BMJ Open

Inequalities in healthcare resources and outcomes threatening sustainable health development in Ethiopia: panel data analysis

Abraha Woldemichael,[1,2] Amirhossein Takian,[1,3,4] Ali Akbari Sari,[1] Alireza Olyaeemanesh[1,4,5]

ABSTRACT

Objective To measure inequalities in the distributions of selected healthcare resources and outcomes in Ethiopia from 2000 to 2015.

Design A panel data analysis was performed to measure inequalities in distribution of healthcare workforce, infrastructure, outcomes and finance, using secondary data.

Setting The study was conducted across 11 regions in Ethiopia.

Participants Regional population and selected healthcare workforce.

Outcomes measured Aggregate Theil and Gini indices, changes in inequalities and elasticity of healthcare resources.

Results Despite marked inequality reductions over a 16 year period, the Theil and Gini indices for the healthcare resources distributions remained high. Among the healthcare workforce distributions, the Gini index (GI) was lowest for nurses plus midwives (GI=0.428, 95% CI 0.393 to 0.463) and highest for specialist doctors (SPDs) (GI=0.704, 95% CI 0.652 to 0.756). Inter-region inequality was the highest for SPDs (95.0%) and the lowest for health officers (53.8%). The GIs for hospital beds, hospitals and health centres (HCs) were 0.592(95% CI 0.563 to 0.621), 0.460(95% CI 0.404 to 0.517) and 0.409(95% CI 0.380 to 0.439), respectively. The interaction term was highest for HC distributions (47.7%). Outpatient department visit per capita (GI=0.349, 95% CI 0.321 to 0.377) and fully immunised children (GI=0.307, 95% CI 0.269 to 0.345) showed inequalities; inequality in the under 5 years of age mortality rate increased overtime (P=0.048). Overall, GI for government health expenditure (GHE) was 0.596(95% CI 0.544 to 0.648), and the estimated relative GHE share of the healthcare workforce and infrastructure distributions were 46.5% and 53.5%, respectively. The marginal changes in the healthcare resources distributions were towards the advantaged populations.

Conclusion This study revealed high inequalities in healthcare resources in favour of the advantaged populations which can hinder equal access to healthcare and the achievements of healthcare outcomes. The government should strengthen monitoring mechanisms to address inequalities based on the national healthcare standards.

Strengths and limitations of this study

► This study attempted to provide a comprehensive picture of the extent of healthcare resources and outcomes inequalities in relation to government health expenditure (GHE) within an under resourced country.

► The application of different inequality measures and Gini inequality decomposition models helped characterise the inequalities in healthcare resources and outcomes in a decentralised health system.

► The estimated Shapley value of the total GHE share of the selected explanatory variables indicated the priority resources, while the multidimensional Gini inequality decomposition provided the relative inequalities, the marginal changes and the elasticity values of the distributions.

► The regional overall Gini values for the distributions analysed are biased downwards around 10%.

► The analysis emphasised only the supply perspective of the health system.

INTRODUCTION

The concept of health has both moral and right elements. The central objective of many health systems is to ensure health equity among populations. Health equity may be viewed as the absence of systematic differences in health among populations regardless of their social, economic, geographical, power and prestige status.[1–3] The guiding principle within this concept is health equality[4] that may be achieved by making healthcare accessible and by addressing any socially unacceptable inequalities within healthcare, which are amenable to policy decisions.[4–6] Thus the principle of health equality begins with creating equal opportunities for people to access needed healthcare resources,[2 7] irrespective of their personal characteristics and ability to pay.[8 9]

The distinction between inequity and inequality can be blurred[10 11] because both

concepts refer to unjust and socially unacceptable differences. The unfair inequities due to avoidable causes are specific forms of inequalities.[12] Nevertheless, the two concepts are not synonymous. Inequality is viewed as the quantitative description of avoidable unfair differences without value judgements that do not belong to the legitimate occurrences from individual responsibility.[13 14] In the human rights field, the concept is used in a much broader sense to describe differences among individuals, of which some could be unavoidable, at least with current knowledge and approaches.[15] Generally, the concept of inequality is dynamic, open to different interpretations and is highly linked to the socioeconomic structure of people.[16] Like inequity, any measure of inequality involves normative judgements.[17] We applied Braveman's definition of inequality which refers to "differences in the distribution of resources or outcomes among people due to conditions that can be minimised or modified by policies".[5]

The success of equality policies in healthcare is subject to the influences of the political context,[18] quality of information concerning the inequality[17 19–21] and the appropriateness of the actions targeting identified unjust inequalities. However, government policies may favour the poor, especially when the share of the private sector is minimal,[22] and the economic, political, moral or practical aspects may be used as criteria for the allocation of resources.[13] Despite the unclear link between decentralisation and inequality, decentralised policies have been common practice to ensure social justice and address inequalities.[23 24] The local governments in decentralised systems are likely to vary in power, boundaries, capacity, socioeconomic and demographic factors, living conditions and healthcare needs of their constituencies.[20 25 26] These conditions highlight the complexity and the likely occurrence of inequalities, and the coexistence of inequalities and judgements.

Ensuring fair allocation of human and material healthcare resources to people across regions contributes to better healthcare outcomes. Healthcare inequality is one of the conditions that hinders the success of healthcare systems and has been a concern to policymakers and planners. However, little evidence is available regarding

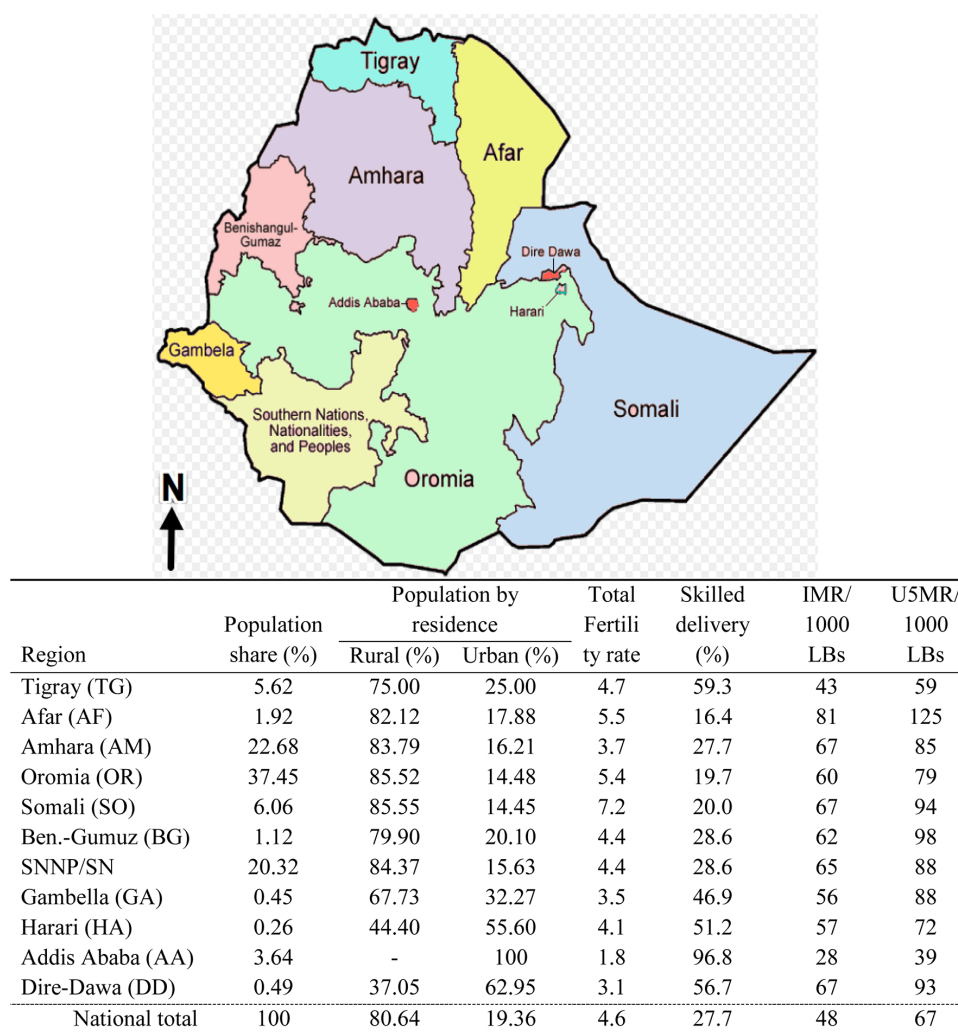| Region	Population share (%)	Population by residence		Total Fertility rate	Skilled delivery (%)	IMR/ 1000 LBs	U5MR/ 1000 LBs
		Rural (%)	Urban (%)				
Tigray (TG)	5.62	75.00	25.00	4.7	59.3	43	59
Afar (AF)	1.92	82.12	17.88	5.5	16.4	81	125
Amhara (AM)	22.68	83.79	16.21	3.7	27.7	67	85
Oromia (OR)	37.45	85.52	14.48	5.4	19.7	60	79
Somali (SO)	6.06	85.55	14.45	7.2	20.0	67	94
Ben.-Gumuz (BG)	1.12	79.90	20.10	4.4	28.6	62	98
SNNP/SN	20.32	84.37	15.63	4.4	28.6	65	88
Gambella (GA)	0.45	67.73	32.27	3.5	46.9	56	88
Harari (HA)	0.26	44.40	55.60	4.1	51.2	57	72
Addis Ababa (AA)	3.64	-	100	1.8	96.8	28	39
Dire-Dawa (DD)	0.49	37.05	62.95	3.1	56.7	67	93
National total	100	80.64	19.36	4.6	27.7	48	67

Figure 1 Regions in Ethiopia, proportion shares and selected indicators for the year 2015 (Source: Central Statistical Agency of Ethiopia, 2015 and Ethiopia Health and Demographic Surveys, 2016). IMR, infant mortality rate; LB, live born; U5MR, under 5 child mortality rate.

the extent of healthcare inequality in the decentralised system of Ethiopia. Our study, therefore, aims to measure inequalities in selected healthcare resources and outcomes from the year 2000 until 2015. The findings are anticipated to contribute to a better understanding of the effects of the existing health policies, provide information for action towards minimising unfair inequalities, contribute to policy decisions for strengthening the universal health coverage and eventually contribute to achieve the sustainable development goals (SDGs) for health in Ethiopia and perhaps beyond.

METHODS

Setting

Ethiopia is a federal democratic country that consists of nine national regional states and two chartered cities (hereafter regions). According to the Central Statistical Agency (CSA) of Ethiopia, 80.6% of the total population for the year 2015 resided in rural areas. The geographic location of the regions, population proportions and other indicators for the year 2015 are presented in figure 1.

