation (7) is the two-stage Theil inequality decomposition equation, in which the overall regional health resource inequality is decomposed into the within-district component (T_{wD}), the between-district component (T_{BD}), and the between-region component (T_{BR}). The within-district component is a weighted average of within-district health resource inequalities (T_{ij}), while the between-district component is a weighted average of between-district component health resource inequalities (T_{di}).

2.4.3. Concentration index

The Concentration index (CI) can quantify the equality of health resource allocation related to the economic level, making up for the defects of the single dimension of the Gini coefficient. Since the principle of the CI is the same as that of the Gini coefficient, the CI is calculated similarly to the Gini coefficient, which is twice the area between the Concentration curve and the equality line. When the CI was positive, the Concentration curve was below the diagonal, indicating that the allocation of health resources tended to the area with a higher economic level. When the CI was negative, the Concentration curve was above the diagonal, indicating that the allocation of health resources tended to the region or group with a lower economic level. In terms of value, the CI ranges from −1 to 1 [26]. When the CI is 0, there is absolute equality. When the absolute value of the CI is greater than 0.1, it is considered inequality, and a larger absolute value of the CI indicates a greater degree of inequality [27]. The calculation formula of that CI is as follows:

$$CI = \frac{2}{\mu} cov(y_i, R_i) \tag{8}$$

In Eq. (8), y_i is health resources for street or town i. R_i is the fractional rank of the ith street or town in the socioeconomic status (GDP per capita). μ is the mean of y. *cov* is the covariance. CI is the Concentration index.

2.4.4. Concentration index decomposition

2.4.4.1. Variable selection. Factors Influencing Human Resource Allocation. Liu Hengyang and colleagues distinguish between direct and indirect factors affecting healthcare human resource allocation in China. Direct factors include healthcare service demand, the quantity and quality of healthcare personnel, and healthcare policies. Indirect factors involve demographic geography, socio-economic conditions, administrative management, and service accessibility, with policy and administrative factors being challenging to quantify [28]. Liu identifies healthcare service demand as the most significant direct factor, measured by indicators such as annual outpatient visits, inpatient admissions, and hospital bed counts. Demographic geography, with indicators like resident population and density, is also crucial. Guan Li et al. note that increases in resident population heighten the demand for healthcare resources [29]. Additionally, the growing demand from elderly, maternal, and pediatric populations necessitates adjustments in resource allocation [28]. Liu further highlights that the scale and type of healthcare institutions influence human resource distribution [30].

Table 1
Factors Influencing Resource Allocation of Guangzhou PHC institutions.

Type	Factors	number	Unit
Health service demand	Number of Outpatients Per Capita	x_1	time
	Number of emergency room visits per capita	x_2	time
	Number of family health services per capita	x_3	time
	Number of referrals to superior hospitals per capita	x_4	time
	Number of Traditional Chinese Medicine (TCM) services per capita	x_5	time
	Number of hospitalizations per capita	x_6	human
Population indicators	people served (resident)	x_7	1000 people
	Proportion of children aged 0–3 years old	x_8	%
	Proportion of aging (Proportion of population over 65 years of age)	x_9	%
Institution type	Institution Type (township health centers equal 1, Community Health Centers equal 0)	x_{10}	–

Factors Influencing Material Resource Allocation. Wang Shuping identifies the main factors affecting material resource allocation as the supply-demand balance, medical service development, and socio-economic conditions. Supply-demand balance includes supply metrics (e.g., number of beds, equipment, patient volumes) and demand metrics (e.g., morbidity, consultation, hospitalization rates). Medical service development involves advancements in technology and coverage. Rising incomes and an aging population also drive increased demand for healthcare services [31]. Yu Ke emphasizes that population growth and the rising number of elderly individuals increase healthcare service demand, suggesting these factors should be integrated into resource allocation [32].

Factors Influencing Financial Resource Allocation. Xiao Haixiang classifies factors affecting government healthcare expenditure into common, demand-side, and supply-side influences. He finds GDP positively impacts spending, while fiscal decentralization and environmental pollution have negative effects. Previous expenditure levels, urbanization rates, and hospitalization rates also influence healthcare spending [33].

This study based on a literature review [34–36] and actual analysis of demand, this paper constructed a system of influencing factors on the resource allocation of Guangzhou PHC institutions from three aspects: health service demand, population indicators and institution (Table 1).

2.4.4.2. Model selection. The influencing factors of the unequal distribution of health resources are obtained by decomposing the inequality index; that is, the factors that contribute to the unequal distribution of health resources are decomposed, and the contribution degree of each influencing factor to inequality is analyzed. At present, the more mainstream inequality index decomposition method is the Concentration index decomposition method proposed by Wagstaff, which is an anti-fact decomposition method.

The CI decomposition formula is as follows:

$$CI = \sum_k \left(\frac{\beta_k \overline{x}_k}{\mu}\right) C_k + \frac{GC_\varepsilon}{\mu} \tag{9}$$

where μ is the mean value of health resources (dependent variable), $\overline{x}_k$ *is* is the mean value of the influencing factor x_k, C_k is the CI of the influencing factor, and GC_ε is a generalized Concentration index for ε.

Within the framework of Wagstaff's CI decomposition, the total inequality in the distribution of health resources can be decomposed into two parts in Equation (9). The first part ($\sum_k \left(\frac{\beta_k \overline{x}_k}{\mu}\right) C_k$) belongs to the inequality caused by the imbalance of influencing factors, which is equal to the weighted sum of the CI of the *k* regressors, where the weight is expressed as elasticity [37]. Elasticity ($\frac{\beta_k \overline{x}_k}{\mu}$) indicates the effect of each determinant on the expected result. C_k indicates the extent to which each influencing factor is distributed unequally among different groups. The second ($\frac{GC_\varepsilon}{\mu}$) is a residual component, and it reflects the inequality in health resource allocation that cannot be explained by systematic variation across income groups in the x_k [38].

CI decomposition step.

1) Establish a linear regression model, the dependent variable and independent variable regression analysis, and then obtain the dependent variable regression coefficient (β_k). The linear regression model was established as follows:

$$y_i = \alpha + \sum_k \beta_k x_{ki} + \varepsilon_i \tag{10}$$

In Eq. (10), y_i is the allocation status of health resources, x_k is the influencing factors (as shown in Table 1), β_k is the regression coefficient of the influencing factors, and ε_i is the residual term.

2) Calculate the average of the explanatory variables and each of their influencing factors (μ and $\overline{x}_k$).
3) The elasticity of each influencing factor can be calculated by multiplying the average value of each influencing factor by the corresponding regression coefficient and then dividing by the average value of health resources.
4) Calculate the explanatory variables and influencing factors of the Concentration index (CI and C_k) and the generalized Concentration index (GC_ε) for ε_i.
5) The absolute contribution of each influencing factor to inequality is revealed by multiplying the elasticity of each influencing factor by its CI. This is the absolute contribution of each contributing factor to the measured inequality. From the perspective of absolute contribution, the contribution to inequality is the result of two factors: one is the marginal effect of influencing factors on explanatory variables, and the other is the distribution of the influencing factors based on economic status [39]. The contribution calculation formula is Eq. (11).

$$\text{Absolute contribution} = \left(\frac{\beta_k \overline{x}_k}{\mu}\right) C_k \tag{11}$$

6) Finally, calculate the contribution rate, the absolute contribution of each influencing factor divided by CI. The positive contribution rate indicated that the difference in the allocation of influencing factor x_k among different economic groups would result in an increase in inequality in the allocation of health resources [40]. The negative contribution rate indicated that inequality of

influencing factor x_k in different income groups would reduce the inequality of health resource allocation. The contribution rate formula is Eq. (12).

$$\text{Contribution rate} = \left(\frac{\beta_k \overline{x}_k}{\mu}\right) C_k / CI \tag{12}$$

3. Results

3.1. Distribution of health resources

From 2012 to 2020, the number of institutions slightly increased from 185 in 2012 to 186 in 2020 (see Table 2). The number of beds experienced a decrease from 4484 to 4,332, indicating a reduction of 152 beds. In contrast, the count of medical equipment consistently increased annually, rising from 5653 to 16,068, demonstrating a substantial growth of 10,415 units or 65 %. Likewise, the number of health technicians witnessed a notable increase from 10,955 to 15,843, resulting in a gain of 4888 professionals. Additionally, the number of practicing (assistant) physicians showed an upward trend, escalating from 4400 to 6,574, reflecting an augmentation of 2174 individuals. Furthermore, the count of registered nurses exhibited growth from 3928 to 6,043, signifying an increase of 2115 nurses. Per thousand individuals, the resources allocated for the three human resource indicators demonstrated a modest growth trend. The distribution of each human resource indicator per square kilometer indicated a significant growth pattern. Notably, income from health financial assistance experienced a substantial increase, surging from 127.770 million yuan in 2012 to 496.518 million yuan in 2020, representing a remarkable gain of 368.748 million yuan or a growth rate of 74 %. Moreover, the financial assistance income per 1000 people and per square kilometer showed growth rates of 68 % and 74 %, respectively.

