Health System Performance in Ethiopia: A subnational analysis utilizing HAQ

Jamal Yearwood

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Committee:

Dr. Rafael Lozano

Dr. Angela Micah

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Abstract

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Jamal Yearwood

Chair of the Supervisory Committee:

Rafael Lozano

Department of Health Metrics Sciences

Motivated by a national prioritization exercise to assess the Ethiopian health system, the Health-Access and Quality (HAQ) index was used to examine subnational Ethiopian performance. Building from methods developed in previous HAQ analyses in 2015 and 2016, the index was decomposed to measure how performance differentiated between young, working, and post-working populations. Additional analyses were performed to assess the effects of spending and development on health. To examine health spending efficiency, a stochastic frontier function was created, and to study gaps between observed and expected performance, a linear mixed effects model was developed.

Results showed that HAQ performance increased over time across all Ethiopian states though at different rates. Differences in performance were seen between age groups, with much of the observed progress since 1990 being accumulated in the young. When compared to other Sub-Saharan African countries, inefficiencies in spending overlapped with other major economies. When controlling for development status, some high performing subnational locations showed observed values lower than expected.

As Ethiopia's population continues to grow, and its disease burden shifts, interventions will need to be targeted at the most needy to prevent inequities from continuing to increase. The HAQ index is a useful and insightful tool to track this progress over time.

Motivation

Approached by researchers at the Ethiopian Public Health Institute (EPHI), the motivation for the work was to take a granular look at the Ethiopian Health system for a national priority setting exercise. A plan was formulated to develop new metrics and perform analyses which were then to be vetted by researchers at EPHI to give context. Decomposing the Health Access and Quality index (HAQ) by-age and assessing the effects of expenditure on access and quality composed the main analyses. Results were presented at the subnational level to provide the highest utility metrics.

Introduction

Located in the horn of Africa, Ethiopia's health system development began in the late 19th century[1]. Its most notable periods of development came under the rule Haile Selassie and after the devolution of power in 1991. At the time of devolution, Ethiopia had one of the highest burdens of disease in Sub-Saharan Africa with 111,150.50 [106,709.75 – 116,163.10] DALYs per 100k but has since made significant progress reducing burden to 36,572.50 [33,572.5-39,930.89] in 2017[2]. Driven at a multisectoral level, exemplary performance has been observed on various metrics including maternal and child health outcomes, but gains have not evenly distributed[3]. In the past decades, rural woredas – or districts – and areas outside of urban development have seen slower progress than peer locations. To mitigate this, the government began to decentralize the health resources and functions to the local level in 1995[4]. This removed some barriers to delivery, but issues still remained leading to various health development initiatives including the Health Sector Development Plan I in 1998.

In the period of 1990 to 2017, the population of Ethiopia more than doubled from 47.8 million to 106.4 million[5]. The large increase in population required that health systems inputs such as Total Health Expenditure (THE), increase vis-a-vis as disease burden makeup transitioned from being primarily

[1] Yayehyirad Kitaw, Gebre-Emanuel Teka, and Hailu Meche, *The Evolution of Public Health in Ethiopia, 1941-2010*.
[2] Roth et al., "Global, Regional, and National Age-Sex-Specific Mortality for 282 Causes of Death in 195 Countries and Territories, 1980–2017."
[3] Yayehyirad Kitaw, Gebre-Emanuel Teka, and Hailu Meche, *The Evolution of Public Health in Ethiopia, 1941-2010*.
[4] "Health-Facility-Governance-in-the-Ethiopian-Health-System.Pdf."
[5] "Population, Total - Ethiopia | Data."

communicable to non-communicable diseases (NCDs)[67]. With a growing and ageing population, access and quality to services has become a centering question in national conversations as the balance between resources, personnel, and global targets tug at each other.

Developed in 2015, the HAQ index is built around the concept of amenable mortality and measures levels of access and quality of health systems across the globe[8]. Amenable mortality in the context of HAQ, looks at deaths that occurred in health systems that should have been averted through the delivery of high-quality care[9]. Using this as its foundation, HAQ is a useful metric for benchmarking and comparison across countries and within countries to explore subnational variation.

Methods

The methods for analysis build from previously published methods from Lozano et. al from the Global Burden of Disease (GBD) 2016 and incorporate new methods from an upcoming publication using GBD 2019 results [10]. As such the aims of the methods will be to articulate novel methods part of the unpublished analysis and describe new procedures used to analyze Ethiopia specifically.