Study design and data source

We performed panel data analysis to measure inequalities in the distribution of selected healthcare resources and outcomes in Ethiopia. Panel data analysis allows a better understanding of the trends and extent of inequalities in healthcare systems.[27] The panel consisted of annual data for 11 regions (n=11) from the year 2000 to 2015. The data were related to government health expenditure (GHE), healthcare workforce, healthcare infrastructure, population and healthcare outcomes of each region. The regional data were retrieved from the Health and Health Related Indicators of Ethiopia. This bulletin has been published annually by the Policy Planning Directorate of the Federal Ministry of Health of Ethiopia since 1994. We also used census based annual population estimates for the regions by the CSA of Ethiopia, plus the 5 yearly reports of the Ethiopia Health and Demographic Surveys (EDHS) for 2000 to 2016.[28–32]

Patient and public involvement

We used data from the public domains and focused on the supply perspective of the healthcare system. There was no direct patient or public involvement in the data collection and analysis. This study intends to answer the following three basic distributional inequality questions in the context of Ethiopia:

- Are healthcare resources and outcomes fairly distributed across the regions?
- How were the trends and extent of the overall inequalities in the selected distributions, and which inequality component (inter-region, within region, interaction term Gini) dominantly explained the overall inequality of each distribution?
- Which healthcare resources had the dominant share of the GHE and what were the relative inequality

changes with respect to the marginal change in the average GHE?

Variables (indicators)

Total GHE and total number of each selected health professional were considered to analyse the finance and healthcare workforce dimensions of the healthcare system. These dimensions are vital for the proper functioning of the healthcare infrastructure. The total number of each functional healthcare infrastructure (health centres, the different levels of public hospitals together and public hospital beds) in each region were also healthcare resources related variables. The annual hospital outpatient department (OPD) visits per capita, the proportions of fully immunised (FIMM) children, and the Ethiopia Health and Demographic Surveys' 5 yearly reports on under 5 child mortality rates (U5MR) and infant mortality rates (IMR) per 1000 live births for each region were healthcare outcome related indicators.

GHE is a crucial determinant of healthcare,[33 34] especially in countries like Ethiopia where the public sector is the main provider of healthcare services. Missing data for GHE for the years 2013 and 2014 and for physicians for the year 2015 for all the regions were estimated using the annual average growth rate of each distribution. The five central hospitals in Addis Ababa (AA), which were financed and managed by the Federal Government of Ethiopia, were included in the analysis for the AA region. The annual total of each distribution (variable) in a region was divided by the annual total population of that region. The ratio of each distribution was again weighted by a fixed number of people to ensure consistency of the indicator, because the regions differ in population size. A summary of the indicators used in the analysis is presented below.

Dimension	Indicator
Finance:	► Per capita government health expenditure (GHE) per annum
Healthcare workforce:	
	► General medical practitioners (GPs) per 10 000 population [a]
	► Specialist doctors (SPDs) per 10 000 population [b]
	► All physicians (APHYs) per 10 000 population [*]
	► Health officers (HOs) per 10 000 population [c]
	► Nurses and midwives (NMWs) per 10 000 population [d]
	► Skilled health professionals (SKHPs) per 10 000 population [**]
	► Pharmacy personnel (PHARP) per 10 000 population
	► Medical laboratory personnel (MLABP) per 10 000 population

Dimension	Indicator
	► Environmental health personnel (ENV'THP) per 10 000 population
Healthcare infrastructure:	
	► Health centre (HC) per 25 000 population
	► Public hospital (PHP) per 1 00 000 population
	► Hospital beds (HPBs) per 10 000 population
Healthcare outcome:	
	► Hospital outpatient department (OPD) visit per capita
	► Fully immunised children (FIMM) (%)
	► Under 5 child mortality rate (U5MR) per 1000 live births
	► Infant mortality rate (IMR) per 1000 live births
*=a + b	**=a +b+c + d

Analysis and interpretation of inequality

We applied various methods to measure and decompose the inequalities. The Theil L (θ_L) and Theil T (θ_T) indices were calculated to quantify the overall inequality of the distributions over the 16 year time period. These measures were applied to highlight different aspects of the same distribution with respect to the annual population size of the regions. The θ_L (mean logarithmic deviation) is more sensitive to changes at the lower tail of a distribution, while θ_T is more sensitive to changes at the upper tail.[35 36] The θ_L and θ_T can be calculated using the following mathematical expressions[37–39]:

$$\theta_L = \frac{1}{n}\sum_{i=1}^{n}\log\frac{Y_i}{P_i} \text{ and } \theta_T = \frac{1}{n}\sum_{i=1}^{n}P_i\log\frac{P_i}{Y_i}$$

Where **n** represents the number of regions, P_i is the population proportion of the ith region, and Y_i is the proportion of a given distribution of the ith region.

Despite the perfect decomposition of the Theil index into between and within region inequality components, this technique hampers the re-ranking effect on the overall inequality of a distribution. Also, the assumption of symmetric distribution with equal variance[40] was easily violated in our case because the regions are heterogenous and more likely to have differences in the distributions.

Furthermore, we calculated the Gini index (GI) which is one of the most commonly used measures of distributional inequalities in healthcare with respect to populations.[41–44] GI is sensitive to differences in distributions about the middle,[45] insensitive to outliers and has a neat relationship with the Lorenz curve.[46] Thus GI can be algebraically described as twice the area between the Lorenz curve and the 45 degree line of equality,[38] and can be calculated using the following mathematical equation[47]:

$\mathbf{GI} = 2 * \sum_{i=1}^{n} \mathbf{Y_i} * \mathbf{P_i} * \mathbf{R_i} - \boldsymbol{\mu}$: where $\boldsymbol{\mu}$ is the mean value of the overall distribution, **n** is the number of regions, Y_i is the value of a distribution in the ith region, P_i is a region's population share and R_i is the relative rank of the ith region.

Despite the claim that the GI allows direct comparison of inequalities between units with different population sizes,[48] the small number of regions (n=11), the wide difference in population size among the regions and the direct association between population size and GI may lead to biased results—that is, the comparison of Gini inequalities among the regions and the inequality changes over time can lead to bias. Therefore, we considered the simple first order bias correction term due to a small sample proposed by Deltas, which is expressed as follows[49]:

$\mathbf{GI_s^{adj}} = \frac{n}{n-1} * \mathbf{GI}$ where GI_s^{adj} represents the adjusted GI for small sample and **n** is the number of regions. Accordingly, the GIs for the regions in our study would be underestimated by about 10%. The values of the GI range from 0 (absolute equality) to 1 (absolute inequality).[50] The extent of the Gini inequality was judged based on the five scale values categorised as absolute equality (GI <0.2), high equality (GI=0.2–0.3), inequality (GI=0.3–0.4), high inequality (GI=0.4–0.6] and absolute inequality (GI >0.6).[51] A distribution with a Gini value above 0.5 can also be considered polarised.[39] This scale was used only to create simplicity of interpretation because the extent of inequality is context specific and can be judged differently.

We further applied different Gini decomposition techniques. First, Pyatt's[52] overall Gini decomposition technique was applied to quantify the extent of the net between region Gini ($\mathbf{G_B}$), within region Gini ($\mathbf{G_W}$) and the interaction pseudo-Gini ($\mathbf{G_I}$) inequality components of each distribution. The sum of these components provides the overall Gini of a distribution. This modelling approach utilises the values of observations >0. The interaction term (trans-variation, an overlap or crossover term) is a re-ranking effect that occurs when the highest distribution in one region overlaps with the lowest distribution of the same variable in another region.[52–55] This method avoids the ambiguity that might arise from the interaction term in the Theil's index of inequality decomposition[52 56] and is more appealing to devise appropriate measures for reducing inequalities.[54]

Second, we calculated the extent of the overall inequality change between the baseline and end of study period using the Jenkins and Van Kerms'[57] decomposition of inequality changes at two points in time. Third, the Shapley post-estimation statistics was done after running the logarithm of the overall GHE (logGHE) per capita regression model on the explanatory variables (healthcare resources) to estimate their relative share of the overall GHE per capita.[58] This method uses the r² value

of the regression model to precisely quantify the estimates by handling the problem that could arise from the residual. The estimates additively yield the overall GHE and point those variables that require explanations.[59–61] Finally, we applied the multidimensional decomposition of the overall GHE inequality (G_{GHE}) by the explanatory variables using the Lerman and Yitzhaki[62] method of decomposition as follows:

$$G_{GHE} = \sum_{k=i}^{K} R_k * G_k * S_k$$

where **K** is a healthcare resource variable, which ranges from **k**=0, ……**K**, R_k is the Gini correlation of the ranked explanatory variable with the overall GHE inequality, G_k is the Gini of the explanatory variable and S_k is the GHE share of the explanatory variable.

This technique incorporates the concept of concentration index and was used to quantify the relative marginal change, the relative GHE inequality and the Gini elasticity of the explanatory variables with respect to the marginal change in the mean GHE and populations of the regions over time. The relative GHE inequalities and the elasticity values of the explanatory variables were calculated manually. These measures enabled us to explain the Gini of inequalities.[63 64] We used the bootstrap and Jackknife techniques as appropriate to determine 95% CI for the indices.[65 66] All analyses were performed using Stata Statistical Software Release 14 (StataCorp LP, College Station, Texas, USA). The interpretations and discussions of the findings were based on the Gini values.

RESULTS

The Theil and Gini indices consistently revealed high overall inequalities in the GHE per capita, healthcare workforce, healthcare infrastructure and in some of the healthcare outcome indicators from 2000 to 2015 in Ethiopia. The aggregate inequality values of at least two of the three indices of all the indicators except for the SPDs and OPD visit per capita had intersection points in common. Despite considerable inequality reductions between the baseline and end of the study period, the GIs of many of the indicators remained strongly correlated with the overall GHE per capita inequality. The marginal increase in the mean GHE per capita resulted in a relative marginal increase in the distributions in favour of the advantaged populations of the regions. The elasticity value of <1 for all the indicators suggests the shortages. The net between region inequality dominantly explained the overall inequality of each distribution, and the interaction term was >0.

Inequality in GHE

The average overall GI for the GHE per capita was 0.596 (95% CI 0.544 to 0.648), and marked reduction in the inequality was observed after 2006 (figure 2A). The overall GI for the regions ranged from 0.317 (95% CI 0.252 to 0.381) for HA to 0.624 (95% CI 0.526 to 0.722) for SNNP. The net inter-region inequality and the interaction term

accounted for 54.4% and 37.9% of the overall GHE per capita inequality, respectively (table 1).