3.2. Equity in the distribution of health resources

3.2.1. Gini analysis

The Lorenz curves in Fig. 2, depicting the distribution of population and geographical area, reveal that in 2020, the curve representing institutions exhibits the highest proximity to the curve of absolute equality, whereas the curve for beds displays the greatest divergence, thus signifying superior equality in institutions and inferior equality in beds.

The Gini coefficients for the population distribution of primary health care (PHC) resources in Guangzhou between 2012 and 2020 varied from 0.1182 to 0.4211. Notably, the Gini coefficients for beds in 2018 and 2019 exceeded the critical threshold of 0.4, reaching 0.4114 and 0.4211, respectively, thereby indicating substantial disparities in resource allocation. Furthermore, the allocation of other health resources maintained an optimal state of equality. Moreover, the most favorable equality exists between the number of institutions and the allocation of medical equipment. Between 2012 and 2020, the Gini coefficients for the number of institutions, beds, and medical equipment exhibited a downward trajectory, thereby signifying a reduction in the disparities in the allocation of these resources. Conversely, the Gini coefficients for health technicians, practicing (assistant) physicians, registered nurses, and financial assistance income displayed an upward trend, suggesting an increase in resource allocation inequalities that warrants careful attention (see Table 3).

Table 2
Basic information on PHC resource allocation from 2012 to 2020.

	Indicators	2012	2013	2014	2015	2016	2017	2018	2019	2020
Institutions	Total	185	180	182	181	184	183	183	183	186
	/1000 persons	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
	/km^2	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03
Beds	Total	4484	4459	4484	4640	4694	4799	5295	5070	4332
	/1000 persons	0.39	0.38	0.39	0.4	0.39	0.39	0.39	0.36	0.3
	/km^2	0.6	0.6	0.6	0.62	0.63	0.65	0.71	0.68	0.58
Medical equipment	Total	5653	6423	7009	8002	8858	10246	12125	12552	16068
	/1000 persons	0.49	0.55	0.6	0.69	0.74	0.83	0.9	0.9	1.1
	/km^2	0.76	0.86	0.94	1.08	1.19	1.38	1.63	1.69	2.16
Health technicians	Total	10955	11917	12508	13026	13456	13930	14963	15569	15843
	/1000 persons	0.95	1.03	1.08	1.12	1.12	1.13	1.11	1.12	1.09
	/km^2	1.47	1.6	1.68	1.75	1.81	1.87	2.01	2.09	2.13
Practicing (assistant) physicians	Total	4400	4805	4923	5163	5504	5652	6039	6397	6574
	/1000 persons	0.38	0.41	0.42	0.44	0.46	0.46	0.45	0.46	0.45
	/km^2	0.59	0.65	0.66	0.69	0.74	0.76	0.81	0.86	0.88
Registered nurses	Total	3928	4235	4559	4749	4895	5190	5624	5866	6043
	/1000 persons	0.34	0.37	0.39	0.41	0.41	0.42	0.42	0.42	0.41
	/km^2	0.53	0.57	0.61	0.64	0.66	0.7	0.76	0.79	0.81
Financial assistance income	Total	127770.1	139475.1	146616.6	178731.3	233634.7	287229.7	385372	396576.9	496518.5
	/1000 persons	11.06	12.03	12.65	15.31	19.52	23.3	28.48	28.47	34.09
	/km^2	17.19	18.76	19.72	24.04	31.43	38.64	51.84	53.34	66.79

Note: The unit of financial assistance income is 10,000 RMB.

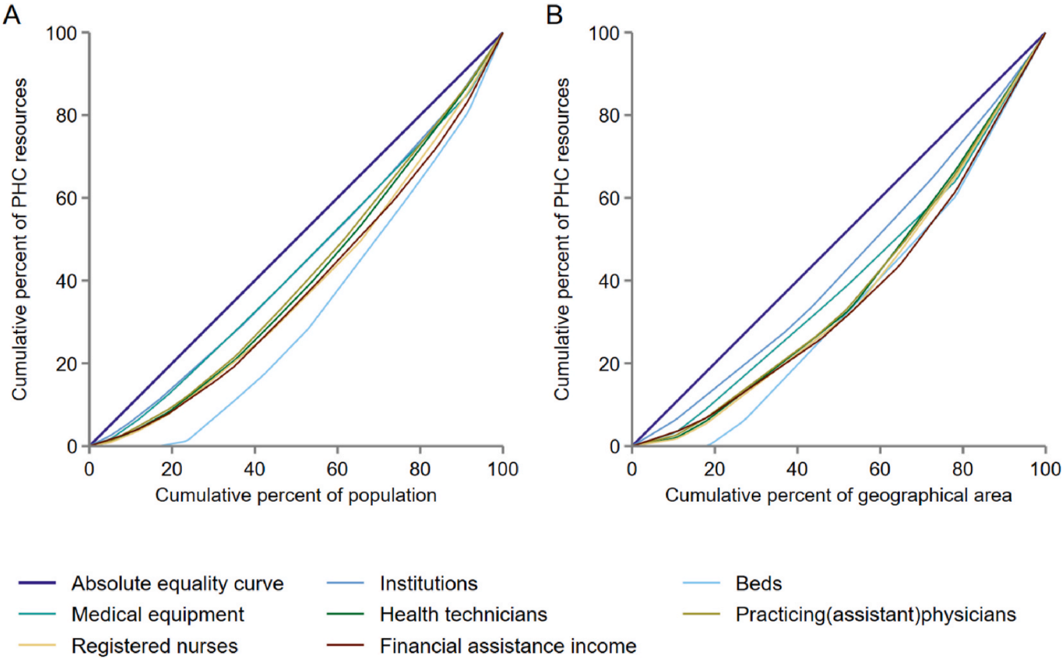

Fig. 2. Lorenz curve of PHC resource distribution in 2020. A and B show the Lorentz curve, A Lorenz curve by population, B Lorenz curve by geographic area.

The Gini coefficients for the distribution of PHC resources by geographical area in Guangzhou between 2012 and 2020 ranged from 0.1228 to 0.3481(see Table 4). All indicators of health resource allocation were below the critical threshold (G = 0.4) of the Gini coefficients, thereby indicating an optimal or normal state of health resource allocation. Between 2012 and 2020, the Gini coefficients for institutions and medical equipment exhibited a decline, indicating an improvement in the equality of health resource allocation. Conversely, the Gini coefficients for beds, health technicians, practicing (assistant) physicians, registered nurses, and financial assistance income demonstrated a gradual increase, reflecting a growing disparity in the allocation of these resources. Furthermore, the Gini coefficients provide additional evidence that the equality of health resource distribution by population (see Fig. 2 panel A and Fig. 3 panel A) generally surpasses the distribution by geographical area (see Fig. 2 panel B and Fig. 3 panel B).