Standardization of Causes

Calculation of the composite HAQ index followed similar procedures used in the HAQ 2016 analysis. After mapping Nolte and McKee's amenable cause list to GBD equivalents, causes were standardized to account for varied risk factor exposure or for difference incidence rates. To standardize for risk factor exposure, a single global joint population attributable fraction (PAF) was applied to all countries to produce a risk-standardized death (RSD) and to standardize for incidence, mortality-incidence ratios (MIRs) were calculated. 1000 draws were used from the modeled posterior distribution of mortality estimates as a measure of uncertainty. Both RSDs and MIRs values were age-standardized.

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[6] IHME, "Financing Global Health Visualization."
[7] "Ethiopia-Health-System-Transformation-Plan.Pdf."
[8] "Healthcare Access and Quality Index Based on Mortality from Causes Amenable to Personal Health Care in 195 Countries and Territories, 1990–2015: A Novel Analysis from the Global Burden of Disease Study 2015 - The Lancet."
[9] Nolte and McKee, "Measuring the Health of Nations."
[10] "Measuring Performance on the Healthcare Access and Quality Index for 195 Countries and Territories and Selected Subnational Locations: A Systematic Analysis from the Global Burden of Disease Study 2016 - The Lancet."

After each measure was created for all causes, the correlation between it and Healthy Average Life Expectancy (HALE) was calculated to determine whether to use an RSD or MIR for index calculation. For causes considered chronic, MIR usage was restricted as to not conflate deaths in one-year with the delivery of care from an earlier period.

Index Calculation

To calculate the composite HAQ index, a log offset was added to RSDs and MIRs before being logarithmically transformed to a scale from 0-100. The 1st and 99th percentiles of the draws were used to set 0 and 100 for each cause to increase stability in the scaling process. The composite HAQ index was calculated by taking the mean of all draws across the 32 causes.

Age Group Analysis

To examine demographic trends over time, HAQ scores were calculated across three age groups that correspond with population age structures[11]. Young (0-14), working (15-64), and post-working (65-74) age categories were used to represent segments of the population used to calculate the demographic dividend.

For each age group, causes were restricted to those that were relevant and amenable to the defined age range. This resulted in a differential list of causes for each age-group. The basis of this was to prevent causes like neonatal disorders from affecting scores outside of a relevant age-group. Risk-standardization, the creation of MIRs, and age-standardization occurred in the same manner as for the composite index. What was considered a 0 and 100 was set relative to each age group.

Stochastic Frontier Analysis

Stochastic frontier meta-regression (SFM) was used to assess how spending related to health-care access and quality. SFM allowed us to approximate maximum HAQ scores for varying levels of economic inputs. We operationalized economic input on two measures of spending, pooled expenditure (which included government health expenditure, private prepaid insurance, plus development assistant for health), along with solely government health expenditure. Pooled expenditure was chosen over Total Health Expenditure (THE) on the basis that out-of-pocket spending by patients, which is included in THE,

[11] Mason, Lee, and Jiang, “Demographic Dividends, Human Capital, and Saving.”

should not be in consideration when examining inefficiencies in spending. Government health expenditure was chosen to test the sensitivity of the theoretical maximum HAQ score when excluding sources outside the direct control of ministries of health.

Using the composite HAQ index as the dependent variable, a production frontier for pooled and government health expenditure was constructed. Frontiers were produced using the associated uncertainty for a value of HAQ with an assumed distribution of efficiency across locations. A flexible spline was used to estimate the functional form of each frontier between cumulative spending between years 2015-2017 and HAQ in year 2019. Cumulative spending was used to account for fluctuations in spending over time and in particular the period for which spending was chosen was used to limit spending outside of the SDG era while allowing for a lag between spending and improved health system performance. We specified the model to increase monotonically with a concave shape and used a generalized trimming methodology to detect and remove outliers. Only 2% of the most extreme observations were trimmed due to relatively small uncertainty intervals in the HAQ score. The resulting frontier represents the maximum possible HAQ expected for a given level of spending.

Efficiency for each country was calculated by taking the variance weighted difference between the frontier and a country's HAQ score.

Regression Analysis

To examine the relationship between HAQ and development, a mixed-effect model was developed to predict HAQ scores based off the socio-demographic index (SDI). SDI is a composite metric of GDP, educational attainment, and fertility that is used to proxy development status.

Year, SDI, and location were included as explanatory variables. A random intercept was specified on location. To compare models Bayesian Information Criteria was used.

Results

Composite

Between the years 1990 and 2019, the composite HAQ score for Ethiopia increased significantly from 9.7 [6.7-12.8] in 1990 to 31.1 [27.4 - 35.6] in 2019. Corresponding with similar increases in SDI, increased

performance was driven primarily through improvements in communicable diseases, maternal, and child health indicators, and. Compared to other observed Sub-Saharan African countries Kenya 28.10 [24.57 - 31.68] in 1990 to 33.36 [29.28 - 38.08] in 2019, Tanzania 23.56 [20.77 – 26.30] in 1990 to 32.46 [29.49 – 35.38] in 2019, and Nigeria 20.53 [16.05 - 25.58] in 1990 to 31.62 [25.99 - 37.97] in 2019, national increases in performance significant.

