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INEQUALITY OF OPPORTUNITY IN CHILD HEALTH IN SUDAN: ACROSS-REGION STUDY*

EBAIDALLA M. EBAIDALLA

University of Khartoum, Sudan and Qatar University, Qatar

This study aims to examine the drivers of inequality of opportunity in health outcome among children below five years of age, using the Sudanese 2014 Multiple Indicator Cluster Survey (MICS). It investigates the variation in inequality across regions, decomposing inequality into a portion that is due to inequality of opportunity and a portion due to other factors, such as random variations in health. The results indicate that the overall inequality in child health is high, particularly in poor and conflict-affected regions. The contribution of inequality of opportunity to total inequality in child health outcome is found to be significant and varies across region. The results also reveal that the share of circumstances in inequality of opportunity in child health varies significantly according to health indicator and geographic region. Specifically, geographic location, parents' education, and parental wealth are among the main factors that contribute to inequality of opportunity in child health.

Keywords: Child Health, Inequality of Opportunity, Parametric Approach, Sudan
JEL Classification: I12, I14, C15, D63

1. INTRODUCTION

Sudan is the third largest country in Africa with large agricultural resources and has always been considered a potential food basket for Africa and the Arab world. The country has vast arable land, considerable amounts of water, cheap labour resources, as well as a diversified climate. Despite these available resources, a large segment of population in Sudan, mainly vulnerable groups such as children, suffers from hunger and

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nutrition insecurity. Indeed, child malnutrition is a widespread phenomenon, particularly in rural areas, where most of the inhabitants live in poverty and food insecurity. According to the 2014 Multiple Indicator Cluster Survey (MICS; see the Central Bureau of Statistics, 2016), about one third (33 per cent) of Sudanese children below 5 years of age (hereafter referred to as 'children under five') are underweight, approximately two in five (38.2 per cent) are stunted (too short for their age), and one in six (16.3 per cent) are wasted (too thin for their height). Regarding gender variation in undernutrition, the survey shows that boys are slightly more underweight, stunted, and wasted than girls. The same report also indicates high regional disparity in child nutritional outcomes, as those residing in poor and conflict-affected regions are more stunted and wasted (Central Bureau of Statistics, 2016).

Moreover, disparity in access to public services such as healthcare, education, and clean water is a prevailing phenomenon across Sudan (Crowther et al., 2014). These inequalities are responsible for a wide range of disparities in socio-economic outcomes among the population, particularly child health. In fact, child health is being affected by parental inputs such as quantity and quality of food as well as by public health services such as availability of clean water and sanitation. Accordingly, unequal distribution of nutrition and health inputs may affect directly child health outcome. In addition, during recent decades several regions have suffered from conflict and underprivileged economic situation, which has negatively affected the distribution of public services and exposed a large segment of children under five to undernutrition. Therefore, understanding the pattern and determinants of inequality of opportunity in child health across regions would help to determine factors that are under the control of policymakers and have important contributions towards enhancing equal opportunities for child health within and between regions.

This paper examines the drivers of inequality of opportunity in child health in Sudan using the 2014 MICS data. More specifically, the paper aims to (i) measure the total inequality in child health outcome along with the share of inequality of opportunity in overall inequality and (ii) identify the contributions of different sets of circumstances, such as geographic location and parental education and wealth, towards the measured inequality of opportunity.

It is common practice in inequality of opportunity literature to consider genetic differences and luck among the set of circumstances an individual has no control over (Roemer, 1998, 2002). Adopting such a framework in the case of child health implies that all observed health inequality would be inequality of opportunity; this is because a child is not responsible for any part of their health outcome by five years of age. Therefore, we take a different path, measuring inequality of opportunity in child health by observable characteristics, while genetic variations other than those directly attributable to parental characteristics and luck are supposedly morally justifiable and therefore included in the residual inequality and are not attributable to differences in opportunities.

The contribution of this paper is three-fold. First, this study fills an important gap in the literature on inequality of opportunity in child health in Sudan. To the best of the author's knowledge, this is the first empirical study conducted to examine this issue in Sudan. Second, this paper addresses the issue of inequality of opportunity across regions; hence provides important evidence for policy makers to distributing public services across regions. Third, this study is relevant and timely in the context of Sudan, given the country suffers from long persistent civil conflicts and poverty. Therefore, the findings of this study would help in designing an effective strategy for achieving the Sustainable Development Goals (SDGs) (especially, SDG Goal 10: Reduced inequalities).