3.2.2. Two-stage nested Theil inequality decomposition

To gain deeper insights into the overall inequality in health resource allocation in Guangzhou and its components, this study employed the Guangzhou grouping decomposition framework and a two-stage nested Theil decomposition method for analysis. The overall inequality in health resource allocation was categorized into between-region, between-district, and within-district disparities.

3.2.2.1. Two-stage nested Theil index and its decomposition from 2012 to 2020. Fig. 4 illustrates the results of the two-stage nested decomposition analysis conducted for Guangzhou between 2012 and 2020. The total Theil index exhibited relatively minor changes for institutions (see Fig. 4 panel A). However, the Theil indices for medical equipment, health technicians, practicing (assistant) physicians, and registered nurses displayed a declining trend, indicating an increasing equality in the allocation of these resources across the city (see Fig. 4 panel C–F). Conversely, the Theil index for financial assistance income showed an increasing trend,

Table 3
Gini coefficient of PHC resource allocation based on population from 2012 to 2020.

Year	Institutions	Beds	Medical equipment	Health technicians	Practicing (assistant) physicians	Registered nurses	Financial assistance income
2012	0.1317	0.3840	0.2954	0.1353	0.1235	0.1626	0.1581
2013	0.1431	0.3580	0.2737	0.1523	0.1563	0.1818	0.1301
2014	0.1371	0.3560	0.2470	0.1512	0.1598	0.1719	0.1149
2015	0.1353	0.3385	0.2304	0.1470	0.1596	0.1652	0.1329
2016	0.1268	0.3304	0.2200	0.1698	0.1695	0.1997	0.1738
2017	0.1245	0.3686	0.2099	0.1751	0.1716	0.2039	0.2022
2018	0.1189	0.4114	0.2512	0.1968	0.1877	0.2308	0.2674
2019	0.1190	0.4211	0.1654	0.1924	0.1807	0.2259	0.2056
2020	0.1182	0.3460	0.1267	0.1966	0.1795	0.2277	0.2341

Table 4
Gini coefficient of PHC resource allocation based on geographical area from 2012 to 2020.

Year	Institutions	Beds	Medical equipment	Health technicians	Practicing (assistant) physicians	Registered nurses	Financial assistance income
2012	0.1429	0.3056	0.2690	0.1723	0.1663	0.1930	0.1362
2013	0.1228	0.2951	0.2576	0.1637	0.1648	0.1790	0.1245
2014	0.1287	0.2990	0.2531	0.1657	0.1566	0.1760	0.1578
2015	0.1282	0.2822	0.2707	0.1661	0.1636	0.1753	0.1763
2016	0.1289	0.2742	0.2586	0.1941	0.1901	0.2150	0.2075
2017	0.1235	0.2906	0.2538	0.2013	0.1940	0.2159	0.2184
2018	0.1274	0.3481	0.3021	0.2438	0.2439	0.2605	0.3374
2019	0.1274	0.3184	0.1864	0.2372	0.2341	0.2562	0.2445
2020	0.1294	0.3078	0.1982	0.2402	0.2386	0.2578	0.2724

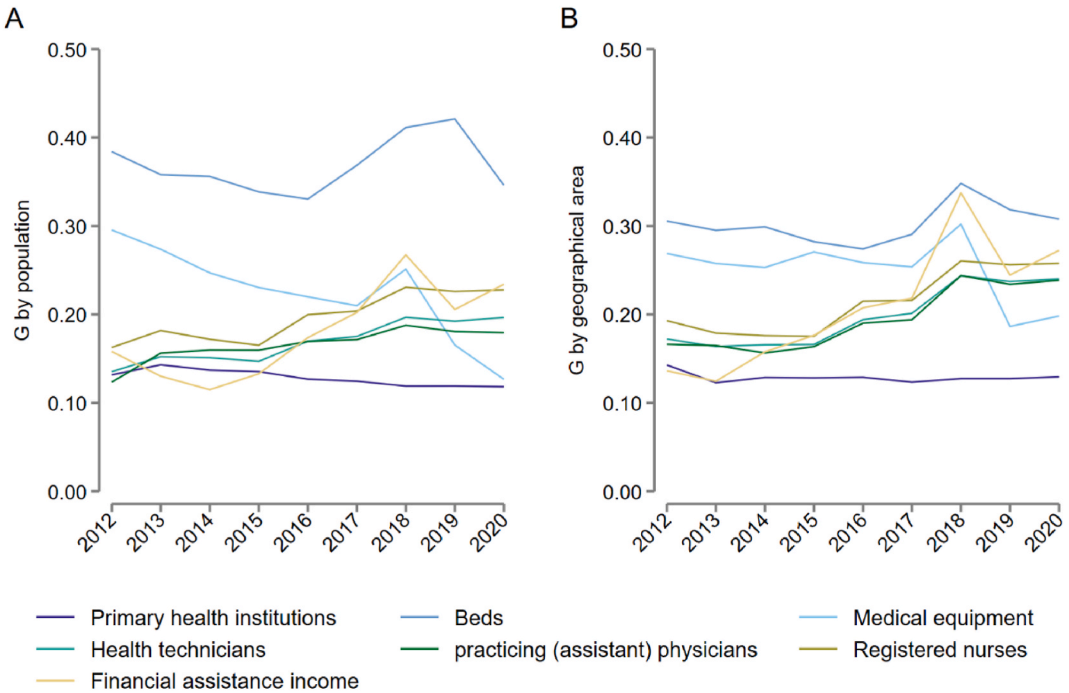

Fig. 3. Gini index of PHC resource distribution in Guangzhou from 2012 to 2020. A and B represent changes in the Gini index, A Gini index distributed by population, B Gini index distributed by geographic area.

suggesting a growing disparity in its allocation within the city (see Fig. 4 panel G). The total Theil index for beds was consistently negative, except in 2012, and its absolute value demonstrated a trend of increasing volatility (see Fig. 4 panel B). This indicates that the inequality in bed allocation across the city has worsened. The negative value of the total Theil index for beds can be attributed to the presence of a positive value in the between-region Theil index, which contributes to reducing the overall inequality in bed allocation. As the Between-region Theil index gradually decreased, the total Theil index became increasingly negative, with an enlarged absolute value.

From 2012 to 2020, the contribution rate of within-district inequality to the total Theil index displayed a fluctuating downward trend for the income of institutions, health technicians, practicing (assistant) physicians, registered nurses, and government financial assistance (see Fig. 4 panel H and J-G). Although the contribution rate of within-district inequality for medical equipment displayed an expanding trend, it accounted for more than 46 % of the overall inequality and emerged as the largest contributor among the three components. This indicates that within-district inequality was the primary driver of the unequal allocation of these health resources. The contribution rates of within-district inequality and between-district inequality to the number of beds were negative in 2012 and positive in 2013–2020 (see Fig. 4 panel I). This suggests that both within-district and between-district inequalities played a role in reducing the overall inequality in bed distribution in 2012. The contribution rate of between-region inequality was positive in 2012 and negative in 2013–2020, indicating that between-region inequality contributed to reducing the overall inequality in bed distribution from 2013 to 2020. From 2012 to 2014, the contribution rate of between-region inequality in the allocation of beds was the largest. During this period, between-region inequality was the main driver of overall inequality. Starting in 2015, the contribution rate