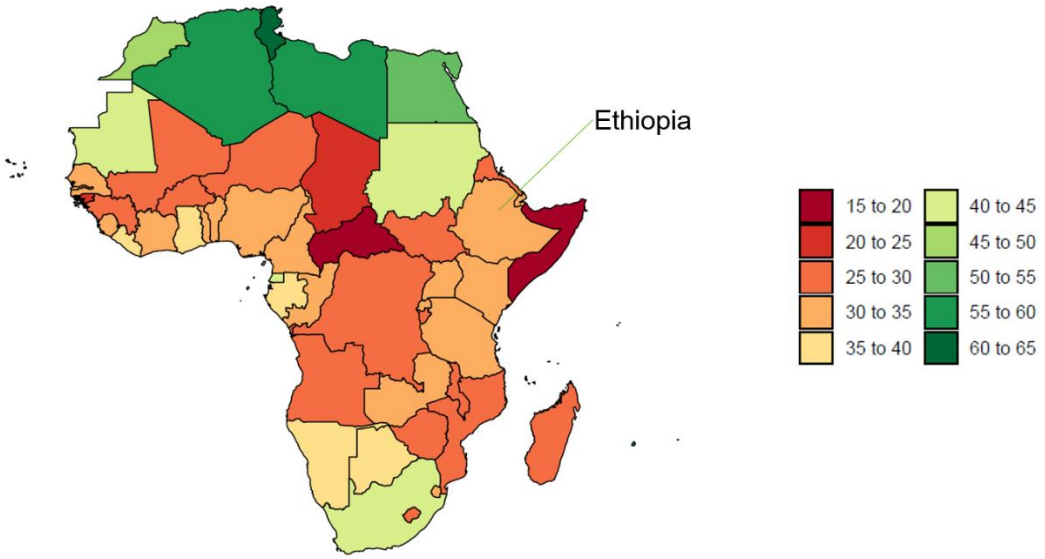

Figure 1 – HAQ Composite Africa Map: 2019

Figure 2, maps Ethiopian performance on the index at a subnational level and over time. Between 1990 and 2019, there was steady progress across the states though the areas that saw the most marked improvements were smaller and more densely populated; this included Addis Ababa, Harare, and Dire Dawa. The difference between the highest and lowest performing subnational in this period was 11.36 [10.90 – 11.65] in 1990 versus 19.12 in 2019 [17.12 – 20.24]. Seen in other countries across the globe, the increase in absolute difference between the highest and lowest performers demonstrate that while improvements are being realized, inequity grew in-tandem.

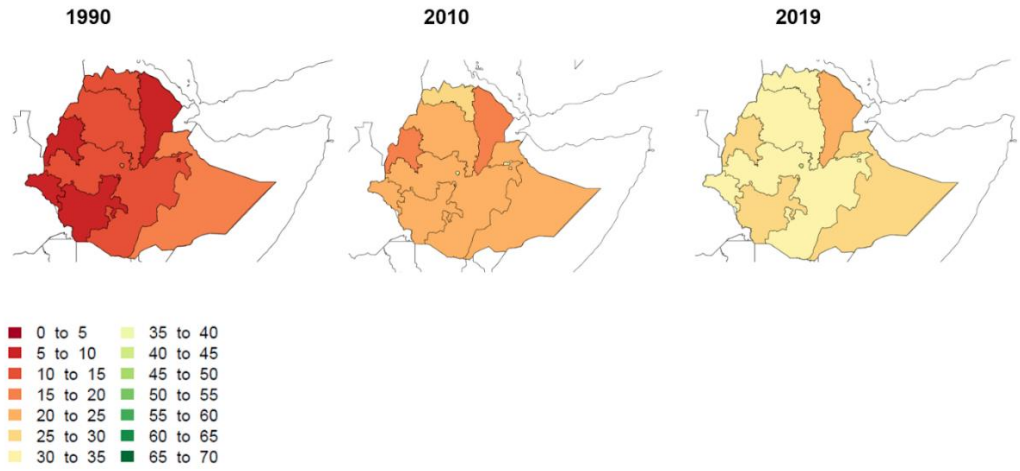

Figure 2 – Ethiopia Subnational Maps: Composite 1990-2019

Figure 3 and figure 4 illuminate how improved performance between 1990 and 2019 has been achieved state by state. In 1990, Benishangul-Gumuz was the lowest performing subnational with an observed HAQ score of 6.82 [3.35- 11.22] and Addis Ababa was the highest with an observed score of 18.18 [14.24 – 22.88]. In 2019, Benishangul-Gumuz gained 19.10 [17.67 - 20.79] points on the index and no longer was the lowest performing state, while Addis Ababa remained the highest performer and increased its score by 24.61 [21.70 - 27.36] to achieve a 43.80 [35.95 – 50.23] on the HAQ index. Nationally, Ethiopia increased its HAQ score by 21.49 [20.67 - 22.75] during this period and the state of Harari saw the largest gain in performance with a 26.63 [24.53 – 29.02]-point increase.