Inequality in healthcare workforce

The overall GI ranged from 0.428 (95% CI 0.393 to 0.463) for NMWs to 0.682 (95% CI 0.646 to 0.718) for the SPDs (table 1). Including zero values in the analysis of the time series observations, the GI for the SPDs was 0.704 (95% CI 0.652 to 0.756). The net inter-region inequality ranged from 53.8% for the HOs to 95.0% for the SPDs, and the interaction term was the lowest for the SPDs (1.6%) and the highest for the HOs (38.7%). Over the 16 year time period, AM (GI=0.387, 95% CI 0.281 to 0.493) and OR (GI=0.319, 95% CI 0.193 to 0.444) among the agrarian regions and BG (GI=0.368, 95% CI 0.248 to 0.487), GA (GI=0.356, 95% CI 0.233 to 0.478) and AF (GI=0.323, 95% CI 0.223 to 0.424) among the pastoral/semi-pastoral regions showed inequality in the SPDs. The inequality in the distribution of the HOs was common to all regions, while SO (GI=0.638; 95% CI 0.435 to 0.841) and AA (GI=0.633, 95% CI 0.494 to 0.771) were the regions with absolute inequality. There were inequalities in NMWs and SKHPs in SO and in all the agrarian regions, except for TG. PHARP in GA, and MLABP in BG and HA regions were fairly equally distributed. GA and all the urban/urban dominated regions had inequality in the distribution of the EVT'THP. Including zero values in the analysis, the overall GI for PHARP and EVT'THP were 0.541 (95% CI 0.492 to 0.590) and 0.467 (95% CI 0.402 to 0.531), respectively. The magnitude and trend of the overall inequalities in the distributions of the GHE and the healthcare workforce at the national level is indicated in figure 2A,B.

Inequality in healthcare infrastructure

The overall GI for the HC, PHP and HPB distributions, and the net between region inequality of the same distributions accounted for 0.409 (95% CI 0.380 to 0.439), 0.460 (95% CI 0.404 to 0.517) and 0.592 (95% CI 0.563 to 0.621), and 44.7%, 94.0% and 92.1% of the overall inequality of each distribution, respectively (table 2). The interaction term was the highest for the HC distributions (47.7%). The overall inequality trend for the healthcare infrastructure is illustrated in figure 2C. BG (GI=0.223, 95% CI 0.168 to 0.278), HA (GI=0.290, 95% CI 0.244 to 0.336) and AA (GI=0.242, 95% CI 0.150 to 0.335) regions had equally distributed HCs. All the regions had GIs for the PHP and HPB distributions <0.3 except for the GI for HPBs in the SO (GI=0.314, 95% CI –0.120 to 0.748) and SNNP (GI=0.598, 95% CI –0.185 to 1.380) regions, which were insignificantly high. The regional disparities in the distributions of selected healthcare resources is graphically illustrated in figure 3. For example, the bottom 50%, middle 40% and the top 10% of the populations in TG had access to 31.2%, 50.5% and 18.3% of the total NMWs in the region, respectively.

Inequality in healthcare outcomes

The overall GIs for hospital OPD visits per capita (GI=0.349, 95% CI 0.321 to 0.377) and FIMM children
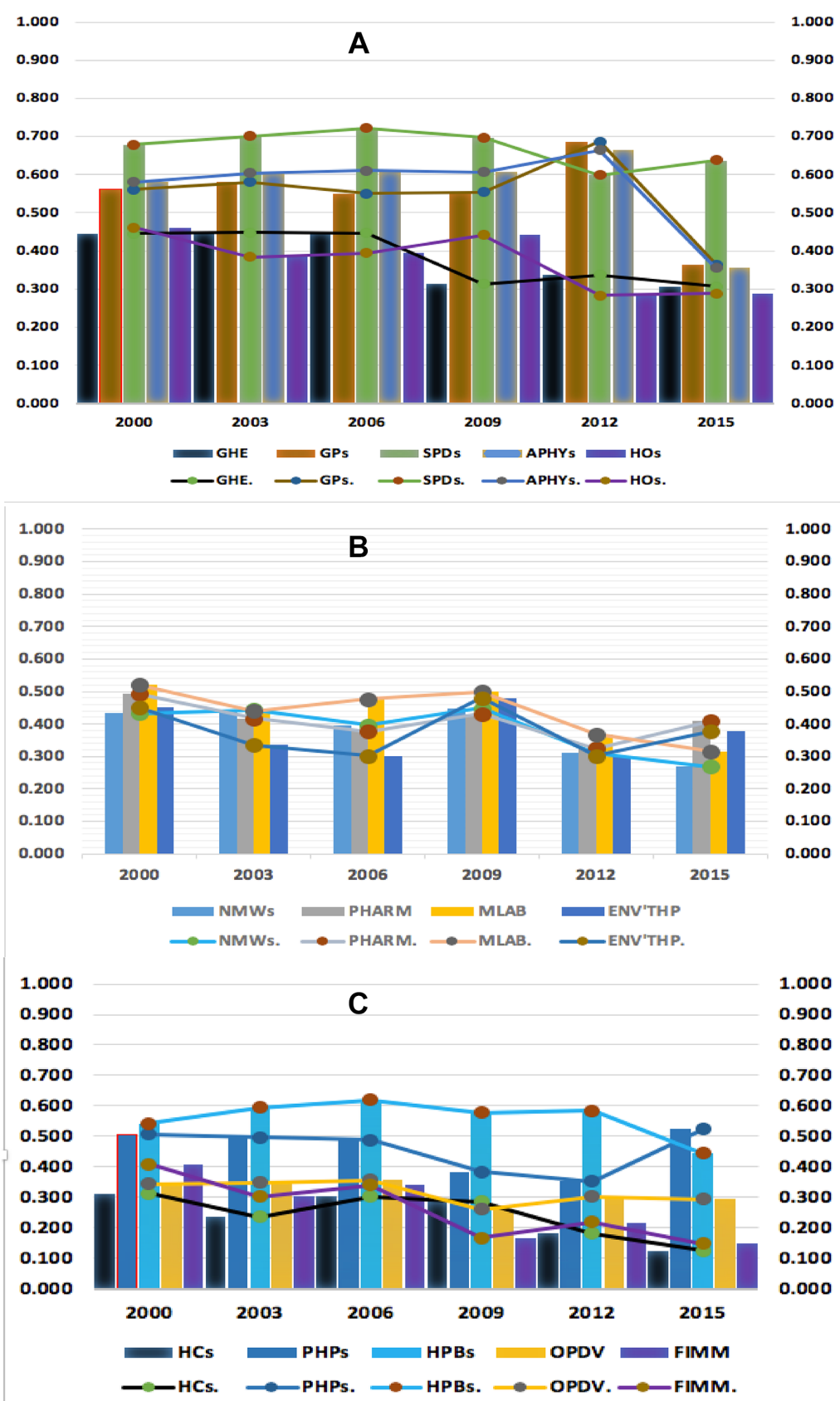
Figure 2 Aggregate inequality trends in selected healthcare resource distributions in Ethiopia from 2000 to 2015. Note: this figure presents the Gini index (GI) for government health expenditure (GHE), general medical practitioners (GPs), specialist doctors (SPDs), health officers (HOs), nurses and midwives (NMWs), all physicians (APHYs), pharmacy personnel (PHARM), medical laboratory personnel (MLABP), environmental health personnel (ENV'THP), health centres (HCs), public hospitals (PHPs), hospital beds (HPBs), hospital outpatient department visits (OPDV) and fully immunised children (FIMM).

Table 1 National level Theil and Gini indices for government health expenditure per capita and healthcare workforce, and Gini index decomposition into its components and by region (with 95% CI for the indices) from 2000 to 2015