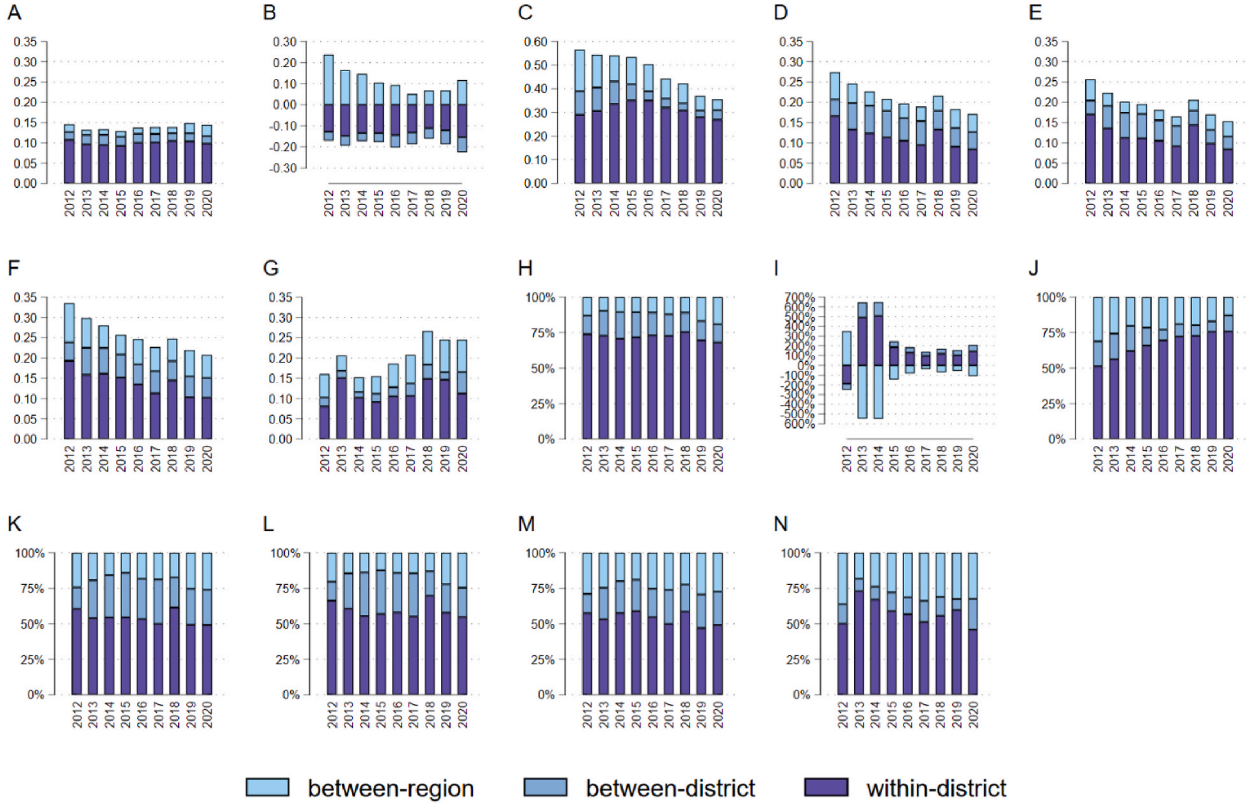

Fig. 4. Two-stage nested inequality decomposition for PHC resource allocation in Guangzhou from 2012 to 2020. A-G Decomposition of the Theil index, A institutions, B beds, C medical equipment, D health technicians, E practicing (assistant) physicians, F registered nurses, G financial assistance income. H-N Indicate the contribution rate of the internal components to the overall inequality based on Theil index decomposition, H institutions, I beds, J medical equipment, K health technicians, L practicing (assistant) physicians, M registered nurses, N financial assistance income.

of within-district inequality became the largest among the three components, suggesting that within-district inequality became the primary reason for the unequal allocation of beds.

3.2.2.2. Two-stage nested Theil index and its decomposition in 2020. The total Theil index, as shown in Table A1 in Appendix, revealed that the allocation of medical equipment exhibited the highest level of inequality, with a Theil index of 0.3552. This indicates that the equality of medical equipment allocation was the poorest throughout the city. Conversely, the total Theil index for beds was the lowest (closer to 0), at −0.1082, indicating that the allocation of beds exhibited the highest level of equality. Further decomposition demonstrated that the Theil indices for HZ, LW, TH, YX, BY, and HP were negative, indicating that these areas had a higher proportion of beds compared to their corresponding population, resulting in a relatively rich allocation of beds. On the other hand, the Theil indices for CH, HD, and ZC were positive, indicating that these districts had a lower proportion of beds compared to their corresponding population, resulting in a shortage of bed allocation. The Theil indices for PY and NS were 0 since the number of beds in PY and NS was 0.

Both the between-region Theil index and between-district Theil index exhibited the highest values for beds, indicating inequalities in bed allocation between regions and districts. This suggests that the substantial inequality in bed allocation between Region C and other regions may be attributed to government policy preferences and increased investments in beds in HD, ZC, and CH. Additionally, due to government policy guidance, the cancellation of beds in township health centers and community health centers in PY and NS in 2020 expanded the inequality in bed allocation between districts.

Regarding within-district inequalities, the Theil index for medical equipment was the largest. TH demonstrated the highest level of within-district inequality in medical equipment allocation, with a Theil index of 0.5095, followed by NS and HP. Fig. 5 panel A–G display the within-district inequalities in various health resources in 2020.

In terms of contribution rates, NS had the highest contribution rate to the overall inequality in Guangzhou's institutional allocation, at 11.92 %, while LW had the lowest contribution rate, at 1.77 %. In the allocation of beds, HZ contributed the most to the overall inequality in Guangzhou, with a contribution rate of 32.57 %, whereas HD had the lowest contribution rate, at −14.93 % (see Fig. 5 panel B). Furthermore, the contribution rates of CH, HD, and ZC were all negative, indicating that the allocation of beds in these three districts could help reduce the inequality in bed allocation in Guangzhou. Concerning medical equipment allocation, TH accounted for

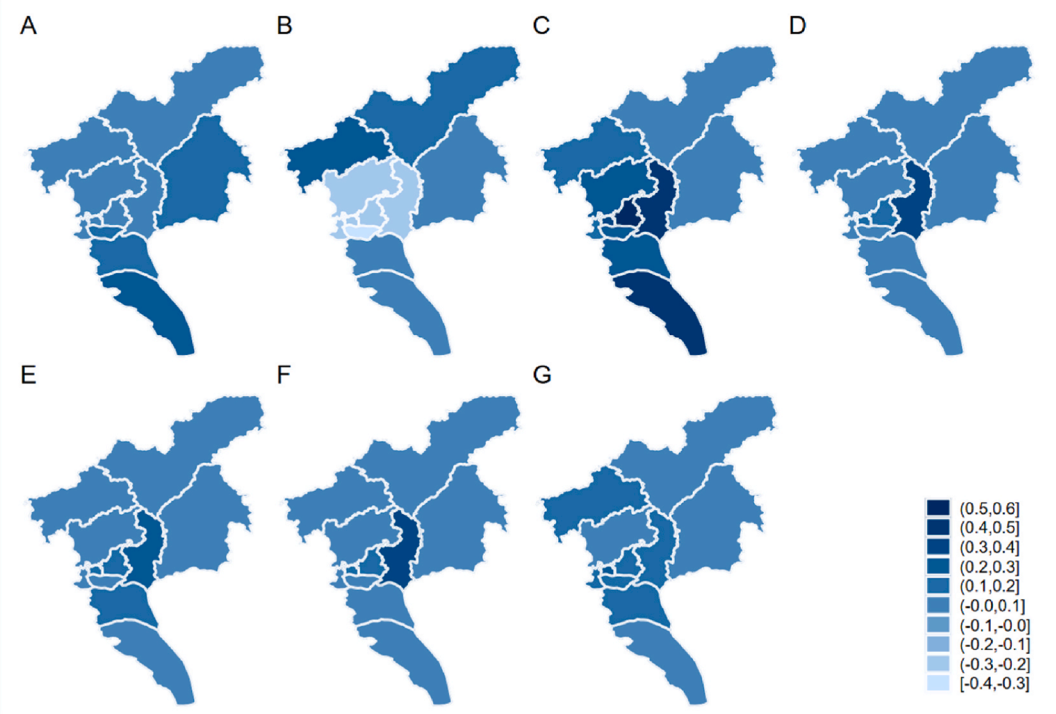

Fig. 5. Measurement of the Equality of the Distribution of Health Resources in Guangzhou in 2020 Based on the Theil index. A-G show the different health resources in each district of the Theil index. A institutions, B beds, C medical equipment, D health technicians, E practicing (assistant) physicians, F registered nurses, G financial assistance income.

the largest contribution to the overall inequality in Guangzhou, with a rate of 16.43 %, while CH contributed the least, at 0.87 % (see Fig. 5 panel C). In the allocation of health technicians, practicing (assistant) physicians, and registered nurses, HP made the most substantial contribution to the overall inequality in Guangzhou, accounting for 15.63 %, 13.74 %, and 13.64 %, respectively (see Fig. 5 panel D–F). CH had the lowest contributions, accounting for 0.25 %, 0.44 %, and 0.20 %, respectively. In terms of financial assistance income allocation, YX had the highest contribution rate to the overall inequality in Guangzhou, at 8.11 %, while CH had the lowest contribution rate, at 0.41 %.