Figures 3 and 4 also demonstrate how performance has varied across causes and disease types. Between 1990 and 2019, upper respiratory infections, tuberculosis, measles, and other communicable diseases all saw large increases in their scores compared to non-communicable which saw comparatively marginal increases. By 2019, 4 causes (diphtheria, tetanus, upper respiratory infections, and chronic respiratory diseases) saw margins of 50.00-points or more between the highest and lowest performing states compared to only one (diphtheria) in 1990. Causes that saw the least amount of progress between study years were mainy cancers but also included whooping cough and neonatal disorders.

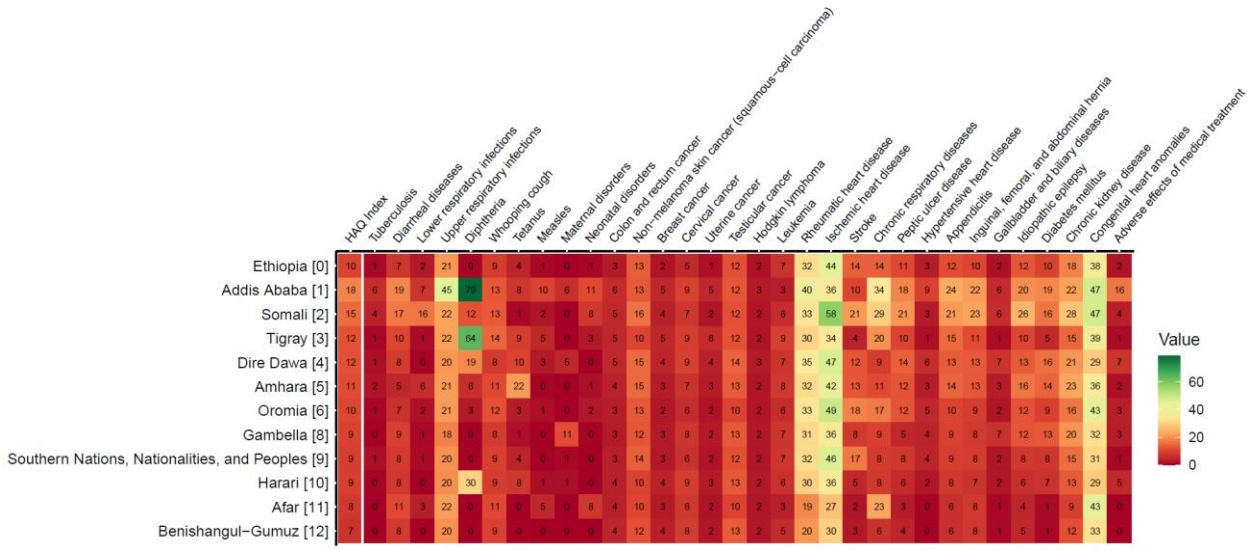

Figure 3 – Ethiopia Subnational Heatmap: Composite HAQ Performance 1990

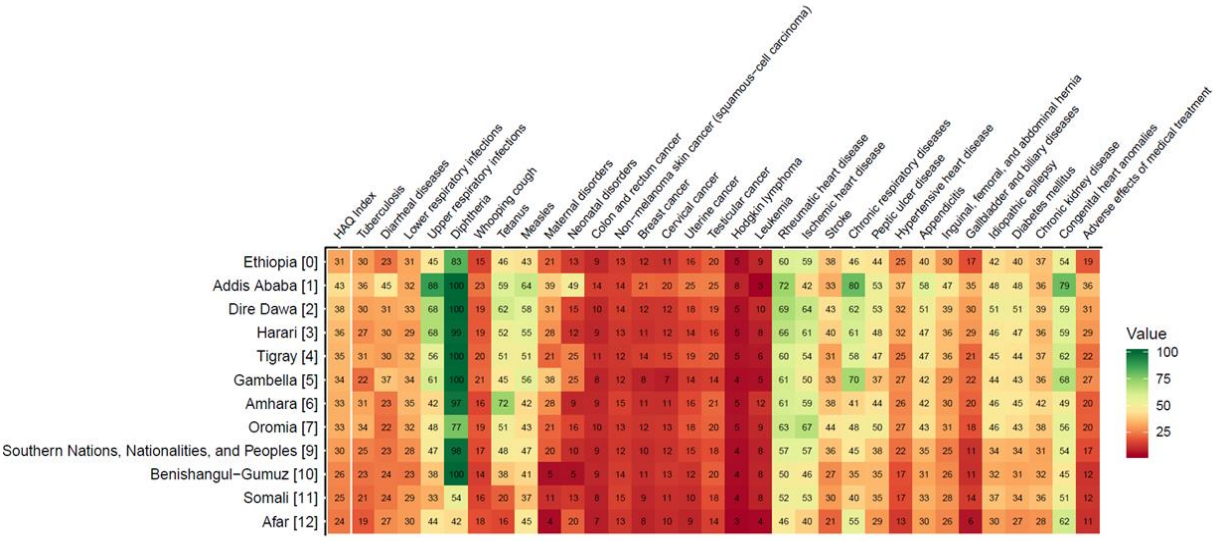

Figure 4 – Ethiopia Subnational Heatmap: Composite HAQ Performance 2019

By-Age

Decomposition of the HAQ by age group revealed that the health system has improved variably across age groups. At a national level, the youngest age group observed a score of 15.22 [10.74 -21.80] in 1990, 31.42 [27.45- 35.59] in 2010, and 42.12 [36.87 - 47.12] in 2019. The working age group followed a

similarly, though less pronounced, increasing upward trend of observed scores of 12.52 [8.69 -16.91] in 1990, 28.84 [24.32 - 33.08] in 2010, and 35.89 [29.85 - 42.66] in 2019. And the post-working age group observed scores of 15.03 [11.11 -19.65] in 1990, 24.91 [21.41 - 28.50] in 2010, and 29.22 [24.93 - 34.10]. Though there was variation, at a subnational level, states also largely followed the trends that were exhibited at a national level. The young index had the largest gains on the index with all states observing at least a 20+ point increase between 1990 and 2019. This difference in gains between the age groups can be seen in Dire Dawa who saw the largest increase in the young index (excluding Gambella which was identified as an outlier). For the young, it observed an increase of 37.60 [34.05-38.95] between 1990 and 2019, though saw smaller gains of 24.68 [22.29-25.88] for working ages, and 15.46 [13.91-17.77] for the post-working.