Measure/region Overall index*	GHE	GPs	SPDs	APHYs	HOs	NMWs	SKHPs	PHARP	MLABP	ENVTHP
θ_L	0.707	0.643	1.066	0.711	0.708	0.345	0.360	0.590	0.440	0.377
	(0.566 to 0.848)	(0.524 to 0.763)	(0.951 to 1.181)	(0.619 to 0.803)	(0.604 to 0.812)	(0.289 to 0.402)	(0.306 to 0.414)	(0.454 to 0.726)	(0.380 to 0.501)	(0.282 to 0.471)
GI	0.596	0.591	0.682	0.612	0.577	0.428	0.437	0.539	0.491	0.457
	(0.544 to 0.648)	(0.545 to 0.638)	(0.646 to 0.718)	(0.578 to 0.646)	(0.544 to 0.610)	(0.393 to 0.463)	(0.402 to 0.473)	(0.484 to 0.593)	(0.457 to 0.524)	(0.399 to 0.515)
θ_T	0.645	0.653	0.864	0.682	0.572	0.299	0.313	0.517	0.414	0.388
	(0.511 to 0.779)	(0.517 to 0.789)	(0.740 to 0.988)	(0.578 to 0.786)	(0.499 to 0.646)	(0.247 to 0.351)	(0.261 to 0.366)	(0.397 to 0.636)	(0.351 to 0.476)	(0.256 to 0.521)
GI decomposition (%)										
G_B	0.324 (54.4)	0.540 (91.3)	0.648 (95.0)	0.571 (93.3)	0.310 (53.8)	0.348 (81.4)	0.364 (83.2)	0.372 (68.1)	0.375 (76.5)	0.336 (73.5)
G_I	0.226 (37.9)	0.028 (4.6)	0.011 (1.6)	0.022 (3.6)	0.223 (38.7)	0.059 (13.7)	0.053 (12.1)	0.129 (24.9)	0.087 (17.7)	0.091 (19.9)
G_W	0.046 (7.7)	0.024 (4.1)	0.023 (3.4)	0.020 (3.2)	0.043 (7.5)	0.021 (4.9)	0.021 (4.7)	0.037 (7.0)	0.029 (5.8)	0.030 (6.6)
Overall GI	0.596 (100)	0.591 (100)	0.682 (100)	0.612 (100)	0.577 (100)	0.428 (100)	0.437 (100)	0.539 (100)	0.491 (100)	0.457 (100)
GI by region										
Agrarian										
TG	0.406	0.215	0.192	0.191	0.428	0.252	0.261	0.371	0.305	0.278
	(0.306 to 0.506)	(0.124 to 0.307)	(0.070 to 0.315)	(0.117 to 0.264)	(0.329 to 0.527)	(0.183 to 0.322)	(0.195 to 0.327)	(0.277 to 0.464)	(0.249 to 0.361)	(0.197 to 0.360)
AM	0.590	0.206	0.387	0.228	0.492	0.331	0.337	0.439	0.385	0.161
	(0.508 to 0.672)	(0.136 to 0.276)	(0.281 to 0.493)	(0.174 to 0.282)	(0.386 to 0.597)	(0.288 to 0.373)	(0.293 to 0.380)	(0.304 to 0.574)	(0.314 to 0.455)	(0.055 to 0.266)
OR	0.562	0.192	0.319	0.158	0.462	0.345	0.339	0.415	0.384	0.212
	(0.473 to 0.651)	(0.097 to 0.286)	(0.193 to 0.444)	(0.099 to 0.218)	(0.358 to 0.567)	(0.292 to 0.397)	(0.294 to 0.384)	(0.326 to 0.504)	(0.287 to 0.482)	(0.174 to 0.250)
SNNP	0.624	0.183	0.269	0.164	0.496	0.342	0.340	0.449	0.323	0.165
	(0.526 to 0.722)	(0.134 to 0.232)	(0.207 to 0.330)	(0.107 to 0.221)	(0.406 to 0.585)	(0.276 to 0.408)	(0.275 to 0.405)	(0.329 to 0.570)	(0.257 to 0.388)	(0.084 to 0.246)
Pastoral/semi- pastoral										
SO	0.555	0.117	0.187	0.100	0.638	0.384	0.383	0.509	0.359	0.259
	(0.464 to 0.647)	(0.073 to 0.162)	(0.125 to 0.249)	(0.076 to 0.125)	(0.435 to 0.841)	(0.326 to 0.442)	(0.316 to 0.450)	(0.405 to 0.614)	(0.298 to 0.421)	(0.157 to 0.361)
AF	0.436	0.171	0.323	0.158	0.407	0.246	0.242	0.392	0.363	0.192
	(0.372 to 0.499)	(0.136 to 0.206)	(0.223 to 0.424)	(0.112 to 0.203)	(0.341 to 0.474)	(0.199 to 0.294)	(0.194 to 0.289)	(0.309, to 0.474)	(0.276 to 0.449)	(0.035 to 0.349)
BG	0.493	0.270	0.368	0.238	0.360	0.179	0.177	0.386	0.242	0.209
	(0.429 to 0.557)	(0.184 to 0.357)	(0.248 to 0.487)	(0.148 to 0.328)	(0.293 to 0.426)	(0.132 to 0.226)	(0.137 to 0.217)	(0.301 to 0.471)	(0.184 to 0.301)	(0.106 to 0.313)
GA	0.511	0.290	0.356	0.207	0.360	0.181	0.180	0.224	0.384	0.316
	(0.447 to 0.575)	(0.201 to 0.379)	(0.233 to 0.478)	(0.130 to 0.284)	(0.293 to 0.427)	(0.083 to 0.278)	(0.095 to 0.266)	(0.117 to 0.330)	(0.308 to 0.461)	(0.219 to 0.414)
Urban/urban dominated										
HA	0.317	0.281	0.197	0.187	0.483	0.169	0.157	0.427	0.276	0.485
	(0.252 to 0.381)	(0.193 to 0.370)	(0.122 to 0.271)	(0.110 to 0.264)	(0.343 to 0.622)	(0.096 to 0.241)	(0.086 to 0.228)	(0.322 to 0.531)	(0.186 to 0.365)	(0.175 to 0.795)
AA	0.547	0.323	0.300	0.295	0.633	0.281	0.275	0.432	0.344	0.436

Continued

Table 1 Continued

Measure/region

Overall index*	GHE	GPs	SPDs	APHYs	HOs	NMWs	SKHPs	PHARP	MLABP	ENV'THP
	(0.447 to 0.646)	[−0.000 to 0.647]	(0.159 to 0.442)	(0.146 to 0.444)	(0.494 to 0.771)	(0.230 to 0.332)	(0.228 to 0.321)	(0.324 to 0.540)	(0.282 to 0.407)	(0.347 to 0.525)
DD	0.606	0.193	0.208	0.174	0.531	0.233	0.225	0.442	0.309	0.362
	(0.509 to 0.703)	(0.139 to 0.247)	(0.138 to 0.277)	(0.107 to 0.242)	(0.422 to 0.639)	(0.191 to 0.276)	(0.188 to 0.262)	(0.345 to 0.539)	(0.236 to 0.382)	(0.183 to 0.540)

*See text for explanation of index.

AA, Addis Ababa; AF, Afar; AM, Amhara; APHYs, all physicians; BG, Ben-Gumuz; DD, Dire-Dawa; ENV'THP, environmental health personnel; FIMM, fully immunised children; GA, Gambella; GI, Gini index; GHE, government health expenditure; GPs, general medical practitioners; HA, Harari; HCs, health centres; HOs, health officers; HPBs, hospital beds; MLABP, medical laboratory personnel; NMWs, nurses and midwives; OPDs, hospital outpatient departments; OR, Oromia; PHARP, pharmacy personnel; PHPs, public hospitals; SKHPs, skilled health professionals; SO, Somali; SNNP, Southern Nations, Nationalities and Peoples; SPDs, specialist doctors; TG, Tigray.

(GI=0.307, 95 CI 0.269 to 0.345) revealed inequalities. The net between region inequality of the same indicators accounted for 75.1% and 59.0% of the overall inequality, respectively (table 2). We observed a continuous reduction in the overall inequality in FIMM children throughout the 16 year time period (figure 2C). The GIs for OPD visits per capita in AF (GI=0.341, 95% CI 0.249 to 0.432) and GA (GI=0.427, 95% CI 0.303 to 0.550), and for FIMM children in the regions SO (GI=0.524, 95% CI 0.384 to 0.665), AF (GI=0.393, 95% CI 0.219 to 0.566) and BG (GI=0.311, 95% CI 0.217 to 0.405) were higher than the GIs in the other regions. The net between region inequality of U5MR and IMR accounted for 47.1% and 49.5% of the overall inequality of each indicator, respectively.

The overall Gini inequality changes between baseline and the end of the study period for GHE per capita indicated a 31.2% reduction in inequality (P=0.030). The GIs for GPs, APHYs, HOs, NMWs, SKHPs and MLABP were each reduced by more than a third (P<0.01) (table 3). The reductions in GIs for SPD, PHARP and ENV'THP distributions were insignificant (P>0.05). The GIs for the overall distributions of HCs and the coverage of FIMM children were reduced by 60.3% and 63.8% (P<0.001), respectively. The inequalities in U5MR increased by 64.5% (P=0.048).

The estimated Shapley value indicated that the relative share of the healthcare workforce and healthcare infrastructure distributions were 46.5% and 53.5% of the overall GHE, respectively. HOs (18.09%), NMWs (17.20%), MLABP (10.65%), PHARP (9.58%) and HCs (32.32%) had higher relative shares of GHE (table 4). Column 3 of table 5 shows the strong correlation between these variables and the overall inequality in GHE per capita. Columns 5 and 7 indicate the relative GHE inequality and elasticity values of the explanatory variables relative to a marginal change in the average GHE per capita. The elasticity values of all the variables were <1.

The highest and lowest relative GHE inequality and Gini elasticity were for HOs (0.8525 vs 0.8513) and environmental health personnel (0.3750 vs 0.3612), respectively. The marginal increase in the average GHE resulted in a marginal increase in the distributions of all the explanatory variables (column 6) towards the privileged people among the regions (the negative sign indicated the concentration of the indicator among the advantaged populations). Ceteris paribus, a 1% increase in the GHE per capita, resulted in a 0.0027% increase in the distribution of the GPs towards the most affluent people among the regions.

DISCUSSION

This study analysed the trend and degree of inequalities in the distributions of selected healthcare resources and outcomes from 2000 to 2015 in Ethiopia. Our findings revealed a high degree of overall inequalities in

Table 2 National level Theil and Gini Indices for healthcare infrastructure and outcomes and Gini decomposition into its components and by region (with 95% CI for the indices) from 2000 to 2015

Measure/region	Healthcare infrastructure, index (95% CI)			Healthcare outcomes, index (95% CI)			
	HCs	PHPs	HPBs	OPD	FIMM	U5MR	IMR
Overall Index*							
θ_L	0.310	0.362	0.673	0.239	0.264	0.072	0.046
	(0.268 to 0.351)	(0.279 to 0.444)	(0.593 to 0.752)	(0.195 to 0.283)	(0.175 to 0.352)	(0.048 to 0.096)	(0.026 to 0.067)
GI	0.409	0.460	0.592	0.349	0.307	0.208	0.163
	(0.380 to 0.439)	(0.404 to 0.517)	(0.563 to 0.621)	(0.321 to 0.377)	(0.269 to 0.345)	(0.175 to 0.241)	(0.130 to 0.195)
θ_T	0.274	0.419	0.616	0.196	0.166	0.068	0.043
	(0.234 to 0.314)	(0.310 to 0.527)	(0.540 to 0.693)	(0.164 to 0.228)	(0.124 to 0.209)	(0.047 to 0.089)	(0.025 to 0.060)
Gini decomposition (%)							
G_B	0.183 (44.7)	0.433 (94.0)	0.545 (92.1)	0.262 (75.1)	0.181 (59.0)	0.098 (47.1)	0.081 (49.5)
G_I	0.195 (47.7)	0.014 (3.1)	0.034 (5.7)	0.069 (19.7)	0.105 (34.2)	0.095 (45.7)	0.068 (41.5)
G_W	0.031 (7.6)	0.013 (2.9)	0.013 (2.2)	0.018 (5.2)	0.021 (6.8)	0.015 (7.2)	0.015 (9.0)
Overall GI	0.409 (100)	0.460 (100)	0.592 (100)	0.349 (100)	0.307 (100)	0.208 (100)	0.163 (100)
GI by region							
Agrarian							
TG	0.380	0.080	0.089	0.084	0.061	0.209	0.198
	(0.330 to 0.431)	(−0.029 to 0.190)	(−0.011 to 0.190)	(0.061 to 0.107)	(0.025 to 0.096)	(0.057 to 0.362)	(0.080 to 0.316)
AM	0.432	0.108	0.131	0.214	0.210	0.160	0.109
	(0.341 to 0.524)	(−0.011 to 0.227)	(0.015 to 0.248)	(0.121 to 0.307)	(0.146 to 0.273)	(0.082 to 0.239)	(0.069 to 0.149)
OR	0.419	0.142	0.149	0.155	0.231	0.175	0.129
	(0.340 to 0.498)	(0.113 to 0.172)	(0.017 to 0.281)	(0.082 to 0.228)	(0.164 to 0.298)	(0.021 to 0.329)	(0.063 to 0.195)
SNNP	0.339	0.159	0.598	0.146	0.250	0.157	0.129
	(0.304 to 0.373)	(0.061 to 0.258)	(−0.185 to 1.380)	(0.090 to 0.202)	(0.150 to 0.350)	(0.052 to 0.263)	(0.058 to 0.199)
Pastoral/semi- pastoral							
SO	0.493	0.051	0.314	0.197	0.524	0.153	0.099
	(0.426 to 0.561)	(0.037 to 0.065)	(−0.120 to 0.748)	(0.113 to 0.281)	(0.384 to 0.665)	(0.015 to 0.290)	(0.051 to 0.146)
AF	0.427	0.186	0.219	0.341	0.393	0.132	0.088
	(0.354 to 0.500)	(0.156 to 0.217)	(0.099 to 0.340)	(0.249 to 0.432)	(0.219 to 0.566)	(−0.073 to 0.338)	(0.048 to 0.128)
BG	0.223	0.113	0.118	0.147	0.311	0.125	0.145
	(0.168 to 0.278)	(0.077 to 0.149)	(0.082 to 0.155)	(0.102 to 0.192)	(0.217 to 0.405)	(−0.004 to 0.255)	(0.038 to 0.253)
GA	0.308	0.161	0.143	0.427	0.293	0.195	0.115