3.2.3. Concentration index analysis

Furthermore, the article examines the change range of the CI value in the allocation of PHC resources in Guangzhou from 2012 to 2020 at the level of streets or towns. The CI values for PHC institutions are within the range of −0.0218 to −0.0334, the CI of the value of beds is within the range of −0.1211 to −0.2373, and the CI of the value of medical equipment is within the range of −0.0902 to −0.1538. The CI of the value of health technicians ranged from −0.0823 to −0.1309. The CI of value of practicing (assistant) physicians ranged from −0.048 to −0.1038. The CI of the value of registered nurses ranged from −0.1081 to −0.1868. The CI of the value

Table 5
Concentration index of PHC resources allocation in Guangzhou, 2012–2020.

Year	Institutions	Beds	Medical equipment	Health technicians	Practicing (assistant) physicians	Registered nurses	Financial assistance income
2010	−0.0248	−0.1540	−0.1328	−0.1040	−0.0832	−0.1206	−0.1344
2011	−0.0209	−0.1464	−0.0997	−0.0967	−0.0730	−0.1160	−0.0567
2012	−0.0218	−0.1598	−0.0902	−0.0918	−0.0695	−0.1081	−0.1419
2013	−0.0281	−0.1786	−0.1323	−0.0895	−0.0571	−0.1137	−0.1456
2014	−0.0284	−0.1514	−0.1197	−0.0823	−0.0480	−0.1134	−0.1177
2015	−0.0334	−0.1649	−0.1449	−0.0954	−0.0606	−0.1374	−0.1467
2016	−0.0314	−0.1631	−0.1509	−0.1168	−0.0844	−0.1756	−0.1811
2017	−0.0320	−0.1995	−0.1239	−0.1224	−0.0892	−0.1793	−0.1971
2018	−0.0306	−0.2373	−0.1538	−0.1309	−0.1038	−0.1868	−0.1742
2019	−0.0222	−0.2200	−0.1233	−0.1149	−0.0928	−0.1621	−0.1473
2020	−0.0248	−0.1211	−0.1066	−0.1093	−0.0851	−0.1590	−0.1333

of financial assistance income ranges from −0.0567 to −0.1971. These findings indicate a concentration of health resources toward the economically disadvantaged population (see Table 5).

3.2.4. Concentration index decomposing influencing factors of unequal allocation of health resources

To explore the factors contributing to the unequal allocation of health resources, this study conducted a literature review and demand analysis to identify key factors related to primary health care (PHC) resource allocation in Guangzhou. These factors were categorized into three dimensions: health service demand, population indicators, and institution type (refer to Table 1). The variance inflation factor (VIF) discrimination method was employed to assess the potential multicollinearity among the influencing factors, revealing VIF values ranging from 1.06 to 2.45, all below the threshold of 10, indicating no significant multicollinearity [41]. Therefore, all variables in the model were retained (see Table A1 in Appendix). Subsequently, a linear regression equation was constructed based on theoretical analysis, and the regression results are presented in Table 6.

Fig. 6 shows that (see also Table A3-A4 in Appendix) the number of hospitalizations per capita, the number of people served (x_7) and the proportion of children aged 0–3 years old (x_8) can increase the inequality in the allocation of health resources. Among them, the number of people served (x_7) contributes the most, accounting for 111.85 %, which is the main factor affecting the inequality in the allocation of institutions. The number of referrals per capita to superior hospitals (−16.63 %) and the number of outpatients per capita (−14.32 %) were the main factors for reducing the inequality in the allocation of institutions.

The number of referrals to superior hospitals per capita (47.40 %), the number of hospitalizations per capita (41.41 %) and the number of people served (72.51 %) were the main factors that affected the increase in unequal allocation of beds. The per capita number of outpatients (−102.82 %) and the number of TCM services per capita (−23.03 %) were the main factors for reducing the inequality in the allocation of beds.

people served (77.05 %) and township health centers (81.42 %) were the main factors increasing inequality in the allocation of medical equipment, while the number of outpatients per capita (−29.66 %) and the proportion of aging (−28.83 %) were the main factors of inequality.

The factors affecting the inequality of health resource allocation of the three types of human resources are similar. Among them, the number of people served (x_7) and the township health centers are the main factors for increasing the inequality of health technicians' allocation, practicing (assistant) physicians and registered nurses, and the number of outpatients per capita (x_1) is the main factor for reducing the inequality.

The number of outpatients per capita (45.45 %), the proportion of children aged 0–3 years old (33.26 %), the number of people served (x_7) (121.15 %) and township health centers (67.84 %) can increase inequality in the allocation of practicing (assistant) physicians, while the number of TCM services per capita (−39.21 %) and the proportion of the population aged 65 and over (−33.55 %) can reduce inequality.

Table 6
Regression coefficient of factors influencing PHC resource allocation for 2020.

Variables(a)	Institutions	Beds	Medical equipment	Health technicians	Practicing (assistant) physicians	Registered nurses	Financial assistance income
x_1	0.0155	0.1077***	0.1005	0.1778***	0.0659***	0.0693***	0.1790
x_2	0.0931	0.1244*	0.0251	0.0692	0.0159	0.0309	0.9943**
x_3	0.0150	0.1030	0.8724*	0.2400	0.1444	0.1120	1.3427
x_4	1.2527	3.3164***	1.8490	1.7361	0.3384	1.0679	7.3725
x_5	0.0780	0.2251	0.3378	0.1333	0.0838	0.0039	2.2046***
x_6	5.2893	24.1611***	5.7933	24.2609***	8.0848***	12.0575***	75.5354***
x_7	0.3908***	0.2720***	1.1369***	1.1245***	0.4334***	0.4585***	3.3989***
x_8	5.0811**	1.3187	17.1780***	6.0911**	2.0469*	2.9346**	43.9441***
x_9	0.2857	1.2720	5.1495**	1.6415	0.5958	0.5783	14.5332**
x_{10}	0.0479	0.1150	0.9503***	0.4033***	0.1284**	0.1691***	1.0828**
_cons	0.4848	0.2748	0.3039	0.4054	0.1400	0.1905	2.0367
P value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R-squared	0.2683	0.6386	0.4816	0.7316	0.6911	0.7381	0.6569
Adjusted R-squared	0.2208	0.6151	0.4480	0.7142	0.6710	0.7211	0.6346
S.E. of regression	0.3796	0.2714	0.7885	0.4495	0.1825	0.1914	1.7927

Note: 1. * defined by a P value < 0.1,** defined by a P value < 0.05,*** defined by a P value < 0.01. 2. (a) Indicates factors affecting the distribution of PHC resources, where x_1 Number of Outpatients Per Capita, x_2 Number of emergency room visits per capita, x_3 Number of family health services per capita, x_4 Number of referrals to superior hospitals per capita, x_5 Number of Traditional Chinese Medicine (TCM)services per capita, x_6 Number of hospitalizations per capita, x_7 people served (resident), x_8 Proportion of children aged 0–3 years old, x_9 Proportion of aging (Proportion of population over 65 years of age), x_{10} Institution Type.

Table 7
Definitions of health resource indicators.