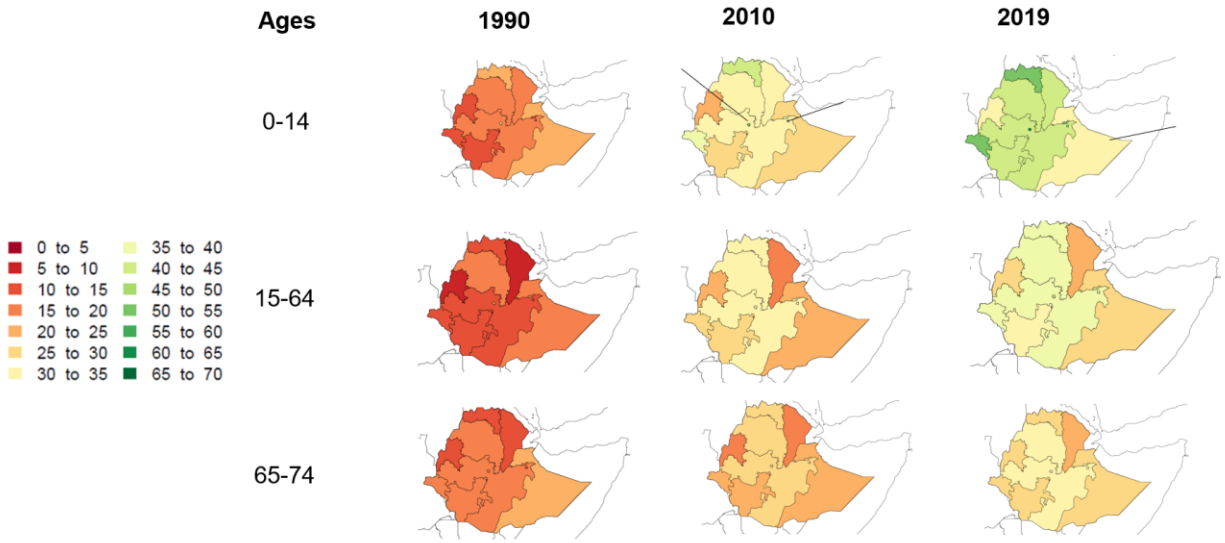

Figure 5 – Ethiopia Subnational Map: By Age 1990 -2019

Stochastic Frontier Analysis

Table 1 reports results from the frontier analysis for Ethiopia and selected neighboring countries. Using cumulative government and pooled expenditure for years 2015-2017 the theoretical maximum HAQ score for Ethiopia was determined to be 37.52 and 48.32, respectively. Seen in Figure 6, across both measures of spending, the expected maximum HAQ score increased exponentially at low levels of spending before reaching a plateau at levels of spending higher than approximately $7,500. The exponential increase was driven by high variability in observed HAQ for similar levels of spending which illustrated factors outside of health spending were likely driving the differing performance.