9

Table 2 Continued

Measure/region	Healthcare infrastructure, index (95% CI)			Healthcare outcomes, index (95% CI)			
	HCs	PHPs	HPBs	OPD	FIMM	U5MR	IMR
	(0.262 to 0.354)	(0.081 to 0.241)	(0.095 to 0.191)	(0.303 to 0.550)	(0.189 to 0.397)	(0.061 to 0.329)	(0.073 to 0.157)
Urban/urban dominated							
HA	0.290	0.197	0.122	0.223	0.133	0.199	0.132
	(0.244 to 0.336)	(0.114 to 0.281)	(0.069 to 0.174)	(0.165 to 0.282)	(0.079 to 0.186)	(0.001 to 0.397)	(0.069 to 0.194)
AA	0.242	0.052	0.103	0.152	0.220	0.219	0.193
	(0.150 to 0.335)	(0.023 to 0.081)	(0.078 to 0.128)	(0.070 to 0.234)	(0.133 to 0.308)	(0.074 to 0.365)	(0.091 to 0.294)
DD	0.327	0.106	0.102	0.274	0.279	0.143	0.107
	(0.241 to 0.413)	(0.039 to 0.173)	(0.056 to 0.149)	(0.177 to 0.371)	(0.168 to 0.389)	(0.064 to 0.223)	(0.067 to 0.146)

*See text for explanation of index.

AA, Addis Ababa; AF, Afar; AM, Amhara; BG, Ben-Gumuz; DD, Dire-Dawa; FIMM, fully immunised children; GA, Gambella; GI, Gini index; HA, Harari; HCs, health centres; HPBs, hospital beds; IMR, infant mortality rate; OPDs, hospital outpatient departments; OR, Oromia; PHPs, public hospitals; SO, Somali; SNNP, Southern Nations, Nationalities and Peoples; TG, Tigray; U5MR, under 5 child mortality rate.

most of the distributions included in our analysis. The net between region inequality in GHE accounted for 54.4% of the average overall GHE inequality in Ethiopia. Although better economic position of a country and sufficient allocation of GHE can positively influence health system outcomes,[67] decentralisation in under resourced countries may lead to more interregional inequalities.[68] Nevertheless, evidence from high income countries with decentralised governance revealed no increased inter-regional inequalities in health expenditure per capita.[69] The high overall GHE inequality observed in our study could be due to multiple factors, including the regional differences in prioritising health, development priorities or compliance to the national health policies.[70] Like the evidence from other studies, the small allocation of GHE, the difference in the roles of the regional governments with respect to spending on health,[71] differences in economic performances of the regions and the weak balancing mechanisms[34 72] could have contributed to the GHE inequalities shown in our findings.

The significant reduction in the GHE inequality observed in our study could be related to an increased fair allocation of the GHE due to the progressive improvement of the national GDP during the past decade.[73] Also, the reduction in GHE inequality might imply the increased regional governments' commitments to spending more on health,[74–76] improvements in governance[77 78] or increased commitment of the development partners to health. Nevertheless, the overall GHE inequality remained too high and sufficient enough to contribute to the regional inequalities in healthcare. The strong correlation between the overall GHE inequality and the inequalities in some of the healthcare resources may indicate the prioritisation of healthcare resources by national and regional governments, whose success depends on the rational distribution of healthcare resources.[79] Evidence from a study in South Africa showed that regions with a better capacity to use the health budget also had better opportunities to receive, allocate and spend more.[80]

A region with a high density of fairly distributed healthcare workforce is more likely to serve the healthcare needs of its people than a region with a low workforce density.[35] The high net between region inequalities in the healthcare workforce observed in our findings might imply the shortage and maldistribution of the limited available healthcare workforce. This was reflected by the relative marginal increase in the distributions of the healthcare resources towards the advantaged populations among the regions and the elasticity values of <1 in all the healthcare resources analysed. The elasticity values of <1 for all the healthcare resources in our study, indicate that the resources are yet necessary inputs to ensure access to healthcare in the regions.[34] One study in China also reported pro-rich concentration of the health workforce,[81] while others from a developed country reported the reductions in inequalities among regions following a decentralised system.[82]
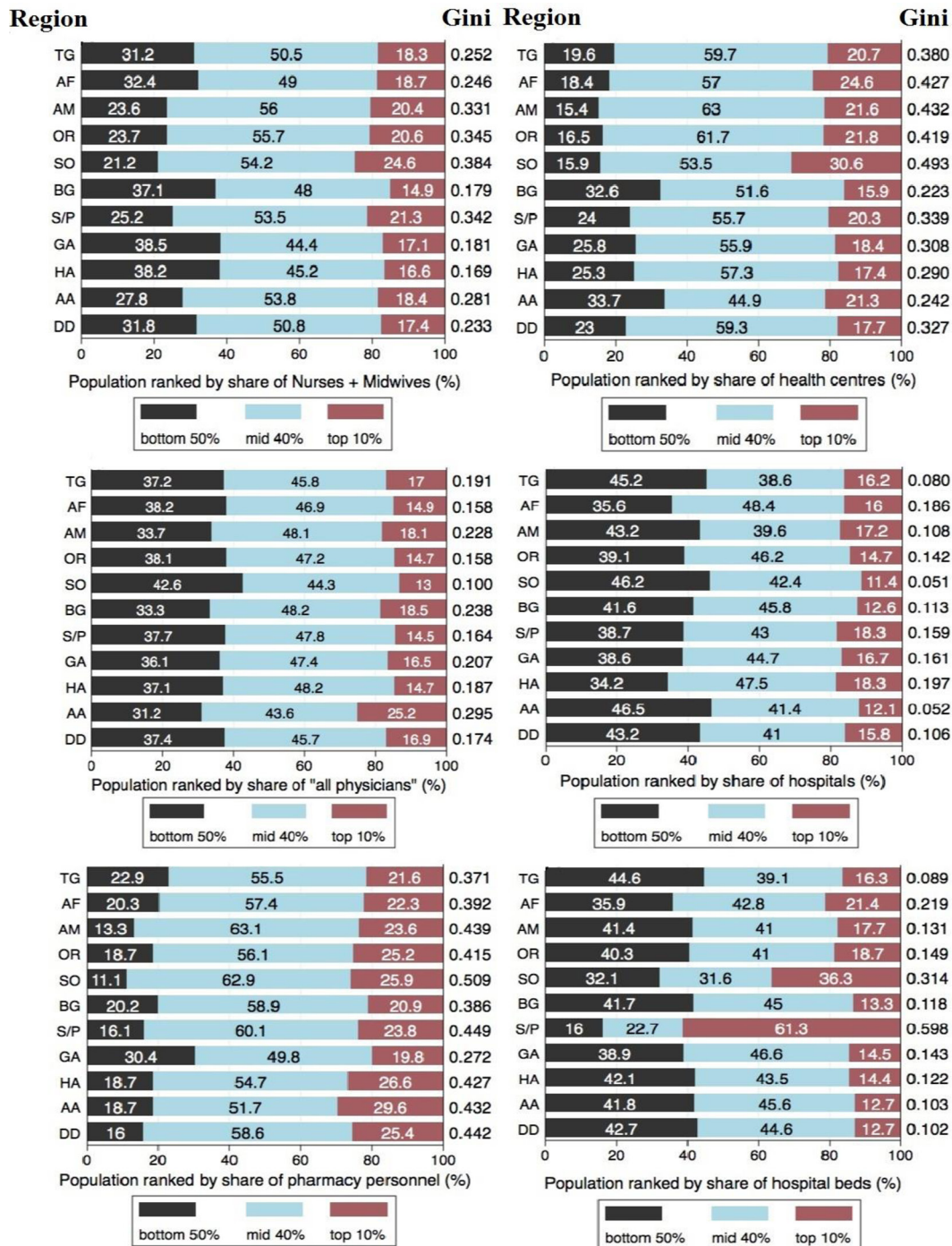
Population ranked by share of Nurses + Midwives (%)

Region	bottom 50%	mid 40%	top 10%	Gini
TG	31.2	50.5	18.3	0.252
AF	32.4	49	18.7	0.246
AM	23.6	56	20.4	0.331
OR	23.7	55.7	20.6	0.345
SO	21.2	54.2	24.6	0.384
BG	37.1	48	14.9	0.179
S/P	25.2	53.5	21.3	0.342
GA	38.5	44.4	17.1	0.181
HA	38.2	45.2	16.6	0.169
AA	27.8	53.8	18.4	0.281
DD	31.8	50.8	17.4	0.233

Population ranked by share of health centres (%)

Region	bottom 50%	mid 40%	top 10%	Gini
TG	19.6	59.7	20.7	0.380
AF	18.4	57	24.6	0.427
AM	15.4	63	21.6	0.432
OR	16.5	61.7	21.8	0.419
SO	15.9	53.5	30.6	0.493
BG	32.6	51.6	15.9	0.223
S/P	24	55.7	20.3	0.339
GA	25.8	55.9	18.4	0.308
HA	25.3	57.3	17.4	0.290
AA	33.7	44.9	21.3	0.242
DD	23	59.3	17.7	0.327

Population ranked by share of "all physicians" (%)