Primary Indicators	Secondary indicators	Interpretation of indicators
Material resources	Number of institutions	In this study, the number of community health centers and township health centers were selected for primary care.
	Number of beds	Inpatient beds actually opened at the end of the year are fixed for medical institutions.
	Number of medical equipment	Number of equipment units over $10,000 owned by the medical organization.
Human resources	Health technicians	All permanent and contractual employees of health institutions who are paid salaries and whose current position is a professional in health technology work.
	Practicing (assistant) physicians	Number of people who have obtained a license to practice (assistant) medicine and work in the field of medical prevention and health care. Those working in management are not included.
	Registered nurses	Number of persons who have obtained a license to practice as nurses and are working in the field of medical prevention and health care.
Financial resources	Financial assistance income	Income received by primary health care organizations from the financial sector in the form of capital subsidies, subsidies for equipment purchases, subsidies for personnel expenses, and subsidies for public health services.

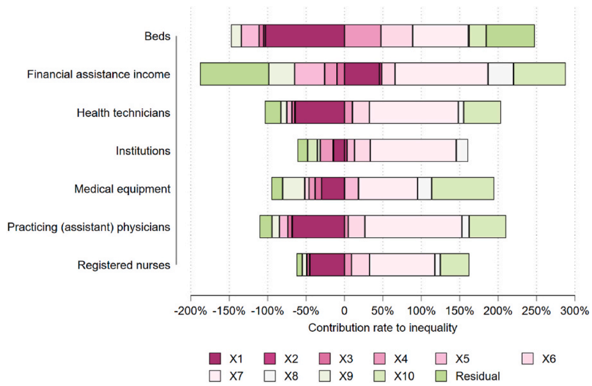

Fig. 6. The contribution of influencing factors to the inequality of PHC resource allocation in Guangzhou in 2020.
Note: x_1 Number of Outpatients Per Capita, x_2 Number of emergency room visits per capita, x_3 Number of family health services per capita, x_4 Number of referrals to superior hospitals per capita, x_5 Number of Traditional Chinese Medicine (TCM) services per capita, x_6 Number of hospitalizations per capita, x_7 people served (resident), x_8 Proportion of children aged 0–3 years old, x_9 Proportion of aging (Proportion of population over 65 years of age), x_{10} Institution Type.

4. Discussion

Throughout the period from 2012 to 2020, all PHC resources in Guangzhou exhibited steady growth, with the exception of beds. The number of beds experienced a decline, decreasing from 4484 in 2012 to 4332 in 2020—a reduction of 4 %. This decline in bed numbers can be attributed primarily to the shift of focus among PHC institutions toward “six in one” general practice services, leading to a decrease in inpatient services. Some community health centers even decided to cancel their inpatient beds. Additionally, shortages of certain medicines and skilled health technicians in PHC institutions resulted in patients seeking care at secondary and tertiary hospitals, leading to underutilization of PHC institutions’ beds [42].

In 2020, the Gini coefficients for health resource distribution by population and geographic area were both below 0.4, indicating a relatively equitable allocation among administrative districts. Notably, equity based on population distribution was superior to that based on geographic area. Similar trends observed in other provinces and cities across China [43–45].These results are significantly influenced by national health policy documents and statistical guidelines [46]. For instance, the “13th Five-Year Plan” issued by the State Council emphasizes population-based health resource distribution [47]. This study suggests that population-based allocation ensures equitable healthcare access for residents. The lower equity in geographic area-based distribution can be attributed to the considerable differences in the sizes of districts in Guangzhou, such as YX District (33.8 square kilometers) and CH District (1974.5 square kilometers), and the sparsely populated districts of ZC, CH, and HD, where providing significant resources is less effective. Secondly, the Gini coefficient for most indicators peaked in 2018 due to government policies. The “Quality Service for Primary Healthcare” initiative and Guangzhou’s “Medical and Health Strong Foundation and Excellence Action Plan” aimed to improve PHC capabilities and address deficiencies in northern mountainous areas [46]. By 2018, the compliance rate for standardized PHC construction exceeded 95 % [47]. The 2019 ″Guangzhou Medical and Health Facility Layout Plan” called for balanced resource distribution and adjustments based on spatial distribution and functional needs [48]. These policies caused a significant increase in health resource inequality in 2018, which eased in 2019, leading to the Gini coefficient peak in 2018.

From 2012 to 2020, the absolute value of the total Theil index for institutions, health technicians, practicing (assistant) physicians, and registered nurses decreased, indicating improved equity in the allocation of these health resources. However, during the same period, the absolute value of the total Theil index for beds and financial assistance income increased, reflecting reduced equity in their distribution. Decomposition analysis shows that, apart from beds, other health resources contributed approximately 46 % to overall inequality from 2012 to 2020, making them the largest contributors among the three decomposition components. Therefore, within-district inequality is the primary reason for the overall inequality in the allocation of other health resources. Additionally, from 2015 to 2020, within-district inequality became the main contributor to the inequality in bed allocation, emphasizing its critical role. Several factors contribute to more pronounced within-district inequality: first, the planning unit is too large. Resource allocation and planning are currently based on districts, which cannot be broken down to the level of streets and townships. This causes resources to be concentrated in central areas or major service points within the district, resulting in significant differences in resource allocation between different streets and townships, which are not addressed by district-level planning. Second, resource and environmental constraints play a role. Some streets and townships face financial limitations and lack sufficient vacant land or suitable buildings, hindering the expansion of health facilities. Effective resource allocation is also influenced by resident support and participation. Opposition by residents to the construction of healthcare facilities near their homes can impede project implementation and affect funding and resource allocation. To address these major factors contributing to within-district inequality, several measures can be taken. Firstly, health resource planning should be refined to smaller units to accurately identify and address inequalities within districts. Secondly, financial support and policy incentives should be provided to financially constrained streets and townships. Additionally, flexible construction and renovation programs should be designed to optimize limited resources, considering the actual availability of land and buildings. Lastly, encouraging resident participation in the planning and decision-making process for health resources can increase community support for new facilities and ensure a social basis for equitable resource allocation.

From 2010 to 2020, the Concentration indexes for various PHC resources across different streets and towns in Guangzhou were negative. In 2020, nearly all Concentration indexes were less than −0.1, indicating an inequitable distribution of healthcare resources, concentrated in lower economic areas. Studies have shown that due to disparities in access to quality healthcare, income levels, and health expenditures, residents with lower economic status are more likely to use PHC services, leading to a concentration of these resources in disadvantaged areas [44]. This suggests that Guangzhou focuses on allocating PHC resources to low-income groups. This contrasts with Liaoning Province, where, except for bed numbers, PHC resources are concentrated in wealthier areas [49]. But it is consistent with the nation as a whole [50].

The number of people served was identified as the most significant factor contributing to the inequality in health resource allocation, with a contribution rate exceeding 72 % for all types of health resources and a staggering 126.37 % for practicing (assistant) physicians. The disparity in the distribution of people served had a substantial impact on increasing the inequality in the allocation of health resources across all types. Regression analysis supported a positive correlation between the number of people served and health resources, consistent with previous studies [5]. Moreover, the number of people served (x_7) was more concentrated in lower-income areas. As the discrepancy in the allocation of people served across different economic levels widened, it continuously exacerbated the inequality in health resource allocation. This underscores Guangzhou's commitment to a people-oriented approach in allocating PHC resources. While population serves as the primary basis for resource allocation, health [50]departments should also consider the guidance of "health needs" and comprehensively evaluate various factors during regional health planning. Furthermore, the type of institution emerged as a key factor influencing the increase in inequality in health resource allocation. Apart from addressing the inequality in bed allocation, differences in the allocation of other health resources among various institution types could further contribute to inequality. In particular, the type of institution had the greatest impact on inequality in medical equipment allocation, accounting for 81.42 % of the contribution rate. The number of referrals per capita and the number of hospitalizations per capita (x_6) played a significant role in the inequality of bed allocation, with a contribution rate of 47.40 %. This highlights the influence of inequality on bed allocation. Additionally, the per capita hospitalization rate and the proportion of children aged 0–3 years also had an impact on the increase in inequality in health resource allocation, albeit with a relatively smaller contribution rate.