When examining inefficiency in spending, Ethiopia performed on-par with its neighbors with an observed value of 6.02 for government expenditure and 17.02 for pooled expenditure. Out of its neighboring countries, Uganda was the only country to observe a lower inefficiency for government health expenditure with a value of 5.15. For pooled expenditure Sudan was the only country to observe a lower inefficiency with a value of 10.17. And though it generally performed well, Ethiopia did observe the second highest difference between its government and pooled inefficiency values with a difference of 10.82. Only Uganda, with an observed difference of 13.04, saw a higher discrepancy.

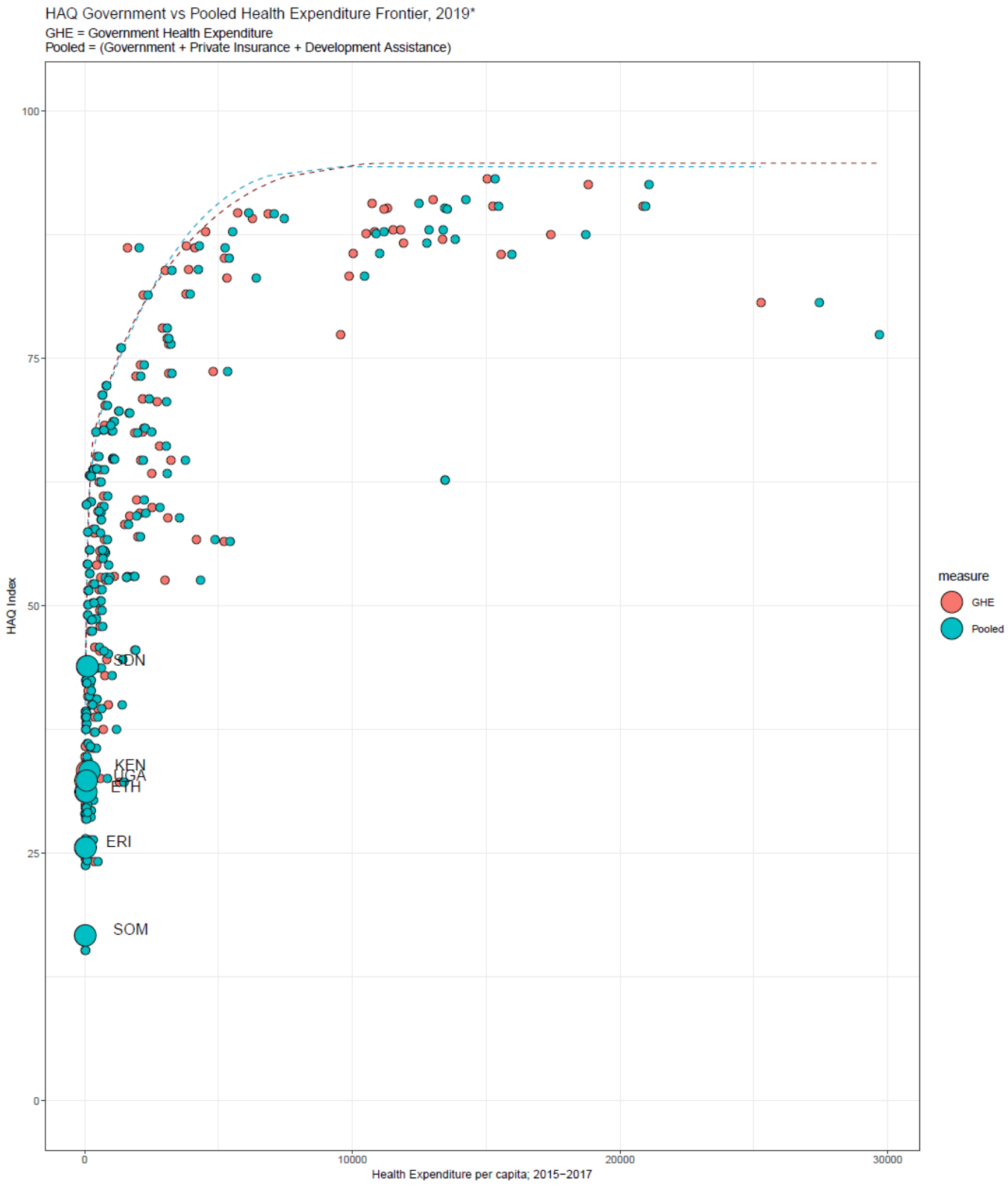

Figure 6 – Cumulative Health Expenditure HAQ Frontier: Spending 2015-2017 vs HAQ 2019