Region	bottom 50%	mid 40%	top 10%	Gini
TG	37.2	45.8	17	0.191
AF	38.2	46.9	14.9	0.158
AM	33.7	48.1	18.1	0.228
OR	38.1	47.2	14.7	0.158
SO	42.6	44.3	13	0.100
BG	33.3	48.2	18.5	0.238
S/P	37.7	47.8	14.5	0.164
GA	36.1	47.4	16.5	0.207
HA	37.1	48.2	14.7	0.187
AA	31.2	43.6	25.2	0.295
DD	37.4	45.7	16.9	0.174

Population ranked by share of hospitals (%)

Region	bottom 50%	mid 40%	top 10%	Gini
TG	45.2	38.6	16.2	0.080
AF	35.6	48.4	16	0.186
AM	43.2	39.6	17.2	0.108
OR	39.1	46.2	14.7	0.142
SO	46.2	42.4	11.4	0.051
BG	41.6	45.8	12.6	0.113
S/P	38.7	43	18.3	0.159
GA	38.6	44.7	16.7	0.161
HA	34.2	47.5	18.3	0.197
AA	46.5	41.4	12.1	0.052
DD	43.2	41	15.8	0.106

Population ranked by share of pharmacy personnel (%)

Region	bottom 50%	mid 40%	top 10%	Gini
TG	22.9	55.5	21.6	0.371
AF	20.3	57.4	22.3	0.392
AM	13.3	63.1	23.6	0.439
OR	18.7	56.1	25.2	0.415
SO	11.1	62.9	25.9	0.509
BG	20.2	58.9	20.9	0.386
S/P	16.1	60.1	23.8	0.449
GA	30.4	49.8	19.8	0.272
HA	18.7	54.7	26.6	0.427
AA	18.7	51.7	29.6	0.432
DD	16	58.6	25.4	0.442

Population ranked by share of hospital beds (%)

Region	bottom 50%	mid 40%	top 10%	Gini
TG	44.6	39.1	16.3	0.089
AF	35.9	42.8	21.4	0.219
AM	41.4	41	17.7	0.131
OR	40.3	41	18.7	0.149
SO	32.1	31.6	36.3	0.314
BG	41.7	45	13.3	0.118
S/P	16	22.7	61.3	0.598
GA	38.9	46.6	14.5	0.143
HA	42.1	43.5	14.4	0.122
AA	41.8	45.6	12.7	0.103
DD	42.7	44.6	12.7	0.102

Figure 3 Regional inequalities in selected healthcare resource distributions in Ethiopia from 2000 to 2015. Note: this figure indicates the extent of Gini index for the nurses and midwives, all physicians, pharmacy personnel, health centres, public hospitals and hospital beds by region. The share of each resource was classified based on the bottom 50%, middle 40% and top 10% of the population ranks of each region. Regions: AA, Addis Ababa; AF, Afar; AM, Amhara; BG, Ben-Gumuz; DD, Dire-Dawa; GA, Gambella; HA, Harari; OR, Oromia; SO, Somali; S/P, Southern Nations, Nationalities and Peoples; TG, Tigray.

The overall inequalities in GPs and NMWs in our study were more than threefold (GI=0.591 vs GI=0.191) and about twofold (GI=0.428 vs GI=0.267), respectively, compared with the inequalities reported from China.[83] The absolute inequality in the distribution of SPDs across the years observed in our study coupled with the prolonged time required to train and produce the qualified GPs and SPDs, plus the turnover of the SPDs for different reasons in

Ethiopia, ranging from 21.4% in DD to 43.3% in the AM region,[84] could make the inequality reduction more challenging. The overall inequality in APHY distribution in our study (GI=0.612 vs GI=0.532) was slightly higher than that reported from a study in Fiji[48] and extremely higher than the reports from Japan[41 85] and Mongolia.[42] The relatively homogenous but small Gini values for APHYs across the regions may imply the hidden inequity phenomenon.[15]

Table 3 Overall Gini decomposition of inequality change between 2000 and 2015 (and 95% bootstrap CI for the inequality change)

Indicator	Gini Index (95% CI)		Change (Δ)		
	Year 2000	Year 2015	Δ (95% CI)	Δ (%)	P value
Finance					
Per capita GHE	0.446	0.307	−0.139	−31.2	0.030
	(0.324 to 0.567)	(0.238 to 0.376)	(−0.265 to −0.014)		
Healthcare workforce					
GPs	0.560	0.364	−0.196	−35.0	0.001
	(0.323 to 0.798)	(0.219 to 0.510)	(−0.316 to −0.076)		
SPDs	0.679	0.637	−0.042	−6.2	0.543
	(0.485 to 0.873)	(0.463 to 0.812)	(−0.177 to 0.093)		
APHYs	0.581	0.355	−0.226	−38.8	0.002
	(0.415 to 0.746)	(0.251 to 0.460)	(−0.366 to −0.085)		
HOs	0.461	0.288	−0.173	−37.5	0.004
	(0.345 to 0.577)	(0.206 to 0.370)	(−0.292 to −0.054)		
NMWs	0.433	0.269	−0.164	−37.9	0.001
	(0.320 to 0.546)	(0.144 to 0.393)	(−0.262 to −0.066)		
SKHPs	0.448	0.277	−0.172	−38.3	0.002
	(0.305 to 0.592)	(0.160 to 0.393)	(−0.263 to −0.081)		
PHARP	0.492	0.409	−0.084	−17.0	0.210
	(0.349 to 0.636)	(0.261 to 0.556)	(−0.215 to 0.047)		
MLABP	0.519	0.315	−0.204	−39.3	<0.001
	(0.220 to 0.819)	(0.116 to 0.514)	(−0.315 to −0.094)		
ENV'THP	0.450	0.378	- 0.072	−16.0	0.284
	(0.252 to 0.648)	(0.219 to 0.536)	(−0.204 to 0.060)		
Healthcare Infrastructure					
HCs	0.313	0.124	−0.189	−60.3	<0.001
	(0.156 to 0.470)	(0.021 to 0.227)	(−0.242 to −0.136)		
PHPs	0.506	0.523	0.016	3.2	0.843
	(0.134 to 0.879)	(0.175 to 0.870)	(−0.146 to 0.179)		
HPBs	0.541	0.444	−0.098	−18.0	0.367
	(0.444 to 0.639)	(0.224 to 0.663)	(−0.310 to 0.115)		
Healthcare outcomes					
OPD visit	0.343	0.294	−0.050	−14.4	0.286
	(0.242 to 0.445)	(0.160 to 0.428)	(−0.141 to 0.042)		
FIMM	0.408	0.148	−0.261	−63.8	<0.001
	(0.264 to 0.553)	(0.064 to 0.232)	(−0.392 to −0.130)		
U5MR	0.082	0.135	0.053	64.5	0.048
	(0.022 to 0.142)	(0.046 to 0.224)	(0.000 to 0.105)		
IMR	0.075	0.117	0.041	54.6	0.150
	(0.027 to 0.123)	(0.031 to 0.202)	(−0.015 to 0.097)		

APHYs, all physicians; ENV'THP, environmental health personnel; FIMM, fully immunised children; GHE, government health expenditure; GPs, general medical practitioners; HCs, health centres; HOs, health officers; HPBs, hospital beds; IMR, infant mortality rate; MLABP, medical laboratory personnel; NMWs, nurses and midwives; OPDs, hospital outpatient departments; PHARP, pharmacy personnel; PHPs, public hospitals; SKHPs, skilled health professionals; SPDs, specialist doctors; U5MR, under 5 child mortality rate.

The overall healthcare infrastructure distributions (HCs, PHPs, and HPBs) were also highly unequal compared with the findings reported from China.[86]

Nevertheless, the continuously marked reduction in the inequality of the HC distributions and the two-thirds (60.3%) reduction in inequality indicate the efforts of

Table 4 Estimated Shapley value of overall logGHE share of selected healthcare resources from 2000 to 2015 in Ethiopia

Factor	Value	%		Value	%
	Estimated Shapley value of GHE share of selected healthcare resources				
GPs	0.0173	2.24	Group 1		
SPDs	0.0155	2.01			
HOs	0.1398	18.09			
NMWs	0.1330	17.20		0.3594	46.48
PHARM	0.0741	9.58			
MLABP	0.0823	10.65			
ENV'THP	0.0171	2.21			
HCs	0.2499	32.32	Group 2		
PHPs	0.0198	2.57		0.4138	53.52
HPBs	0.0242	3.13			
Total	0.7731	100.00		0.7731	100.00

ENV'THP, environmental health personnel; GHE, government health expenditure; GPs, general medical practitioners; HCs, health centres; HOs, health officers; HPBs, hospital beds; MLABP, medical laboratory personnel; NMWs, nurses and midwives; OPDs, hospital outpatient departments; PHARP, pharmacy personnel; PHPs, public hospitals; SKHPs, skilled health professionals; SPDs, specialist doctors.

the central and regional governments in improving access to primary healthcare among rural residents.[87] In contrast, the increasing tendency in the overall inequality of the PHPs may also imply an increasing inequality in the healthcare workforce, especially among GPs and SPDs. Similarly, others reported a wide disparity in the geographic distribution of healthcare workforce, health facilities and hospital beds.[86] The high inequalities in the distributions of the healthcare infrastructure in our study might inform the regional differences in development, management, institutional capacity, priorities and strategies followed by the regions to meet the healthcare needs of the local people.

The high overall inequalities in the distributions of the healthcare resources in the context of Ethiopia, where most people live in rural areas, can challenge the uniform achievement of the health sector goals in the country. As Atkinson stated, "a smaller cake more fairly distributed may be preferable to a bigger one with high levels of inequality".[16] Thus the high inequality in the GHE across the regions might challenge the reduction of inequalities for other healthcare resources. It is pivotal to minimise the existing inequalities among the regions, yet success may depend on the government's commitment to improve financing, allocation of healthcare resources in addition to identification of other context specific opportunities and barriers to reduce the inequalities.