The number of outpatients per capita (x_1) contributed 45.45 % to the inequality in the allocation of financial assistance income. However, it also had a negative impact on inequality in the allocation of material and human resources, leading to a greater reduction in overall inequality. In particular, it exhibited a −102.82 % contribution to the inequality in bed allocation. The CI for the number of

Table 8
List of abbreviations.

Abbreviations	Definitions
PHC	Primary health-care
CI	Concentration index
TH	Tianhe District
YX	Yuexiu District
LW	Liwan District
HZ	Haizhu District
BY	Baiyun District
HP	Huangpu District
PY	Panyu District
NS	Nansha District
HD	Huadu District
ZC	Zengcheng District
CH	Conghua District

outpatients per capita (x_1) was positive, indicating that individuals with higher economic status displayed greater health-care consciousness and proactively sought PHC institutions for services. Consequently, the group with higher economic status had a higher number of outpatient visits per capita. Additionally, an increase in the number of outpatients per capita (x_1) influenced the allocation of material and human resources. As the inequality in the inequality of the number of outpatients per capita (x_1) leaned toward higher-income groups, it affected the reduction of inequality in the allocation of material and human resources to lower-income groups. Furthermore, the proportion of aging (x_9) and the number of family health services per capita (x_3) contributed negatively to inequality in health resource allocation, thereby reducing overall inequality. Furthermore, the number of TCM services per capita (x_5) impacted bed allocation and contributed to reducing inequality in the allocation of financial assistance income. These findings highlight that the rational allocation of medical resources in Guangzhou is guided by residents' health service needs, yielding positive outcomes in health resource allocation.

5. Conclusions

Firstly, the total amount of primary healthcare resources in Guangzhou from 2012 to 2020 will rise steadily in all types of healthcare resources except for the number of beds, but the number of beds and the number of financial resources allocated have not yet met the requirements. There are obvious differences in the allocation of primary healthcare resources between administrative districts in Guangzhou, especially between ZC District and other districts. Secondly, primary healthcare resources in Guangzhou are more equitably allocated across administrative districts, and the equity of health resources allocated by population is better than that allocated by geographical area. Third, the number of beds, medical equipment, health technicians, registered nurses and government financial subsidies in 2020 were allocated unfairly and benefited low-income groups in each street/township. Fourth, there are large differences in the distribution of health resources within-districts in Guangzhou, and within-district differences are the main source of overall inequity in the allocation of other health resources. Fifth, the number of people served (residents) at the end of the year, institution type (township health centers), the number of hospitalizations per capita and the number of children aged 0–3 years as a percentage of the total population are the main influencing factors that increase the inequitable allocation of resources to primary health care institutions in Guangzhou.

In order to promote a more equitable allocation of PHC resources, this study has the following policy recommendations. Firstly, increase investment in health resources, especially in terms of human resources for health and financial resources for health. Introduce high-quality professionals, especially in the area of general practitioners. Adopt targeted training to send talents to areas where human resources for health are in short supply. For existing health workers, relevant vocational training, further training and other re-continuing education opportunities are constantly provided. Second, scientific indicators should be used to make superior regional health planning. When formulating health regional planning and allocating medical resources, both demographic accessibility factors and geographic accessibility factors should be considered. Health resource planning should be refined to smaller units in order to more accurately identify and address resource inequalities within regions. In addition, it is important to pay attention to population distribution and its future mobility trends, as well as to consider local economic conditions, service radius, transport conditions and the diverse health service needs of residents of different age structures, so as to improve the efficiency of resource utilization while taking into account the accessibility and equity of health resources.

6. Limitations

First, due to data availability constraints, this study only included community health service centers and town health centers in Guangzhou. Consequently, the analysis lacks a comprehensive examination of the allocation and equity of all primary health care institutions in the city, leading to research limitations. Second, the difficulty in accessing policies related to primary health care resource allocation in Guangzhou limited the thoroughness of the analysis regarding the current situation of health resource allocation.

Glossary

Table 7 provides definitions of health resource terms used in the article.

List of abbreviations

Table 8 shows the definitions of all the abbreviations used in this manuscript.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Ethics declarations

Ethics and Consent Statement: review and/or approval by an ethics committee was not needed for this study because without human or animal participation in this study.

Data availability

Data associated with study don't deposit into a publicly available repository, Because the authors do not have permission to share data.

CRediT authorship contribution statement

Meiling Chen: Writing – review & editing, Writing – original draft, Supervision, Software, Project administration, Methodology, Formal analysis. **Xiongfei Chen:** Writing – review & editing, Resources, Methodology, Formal analysis, Data curation. **Ying Tan:** Supervision, Project administration, Methodology. **Min Cao:** Supervision, Resources, Methodology. **Zedi Zhao:** Supervision, Methodology. **Wanshan Zheng:** Software, Methodology, Conceptualization. **Xiaomei Dong:** Supervision, Project administration, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

Table A1
Test results of the multicollinearity of influencing factors

Variables	VIF	1/VIF
x_1	2.45	0.41
x_2	1.62	0.62
x_3	1.06	0.95
x_4	1.86	0.54
x_5	1.36	0.74
x_6	2.12	0.47
x_7	1.29	0.77
x_8	1.35	0.74
x_9	1.72	0.58
x_{10}	2.28	0.44
Mean VIF	1.71	

Note: x_1 Number of Outpatients Per Capita, x_2 Number of emergency room visits per capita, x_3 Number of family health.
Services per capita, x_4 Number of referrals to superior hospitals per capita, x_5 Number of Traditional Chinese Medicine (TCM).
Services per capita, x_6 Number of hospitalizations per capita, x_7 people served (resident), x_8 Proportion of children aged 0–3 years.
Old, x_9 Proportion of aging (Proportion of population over 65 years of age), x_{10} Institution Type.

Table A2
Two-stage nested Theil decomposition in 2020

Regions districts (a)	institutions		Beds		Medical equipment		Health technicians		Practicing (assistant) physicians		Registered nurses		Financial assistance income	
	Theil L	Contrib to total(b)	Theil L	Contrib to total(b)	Theil L	Contrib to total(b)	Theil L	Contrib to total(b)	Theil L	Contrib to total(b)	Theil L	Contrib to total(b)	Theil L	Contrib to total(b)
Region A (4)	0.0988	25.22 %	−0.1408	48.01 %	0.3280	34.07 %	0.0916	19.77 %	0.0934	22.40 %	0.1067	18.94 %	0.2385	35.94 %
HZ	0.1096	8.11 %	−0.3299	32.57 %	0.2113	6.36 %	0.0606	3.78 %	0.0553	3.84 %	0.0765	3.94 %	0.1323	5.77 %
LW	0.0384	1.77 %	−0.2727	16.78 %	0.1684	3.16 %	0.0214	0.83 %	0.0290	1.25 %	0.0254	0.81 %	0.1835	4.99 %
TH	0.0986	7.82 %	−0.2947	31.20 %	0.5095	16.43 %	0.1024	6.86 %	0.1099	8.19 %	0.1209	6.67 %	0.1252	5.86 %
YX	0.0602	3.37 %	−0.2921	21.85 %	0.3136	7.14 %	0.1137	5.38 %	0.1173	6.17 %	0.1428	5.57 %	0.2453	8.11 %
Region B (3)	0.1206	31.44 %	−0.4101	142.70 %	0.3149	33.38 %	0.1198	26.39 %	0.1232	30.16 %	0.1341	24.30 %	0.1038	15.96 %
BY	0.0656	8.43 %	−0.2548	43.72 %	0.2308	12.07 %	0.0568	6.17 %	0.0630	7.61 %	0.0925	8.27 %	0.0669	5.07 %
PY	0.1466	11.92 %	0	0	0.2421	8.00 %	0.0644	4.43 %	0.1132	8.65 %	0.0410	2.32 %	0.1035	4.96 %
HP	0.0917	4.66 %	−0.2461	16.69 %	0.4387	9.06 %	0.3644	15.63 %	0.2879	13.74 %	0.3862	13.64 %	0.1236	3.70 %
Region C (4)	0.1378	24.28 %	−0.0742	17.45 %	0.2750	19.70 %	0.1874	27.89 %	0.1379	22.82 %	0.2395	29.35 %	0.1505	15.64 %
CH	0.0788	2.42 %	0.1057	−4.34 %	0.0699	0.87 %	0.0098	0.25 %	0.0154	0.44 %	0.0093	0.20 %	0.0225	0.41 %
HD	0.0696	3.61 %	0.2154	−14.93 %	0.1713	3.62 %	0.0818	3.59 %	0.0686	3.35 %	0.0960	3.47 %	0.1538	4.71 %
NS	0.2420	8.64 %	0	0	0.4687	6.81 %	0.0276	0.83 %	0.0142	0.48 %	0.0901	2.24 %	0.0476	1.00 %
ZC	0.1266	7.31 %	0.0226	−1.74 %	0.0963	2.26 %	0.0309	1.51 %	0.0215	1.17 %	0.0522	2.10 %	0.0419	1.43 %
Within-district	0.0983	68.06 %	−0.1534	141.79 %	0.2692	75.79 %	0.0843	49.27 %	0.0844	54.89 %	0.1022	49.21 %	0.1127	46.01 %
Between-district	0.0186	12.88 %	−0.0718	66.37 %	0.0404	11.36 %	0.0424	24.78 %	0.0315	20.49 %	0.0486	23.38 %	0.0527	21.53 %
Between-region	0.0275	19.06 %	0.1171	−108.16 %	0.0456	12.85 %	0.0444	25.95 %	0.0379	24.62 %	0.0569	27.41 %	0.0795	32.46 %
Total	0.1445	100 %	−0.1082	100 %	0.3552	100 %	0.1710	100 %	0.1538	100 %	0.2077	100 %	0.2449	100 %