Location	Expenditure	measure	HAQ	Inefficiency	Frontier
Eritrea	16.81	GHE	25.60	10.33	36.08
Eritrea	32.93	Pooled	25.60	18.06	43.74
Ethiopia	20.69	GHE	31.21	6.20	37.52
Ethiopia	60.64	Pooled	31.21	17.02	48.32
Kenya	83.66	GHE	33.36	20.39	53.92
Kenya	179.27	Pooled	33.36	27.88	61.26
Uganda	20.90	GHE	32.36	5.15	37.60
Uganda	76.12	Pooled	32.36	18.19	50.59
Sudan	80.97	GHE	43.92	9.40	53.46
Sudan	103.69	Pooled	43.92	10.17	54.16

Table 1 – Reported Values of Stochastic Health Expenditure Frontier: Cumulative Spending 2015-2017 vs HAQ 2019

Regression Analysis

Results from the linear mixed effect model predictions are presented in Table 2 and Figure 7. Outputs form the model showed that though subnationals like Addis Ababa and Harari had the highest HAQ scores in country, when controlling for their development status, their scores were lower than what would be expected. All subnationals in Ethiopia had confidence intervals that overlapped with negative coefficients but to varying degrees. A general trend of locations with higher levels of SDI experiencing more negative coefficients was observed.

Location Name	Coefficient	2.50%	97.50%	Standard Error
Ethiopia	-5.68	-8.21	-3.15	1.29
Tigray	-3.67	-6.20	-1.14	1.29
Afar	-5.94	-8.47	-3.41	1.29
Amhara	-1.88	-4.41	0.65	1.29
Oromia	-2.37	-4.89	0.16	1.29
Somali	2.02	-0.51	4.55	1.29
Benishangul-Gumuz	-8.58	-11.11	-6.05	1.29
Southern Nations, Nationalities, and Peoples	-5.69	-8.22	-3.16	1.29
Harari	-13.04	-15.57	-10.51	1.29
Gambella	-7.99	-10.52	-5.46	1.29
Addis Ababa	-15.77	-18.30	-13.24	1.29
Dire Dawa	-10.78	-13.31	-8.25	1.29