The economic, social, political and infrastructural positions of a country or a region are fundamental to determine the success in healthcare outcomes.[67] The expansion of the PHPs in Ethiopia are believed to have created an opportunity for people to use hospital services.[87] However, the net between region inequality in OPD visits per capita was considerably high (75.1%), and the reduction in inequality over time was insignificant. Over a 16 year period, two of the four pastoral/semi-pastoral regions (AF and GA) had high inequality in OPD visits per capita. In Ethiopia, this inequality might be explained by low access to the hospital services among the majority of rural residents, the shortage of qualified providers, the weak referral linkage between the primary healthcare units and PHPs and other individual factors, such as low awareness of the benefits of hospital services and financial constraints. A recent study in Ethiopia also reported the practice of daily or weekly rationing of laboratory tests, hospital drugs prescriptions, radiological investigations and the provision of the second best treatment,[88] all of which might contribute to the low utilisation of hospital services. People living in remote areas, those who were poor, and of ethnic minorities, were also reported to have a low hospital services use.[7 79]

Despite the marked reduction in the overall inequalities in FIMM children (63.8%) over the study period, the U5MR presented a significant inequality. Micro-level studies in Ethiopia identified the association between hospital inaccessibility and death from a vaccine preventable disease (measles)[89] as well as the association between HC inaccessibility and a high child mortality.[90] Others also reported an increasing tendency in socioeconomic inequality in neonatal and under 5 child mortality rates.[21] Due to the possible occurrence of unavoidable contextual and individual differences, such as the biological factors, it would be difficult to further reduce the small degrees of overall inter-regional inequalities in the U5MR and IMR.[91]

Strengths and limitations of this study

This study provided a comprehensive understanding of the extent and trend of inequalities in selected healthcare resources and outcomes over a 16 year period in Ethiopia. Application of the different econometric models helped us describe the inequalities in the decentralised system. The comprehensive use of data from the annually published Health and Health Related Indicators bulletin of the Federal Ministry of Health of Ethiopia, the CSA of Ethiopia census based population estimates for the regions and data from the 5 yearly EHDS reports could have contributed to the reliability and credibility of the findings. The analysis was based on a small number of regions, which could lead to a downward biased GIs for the regions with small populations. Despite this, we observed relatively higher inequalities for some of the indicators among the regions with smaller population sizes; the Gini values of the regions

Table 5 Relative marginal effects of overall government health expenditure inequality and elasticity of selected healthcare resources over time, from 2000 to 2015 in Ethiopia

Explanatory variable (K_i)	GHE share (S_k)	Gini of component (G_k)	Correlation with GHE (R_k)	Share of GHE inequality (I_k)=(R_k * G_k * S_k)/G_{GHE}	Relative GHE inequality (I_k/S_k)	Relative marginal change (I_k-S_k) % (95% bootstrap CI)	Elasticity (η_k) = (R_k * G_k)/G_{GHE}
GPs	0.0048	0.5913	0.4430	0.0021	0.4375	−0.0027 (−0.0036 to −0.0018)	0.4395
SPDs	0.0026	0.7036	0.4032	0.0013	0.5000	−0.0014 (−0.0019 to −0.0008)	0.4760
HOs	0.0061	0.5771	0.8792	0.0052	0.8525	−0.0009 (−0.0013 to −0.0005)	0.8513
NMWs	0.0674	0.4281	0.7967	0.0386	0.5727	−0.0288 (−0.0340 to −0.0237)	0.5723
PHARP	0.0082	0.5413	0.8166	0.0061	0.7439	−0.0021 (−0.0027 to −0.0015)	0.7417
MLABP	0.0093	0.4909	0.8061	0.0062	0.6667	−0.0031 (−0.0038 to −0.0025)	0.6640
ENV'THP	0.0040	0.4665	0.4615	0.0015	0.3750	−0.0026 (−0.0033 to −0.0018)	0.3612
HCs	0.0068	0.4092	0.8107	0.0038	0.5588	−0.0030 (−0.0036 to −0.0024)	0.5566
PHPs	0.0109	0.4605	0.5459	0.0046	0.4220	−0.0063 (−0.0076 to −0.0050)	0.4218
HPBs	0.0764	0.5920	0.4889	0.0371	0.4856	−0.0393 (−0.0511 to −0.0275)	0.4856
Total G_{GHE}		0.5960					

ENV'THP, environmental health personnel; GHE, government health expenditure; GPs, general medical practitioners; HCs, health centres; HOs, health officers; HPBs, hospital beds; MLABP, medical laboratory personnel; NMWs, nurses and midwives; OPDs, hospital outpatient departments; PHARP, pharmacy personnel; PHPs, public hospitals; SKHPs, skilled health professionals; SPDs, specialist doctors.

generated by Pyatt's Gini decomposition technique might be underestimated. We also acknowledge that the decomposition of the inequality change in two points in time cannot provide information about the whole story of the inequality dynamics over time. Also, the analysis was based on aggregate level data that emphasised the supply perspective of the health system.

Policy implications

The success of the healthcare system as a whole and the SDGs for health in the context of Ethiopia require a continuous and coordinated effort to further reduce the observed inequalities in healthcare access. This study highlighted not only the magnitude and trend of the inequalities in the distributions of the healthcare resources, but also an overall shortage of the healthcare resources. The relatively higher GHE share of the healthcare infrastructure also shows the regional and central governments' greater emphasis on the expansion of healthcare facilities, rather than meeting the healthcare workforce standards of the facilities. This situation calls for a more coordinated effort to meet the healthcare needs of all people across all regions, especially those living in the pastoral and semi-pastoral areas. The healthcare resource gaps identified in this study imply the need for:

► Implementing healthcare standards and certifying the health facilities on the fulfilment of predetermined minimum healthcare workforce and material requirements, and strengthening mechanisms for monitoring inequalities in basic healthcare access in all regions.
► Building the institutional capacity of the regional health bureaus to closely track and address inequalities in distributions within each region.
► Introducing mechanisms to raise sufficient health budget without increasing the burden of cost on poor citizens.

CONCLUSION

Despite the progressive reductions in inequalities, there are still significant inequalities in the distributions of some healthcare resources and outcomes in Ethiopia. The small GHE per capita coupled with high inequalities make the situation more challenging. Similar to most member states, Ethiopia has committed to achieving SDGs by 2030. Unless Ethiopia significantly scales up its efforts to increase the GHE per capita and implement inequality reduction mechanisms, the proportional progress towards achieving the health related SDGs across the regions may become less feasible. Further investigation of context specific barriers to more equitable access in healthcare and their root causes is of paramount importance to contribute to the inequality reduction in healthcare in Ethiopia, and perhaps similar low income settings.

Author affiliations
¹Department of Health Management and Economics, School of Public Health, Tehran University of Medical Science, Tehran, Iran (the Islamic Republic of)
²School of Public Health, College of Health Sciences, Mekelle University, Mekelle, Ethiopia
³Department of Global Health and Public Policy, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran (the Islamic Republic of)
⁴Health Equity Research Centre (HERC), Tehran University of Medical Sciences, Tehran, Iran (the Islamic Republic of)
⁵National Institute for Health Research, Tehran, Iran (the Islamic Republic of)

REFERENCES

1. Whitehead M. The concepts and principles of equity and health. *Health Promot Int* 1991;6:217–28.
2. O'Donnell O, Propper C. Equity and the distribution of UK National Health Service resources. *J Health Econ* 1991;10:1–19.
3. Braveman P. Defining equity in health. *J Epidemiol Community Health* 2003;57:254–8.
4. Culyer AJ, Wagstaff A. Equity and equality in health and health care. *J Health Econ* 1993;12:431–57.
5. Braveman P. Health disparities and health equity: concepts and measurement. *Annu Rev Public Health* 2006;27:167–94.
6. Asthana S, Gibson A. Health care equity, health equity and resource allocation: towards a normative approach to achieving the core principles of the NHS. *Radic Stat* 2008;96:6.
7. Morris S, Sutton M, Gravelle H. Inequity and inequality in the use of health care in England: an empirical investigation. *Soc Sci Med* 2005;60:1251–66.
8. van Doorslaer E, Wagstaff A, Calonge S, *et al*. Equity in the delivery of health care: some international comparisons. *J Health Econ* 1992;11:389–411.
9. Wagstaff A, Van Doorslaer E, Paci P. Equity in the finance and delivery of health care: concepts and definitions. *Oxford Rev Econ Policy* 1989;5:89–112.
10. Woodward A, Kawachi I. Why reduce health inequalities? *J Epidemiol Community Health* 2000;54:923–9.
11. Asada Y. A framework for measuring health inequity. *J Epidemiol Community Health* 2005;59:700–5.
12. Kawachi I, Subramanian SV, Almeida-Filho N. A glossary for health inequalities. *J Epidemiol Community Health* 2002;56:647–52.
13. Arcaya MC, Arcaya AL, Subramanian SV. Inequalities in health: definitions, concepts, and theories. *Glob Health Action* 2015;8:27106–12.
14. Fleurbaey M, Schokkaert E. Unfair inequalities in health and health care. *J Health Econ* 2009;28:73–90.
15. Starfield B. The hidden inequity in health care. *Int J Equity Health* 2011;10:15.
16. Atkinson AB. *INEQUALITY: What Can Be Done?* Cambridge, Massachusetts: Harvard University Press, 2015.