Note:1. (a) Number in parentheses is the number of districts. (b) Contribution to the overall inequality (in %). 2. Tianhe District (TH), Yuexiu District (YX), Liwan District (LW), Haizhu District (HZ), Baiyun.
District (BY), Huangpu District (HP), Panyu District (PY), Nansha District (NS), Huadu District (HD), Zengcheng District (ZC) and Conghua District (CH).

Table A3
CI decomposition of PHC resource allocation inequality, 2012–2020

Variables	CI	Institutions			Beds			Medical equipment		
		Elasticity	Absolute contribution	Contribution rate	Elasticity	Absolute contribution	Contribution rate	Elasticity	Absolute contribution	Contribution rate
x_1	0.1469	0.0241	0.0035	−14.32 %	0.8476	0.1245	−102.82 %	0.2152	0.0316	−29.66 %
x_2	−0.1086	0.0075	−0.0008	3.27 %	−0.0268	0.0029	−2.40 %	0.0031	−0.0003	0.31 %
x_3	0.1953	0.0007	0.0001	−0.56 %	0.0371	0.0072	−5.98 %	0.0468	0.0091	−8.58 %
x_4	0.2293	0.0180	0.0041	−16.63 %	−0.2504	−0.0574	47.40 %	0.0373	0.0086	−8.03 %
x_5	0.3756	−0.0065	−0.0024	9.87 %	0.0743	0.0279	−23.03 %	−0.0507	−0.0191	17.87 %
x_6	−0.2403	0.0211	−0.0051	20.45 %	0.2087	−0.0502	41.41 %	−0.0242	0.0058	−5.44 %
x_7	−0.0955	0.2900	−0.0277	111.85 %	0.9195	−0.0878	72.51 %	0.8602	−0.0822	77.05 %
x_8	−0.0271	0.1425	−0.0039	15.59 %	0.0429	−0.0012	0.96 %	0.7220	−0.0196	18.35 %
x_9	0.0496	0.0189	0.0009	−3.78 %	0.3304	0.0164	−13.53 %	0.6197	0.0307	−28.83 %
x_{10}	0.0814	0.0388	0.0032	−12.76 %	−0.3304	−0.0269	22.22 %	−1.0661	−0.0868	81.42 %
_cons			0.0032	−12.99 %		−0.0766	63.27 %		0.0154	−14.46 %

Note: x_1 Number of Outpatients Per Capita, x_2 Number of emergency room visits per capita, x_3 Number of family health services per capita, x_4 Number of referrals to superior hospitals per capita.
x_5 Number of Traditional Chinese Medicine (TCM) services per capita, x_6 Number of hospitalizations per capita, x_7 people served (resident), x_8 Proportion of children aged 0–3 years old, x_9 Proportion.
Of aging (Proportion of population over 65 years of age), x_{10} Institution Type.

Table A4
CI decomposition of PHC resource allocation inequality, 2012–2020 (Continued)

Variables	Health technicians			Practicing (assistant) physicians			Registered nurses			Financial assistance income		
	Elasticity	Absolute contribution	Contribution rate	Elasticity	Absolute contribution	Contribution rate	Elasticity	Absolute contribution	Contribution rate	Elasticity	Absolute contribution	Contribution rate
x_1	0.4781	0.0702	−64.29 %	0.3941	0.0579	−68.06 %	0.4872	0.0716	−45.01 %	0.4872	0.0716	−45.01 %
x_2	−0.0063	0.0007	−0.62 %	−0.0026	0.0003	−0.34 %	−0.0082	0.0009	−0.56 %	−0.0082	0.0009	−0.56 %
x_3	0.0197	0.0039	−3.53 %	0.0233	0.0045	−5.34 %	0.0259	0.0051	−3.19 %	0.0259	0.0051	−3.19 %
x_4	−0.0493	−0.0113	10.34 %	−0.0182	−0.0042	4.89 %	−0.0638	−0.0146	9.21 %	−0.0638	−0.0146	9.21 %
x_5	0.0191	0.0072	−6.58 %	0.0248	0.0093	−10.94 %	0.0017	0.0006	−0.41 %	0.0017	0.0006	−0.41 %
x_6	0.1004	−0.0241	22.09 %	0.0767	−0.0184	21.67 %	0.1557	−0.0374	23.53 %	0.1557	−0.0374	23.53 %

(continued on next page)

Table A4 (*continued*)

Variables	Health technicians			Practicing (assistant) physicians			Registered nurses			Financial assistance income		
	Elasticity	Absolute contribution	Contribution rate	Elasticity	Absolute contribution	Contribution rate	Elasticity	Absolute contribution	Contribution rate	Elasticity	Absolute contribution	Contribution rate
x_7	1.3247	−0.1265	115.79 %	1.1258	−0.1075	126.37 %	1.4147	−0.1351	84.98 %	1.4147	−0.1351	84.98 %
x_8	0.2809	−0.0076	6.97 %	0.2946	−0.0080	9.38 %	0.4098	−0.0111	6.98 %	0.4098	−0.0111	6.98 %
x_9	0.1717	0.0085	−7.79 %	0.1662	0.0082	−9.69 %	0.1822	0.0090	−5.68 %	0.1822	0.0090	−5.68 %
x_{10}	−0.6506	−0.0530	48.49 %	−0.5036	−0.0410	48.20 %	−0.7366	−0.0600	37.73 %	−0.7366	−0.0600	37.73 %
_cons		0.0228	−20.85 %		0.0137	−16.15 %		0.0120	−7.57 %		0.0120	−7.57 %

Note: x_1 Number of Outpatients Per Capita, x_2 Number of emergency room visits per capita, x_3 Number of family health services per capita, x_4 Number of referrals to superior hospitals per capita.

x_5 Number of Traditional Chinese Medicine (TCM) services per capita, x_6 Number of hospitalizations per capita, x_7 people served (resident), x_8 Proportion of children aged 0–3 years old, x_9 Proportion.

Of aging (Proportion of population over 65 years of age), x_{10} Institution Type.

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