Table 2 – Linear Mixed Model Coefficients Outputs: Year 2019

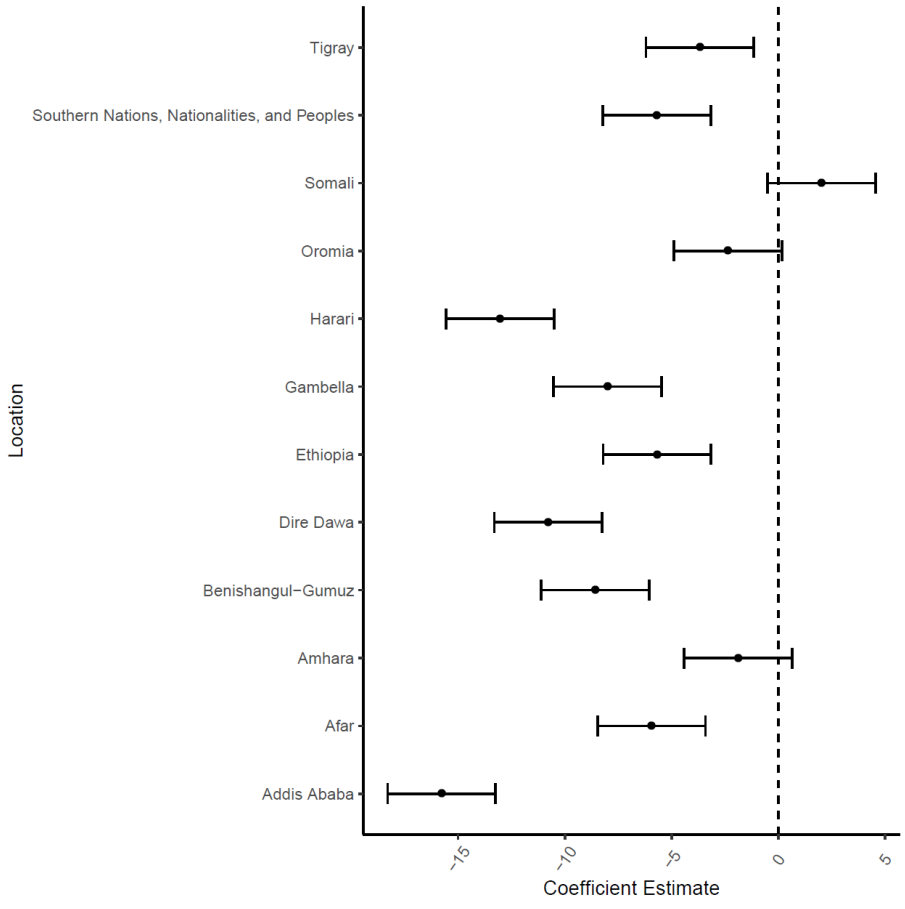

Figure 7 – Subnational Coefficients: Year 2019

Discussion

Subnational Variation

Examination of the HAQ index at the subnational level gave quantitative evidence of how the Ethiopian health system has developed over the past decades. Highlighting that national progress does not equate to uniform subnational progress, clear differences in rate of achievement were seen between more urban areas of the country like Addis Ababa and Dire Dawa versus more rural areas like Afar, Benishangul-Gumuz, and Somali. Still, even with inequities in progress, it is most important to highlight significant progress was made. In 1990, Ethiopia was a low-income country with a life expectancy for females of 46.73 and an under-5 mortality rate of 197.70 and by 2017 its female life expectancy had increased to 61.43 and the under-5 mortality rate had dropped to 56.11[12]. These gains in health were not by chance but came as part of targeted efforts of health initiatives such as the Health System Transformation Plan[13]. With its demonstrated past success, it could be expected that Ethiopia could use past lessons to address current inequities through additional targeted initiatives.

By age

Decomposing the HAQ Index by the young, working, and post-working age groups gave further insight into how the Ethiopian health system has evolved over time. As a function of the causes that were included and excluded from the index, the young age group had notably higher performance across all states. That performance was higher, after excluding causes like the cancers, was expected given that most health systems germinate from interventions centered on maternal and child health. And though there was an expected increase, the progression of the health system for the young was marked by the speed and breadth in which it occurred.

The cause composition of the working and post-working index was much more similar in comparison to the young index and the less pronounced difference in their scores reflected it. Three causes were included in the working age index that were not in the index for the post-working: diabetes, leukemia, and uterine cancer. Because of the stronger similarity between the two indices, similarities and

[12] "GBD Compare | IHME Viz Hub."
[13] "Ethiopia-Health-System-Transformation-Plan.Pdf."

differences were more easily attributable to factors associated with access to and receival of high-quality services. Still, factors outside of the health system, like population age structure, educational attainment, and political climate influenced delivery and are important for comprehension of the results.

Health expenditure and HAQ

Though the methodology does not make it possible to identify factors that contribute to cross-national variation in inefficiency, the frontier illuminates that high-quality care can be achieved with various levels of spending. A simple and powerful analysis, the stochastic frontier allowed for insights into how health expenditure affects achievement of HAQ. At a global level, a clear relationship existed between expenditure, whether it be government or pooled, and the theoretical maximum HAQ. A noted feature of the relationship was its non-linear fashion and the observed plateau of progress at high levels of spending. Seen in Figure 6, relatively high levels of HAQ with – low levels of spending – are both theoretically possible and achievable as countries like Bangladesh, Nepal, and Egypt are close to or at the frontier. Spending $39.87, $59.14, and $149.74 cumulative pooled dollars per capita respectively, these countries illustrate that there is growth potential for Ethiopia though it is important to recognize that the needed interventions may lie outside the health system.

Limitations

The major limitation of the analysis was that it was not performed in a causal framework and so prescriptions cannot be made on the analysis alone.

An additional limitation was the use of the Nolte and McKee framework. While it provides a strong basis to examine amenable deaths, it has not been updated recently to reflect the status of current medicine. The upper age limit for all included causes is 74 years of age which with the improvements in modern medicine should be revisited. In addition, with the advent of antiretrovirals, HIV's exclusion should be reconsidered. With a large burden in subnationals of like Gambella, the impact of not including HIV in the index had a differential impact. Other limitations to the analysis include the choice to use a relative scale in the by-age analysis instead of a single scale across age groups. While the relative scale made differences in performance more apparent it also prevented simple comparison of HAQ scores across

the age groups. A final limitation to note is that the frontier analysis only looks at the effects of spending on HAQ with the recognition there are many factors outside of spending that affect the quality of health systems.

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