17. Harper S, King NB, Meersman SC, *et al*. Implicit value judgments in the measurement of health inequalities. *Milbank Q* 2010;88:4–29.
18. Beckfield J, Olafsdottir S, Sosnaud B. Healthcare systems in comparative perspective: classification, convergence, institutions, inequalities, and five missed turns. *Annu Rev Sociol* 2013;39:127–46.
19. Kjellsson G, Gerdtham UG, Petrie D. Lies, damned lies, and health inequality measurements: understanding the value judgments. *Epidemiology* 2015;26:673–80.
20. Sadana R, Blas E. What can public health programs do to improve health equity? *Public Health Rep* 2013;128 Suppl 3:12–20.
21. Skaftun EK, Ali M, Norheim OF. Understanding inequalities in child health in Ethiopia: health achievements are improving in the period 2000-2011. *PLoS One* 2014;9:e106460.
22. Costa-i-Font J. Inequalities in self-reported health within Spanish regional health services: devolution re-examined? *Int J Health Plann Manage* 2005;20:41–52.
23. Jiménez D, Smith PC. Decentralisation of health care and its impact on health outcomes. *Discuss Pap Econ* 2005;10.
24. Nuti S, Vola F, Bonini A, *et al*. Making governance work in the health care sector: evidence from a 'natural experiment' in Italy. *Health Econ Policy Law* 2016;11:17–38.
25. Azfar O, Kahkonen S, Lanyi A, *et al*. Decentralization, governance and public services: the impact of institutional arrangements. Devolution Dev Gov Prospect Decentralizing States (contemporary perspect). *Dev Soc* 252004:19–62.
26. Bossert TJ, Mitchell AD. Health sector decentralization and local decision-making: Decision space, institutional capacities and accountability in Pakistan. *Soc Sci Med* 2011;72:39–48.
27. Bago d'Uva T, Jones AM, van Doorslaer E. Measurement of horizontal inequity in health care utilisation using European panel data. *J Health Econ* 2009;28:280–9.
28. MoH of Ethiopia. *Health and Health Related Indicators. Annual publications from 1992–2007 E.C (2000 – 2015 G.C)*. Addis Ababa, Ethiopia. http://www.cnhde.org.et/
29. Central Statistical Agency. Ethiopia DHS 2000. 2001:1–299 http://www.dhsprogram.com/pubs/pdf/FR118/FR118.pdf
30. Central Statistical Agency, ICF International. Ethiopia Demographic and Health Survey 2005, 2006:1–430. http://www.measuredhs.com
31. Central Statistical Agency [Ethiopia] and ICF International. *Ethiopia Demographicand Health Survey 2011*. Addis Ababa, Ethiopia and Calverton, Maryland, USA: Central Statistical Agency and ICF International, 2012. http://www.measuredhs.com
32. Central Statistical Agency (CSA) (Ethiopia) and ICF. *Ethiopia Demographic and Health Survey 2016*. Rockville, Maryland, USA: CSA and ICF: Addis Ababa, Ethiopia, 2016. www.DHSprogram.com.
33. Cantarero D. Decentralization and health care expenditure: the Spanish case. *Appl Econ Lett* 2005;12:963–6.
34. Prieto DC, Lago-Peñas S. Decomposing the determinants of health care expenditure: the case of Spain. *Eur J Health Econ* 2012;13:19–27.
35. Anand S. *Measuring health workforce inequalities: methods and application to China and India*. Geneva. World Health Organization, 2010.
36. Anand S, Fan VY, Zhang J, *et al*. China's human resources for health: quantity, quality, and distribution. *Lancet* 2008;372:1774–81.
37. Muszyńska J, Oczki J, Wędrowska E. Income inequality in Poland and the United Kingdom. Decomposition of the Theil index. *Folia Oeconomica Stetinensia* 2018;18:108–22.
38. Tao Y, Henry K, Zou Q, *et al*. Methods for measuring horizontal equity in health resource allocation: a comparative study. *Health Econ Rev* 2014;4:10.
39. Zhou Y, Qin Y. *Empirical analysis on income inequality of Chinese residents*. New York: Springer, 2012:1.
40. Camilo D. A new approach to the decomposition of the gini income inequality ratio. *Empir Econ* 1997;22:515–31.
41. Toyabe S. Trend in geographic distribution of physicians in Japan. *Int J Equity Health* 2009;8:5.
42. Erdenee O, Paramita SA, Yamazaki C, *et al*. Distribution of health care resources in Mongolia using the Gini coefficient. *Hum Resour Health* 2017;15:56.
43. Wu J. Measuring inequalities in the demographical and geographical distribution of physicians in China: Generalist versus specialist. *Int J Health Plann Manage* 2018;33:860–79.
44. Munga MA, Maestad O. Measuring inequalities in the distribution of health workers: the case of Tanzania. *Hum Resour Health* 2009;7:1–12.
45. Williams RF, Doessel DP. Measuring inequality: tools and an illustration. *Int J Equity Health* 2006;5:5.
46. Weich S, Lewis G, Jenkins SP. Income inequality and the prevalence of common mental disorders in Britain. *Br J Psychiatry* 2001;178:222–7.
47. Skaftun EK, Verguet S, Norheim OF, *et al*. Geographic health inequalities in Norway: a Gini analysis of cross-county differences in mortality from 1980 to 2014. *Int J Equity Health* 2018;17:64.
48. Wiseman V, Lagarde M, Batura N, *et al*. Measuring inequalities in the distribution of the Fiji Health Workforce. *Int J Equity Health* 2017;16:115.
49. Deltas G. The small-sample bias of the Gini coefficient: results and implications for empirical research. *Rev Econ Stat* 2003;85:226–34.
50. Hsu YE, Lin W, Tien JJ, *et al*. Measuring inequality in physician distributions using spatially adjusted Gini coefficients. *Int J Qual Health Care* 2016;28:657–64.
51. Miao CX, Zhuo L, Gu YM, *et al*. Study of large medical equipment allocation in Xuzhou. *J Zhejiang Univ Sci B* 2007;8:881–4.
52. Pyatt G. On the interpretation and disaggregation of Gini coefficients. *Econ J* 1976;86:243–55.
53. Silber J. Factor components, population subgroups and the computation of the Gini index of inequality. *Rev Econ Stat* 1989;71:107–15.
54. Ogwang T. A convenient method of decomposing the Gini index by population subgroups. *J Off Stat* 2014;30:91–105.
55. Lambert PJ, Aronson JR. Inequality decomposition analysis and the Gini coefficient revisited. *Econ J* 1993;103:1221–7.
56. Podder N. A new decomposition of the Gini coefficient among groups and its interpretations with applications to Australia. *Sankhyā Indian J Stat Ser B* 1993;55:262–71.
57. Jenkins S, Van Kerm P. *'dsginideco – Decomposition of inequality change into pro-poor growth and mobility components'*. Luxembourg: Differdange, 2009.
58. Manna R, Regoli A. Regression-based approaches for the decomposition of income inequality in Italy, 1998-2008. *Riv di Stat Uff* 2012;1:1998–2008.
59. Shorrocks AF. Inequality decomposition by factor components. *Econometrica* 1982;50:193–211.
60. Shorrocks AF. Inequality decomposition by population subgroups. *Econometrica* 1984;52:1369–85.
61. Shorrocks AF. Decomposition procedures for distributional analysis: a unified framework based on the Shapley value. *J Econ Inequality* 2013;11:99–126.
62. Lerman RI, Yitzhaki S. Income inequality effects by income source: a new approach and applications to the United States. *Rev Econ Stat* 1985;67:151–6.
63. Garner TI. Consumer expenditures and inequality: an analysis based on decomposition of the Gini coefficient. *Rev Econ Stat* 1993;75:134–8.
64. López-Feldman A. Decomposing inequality and obtaining marginal effects. *Stata J* 2006;6:106–11.
65. Davidson R. Reliable inference for the Gini index. *J Econom* 2009;150:30–40.
66. Biewen M. Bootstrap inference for inequality, mobility and poverty measurement. *J Econom* 2002;108:317–42.
67. Romaniuk P, Szromek AR. The evolution of the health system outcomes in Central and Eastern Europe and their association with social, economic and political factors: an analysis of 25 years of transition. *BMC Health Serv Res* 2016;16:95.
68. Lessmann C. Regional inequality and decentralization: an empirical analysis. *Environment and Planning A* 2012;44:1363–88.
69. Costa-Font J, Turati G. Regional healthcare decentralization in unitary states: equal spending, equal satisfaction? *Reg Stud* 2018;52:974–85.
70. Giannoni M, Hitiris T. The regional impact of health care expenditure: the case of Italy. *Appl Econ* 2002;34:1829–36.
71. Willis K, Khan S. Health reform in Latin America and Africa: decentralisation, participation and inequalities. *Third World Q* 2009;30:991–1005.
72. Cantarero D, Lago-Peñas S. The determinants of health care expenditure: a reexamination. *Appl Econ Lett* 2010;17:723–6.
73. Abegaz KH, Mohammed AA. Healthcare expenditure and GDP in Ethiopia from 1995 to 2014: a time-series analysis. *Agric Food Security* 2018;7:47.
74. Lu C, Schneider MT, Gubbins P, *et al*. Public financing of health in developing countries: a cross-national systematic analysis. *Lancet* 2010;375:1375–87.
75. King A, Hansen P. Aggregate health care expenditure in the United States: evidence from cointegration tests: a comment. *Appl Econ Lett* 1996;3:37–9.
76. Parkin D, McGuire A, Yule B. Aggregate health care expenditures and national income. Is health care a luxury good? *J Health Econ* 1987;6:109–27.

77. Gregorio LE, Gregorio DI. Polity and health care expenditures: the association among 159 nations. *J Epidemiol Glob Health* 2013;3:49–57.

78. Liang LL, Mirelman AJ. Why do some countries spend more for health? An assessment of sociopolitical determinants and international aid for government health expenditures. *Soc Sci Med* 2014;114:161–8.

79. Kreng VB, Yang CT. The equality of resource allocation in health care under the National Health Insurance System in Taiwan. *Health Policy* 2011;100:203–10.

80. Stuckler D, Basu S, McKee M. Health care capacity and allocations among South Africa's provinces: infrastructure-inequality traps after the end of apartheid. *Am J Public Health* 2011;101:165–72.

81. Li D, Zhou Z, Si Y, *et al*. Unequal distribution of health human resource in mainland China: what are the determinants from a comprehensive perspective? *Int J Equity Health* 2018;17:29.

82. Costa-Font J. Does devolution lead to regional inequalities in welfare activity? *Environment and Planning C: Government and Policy* 2010;28:435–49.

83. Zhou K, Zhang X, Ding Y, *et al*. Inequality trends of health workforce in different stages of medical system reform (1985-2011) in China. *Hum Resour Health* 2015;13:94.

84. Assefa T, Haile Mariam D, Mekonnen W, *et al*. Physician distribution and attrition in the public health sector of Ethiopia. *Risk Manag Healthc Policy* 2016;9:285–95.

85. Ishikawa T, Fujiwara K, Ohba H, *et al*. Forecasting the regional distribution and sufficiency of physicians in Japan with a coupled system dynamics-geographic information system model. *Hum Resour Health* 2017;15:64.

86. Zhang T, Xu Y, Ren J, *et al*. Inequality in the distribution of health resources and health services in China: hospitals versus primary care institutions. *Int J Equity Health* 2017;16:42.

87. Admassie A, Abebaw D. Gatzweiler J von B, *Rural poverty and marginalization in Ethiopia: a review of development, in marginality*. The Netherlands: Springer, 2014:269–300.

88. Defaye FB, Desalegn D, Danis M, *et al*. A survey of Ethiopian physicians' experiences of bedside rationing: extensive resource scarcity, tough decisions and adverse consequences. *BMC Health Serv Res* 2015;15:467.

89. Poletti P, Parlamento S, Fayyisaa T, *et al*. The hidden burden of measles in Ethiopia: how distance to hospital shapes the disease mortality rate. *BMC Med* 2018;16:177.

90. Okwaraji YB, Cousens S, Berhane Y, *et al*. Effect of geographical access to health facilities on child mortality in rural Ethiopia: a community based cross sectional study. *PLoS One* 2012;7:e33564.

91. Kakwani N, Wagstaff A, van Doorslaer E. Socioeconomic inequalities in health: Measurement, computation, and statistical inference. *J Econom* 1997;77:87–103.