The analysis was performed for both national and regional levels, adopting parametric and non-parametric decomposition approaches. It revealed that the share of child health inequality attributable to inequality of opportunity is significant but varies across regions. The results also indicated that geographic regions, parental wealth, and parents' education represent the principal factors of inequality of opportunity in child health across and within regions. However, infrastructure and demographic factors have less impact on inequality of opportunity.

The rest of this paper is organized as follows. Section 2 outlines data sources and methodology. Section 3 presents some descriptive statistics about child health in Sudan along with the findings on measurement and decomposition of inequality of opportunity. Section 4 concludes with some policy implications.

2. METHODOLOGY AND DATA

To analyse inequality of opportunity in child health, first we compute the standardized anthropometric indicators of child health outcome, namely, the variables height-for-age and weight-for-height.[1] Next, we measure inequality for height-for-age and weight-for-height variables, and then decompose them into a portion that is due to observable circumstances (i.e. inequality of opportunity) and a residual measure. We also identify the partial effect of each group of circumstances on inequality of opportunity. Furthermore, for further investigation of effect of circumstances on inequality we stimulate the standardized height and weight for children with the 'greatest' and 'worst' amalgamation of observed circumstances.

[1] We focus on two anthropometric measures, namely, height-for-age and weight-for-height. Height-for-age is considered an appropriate indicator for child health status because it reflects general health status and represents the accumulation of episodes of poor nutrition or illness (Pradhan et al., 2003). On the other hand, weight-for-height is also a good outcome measure because it helps determine the short-term variations in nutrition. Moreover, as height-for-age and weight-for-age are highly correlated across individuals, a more independent measure of the short-term nutritional achievement controlling for long-term nutrition is weight-for-height (Assaad et al., 2012).

2.1. Computing Standardized Child Health Outcome

It is well known that height and weight of children increase with age and vary according to gender of the child (Pradhan et al., 2003; Assaad et al., 2012). Thus, to remove the standard variations in height and weight over age and sex, most empirical literature on child health uses a reference distribution for 'healthy' children developed by the US Center for Disease Control (CDC). This reference is commonly used to measure either the percentile of child height and weight in the reference distribution of children of the same sex or age (usually in months) or their z-score (Kuczmarski et al., 2002). The z-score measures the divergence of child health outcome from the median of the reference, calculated in terms of standard deviation of the reference distribution. Nevertheless, both percentile measures and z-score transformations change the scale of measurement, and hence alter inequality measures in arbitrary ways (Assaad et al., 2012). To address this problem, we compute the standardized value of height and weight variables, following the literature on child health inequality (e.g. Pradhan et al., 2003; Assaad et al., 2012). Therefore, using the CDC reference distribution we transform the z-score of the height or weight into the equivalent height or weight for a 24-month-old female with the identical z-score. In other words, the actual height of a child in the sample is transformed to a standardized height using the distribution of height based on the CDC reference. Accordingly, the standardized height can be set as follows:

$$H = F_{\bar{a},\bar{g}}^{-1}\left(F_{a,g}(h)\right), \tag{2}$$

where F denotes the distribution function of heights in the CDC population for a child of age (a) and gender (g). h is the actual height of that child; $\bar{a} = 24$ months; $\bar{g}$ is the female; and H is the standardized height.

To compute the standardized weight-for-height measure, we adopt a formula similar to that used in the case of standardized height-for-age. Appendix A provides an example for height-for-age and weight-for-height transformation.

2.2. Measuring and Decomposing Inequality

2.2.1. Measuring Inequality

To measure inequality of opportunity in child health outcome, this study uses the general entropy (GE) measures. This measure has several advantages over the conventional inequality measures such as Gini coefficient and decile ratio index (Ferreira and Gignoux, 2008). The general entropy measures are decomposable into inequality within and between groups, hence allowing us to identify the contribution of inequality of opportunity to total inequality. In addition, compared to other inequality methods (e.g. Gini index), GE measures are additively inequality indices with a number of desirable theoretical properties (Duclos and Araar, 2006).

Following Duclos and Araar (2006), the classes of GE for a distribution with a continuous outcome variable y can be described as follows:

$$GE(\alpha)\begin{cases} \int_0^1 \ln\left(\frac{\mu}{Q(p)}\right) dp & if\ \alpha = 0, \quad (3) \\ \int_0^1 \frac{Q(p)}{\mu} \ln\left(\frac{Q(p)}{\mu}\right) dp & if\ \alpha = 1, \quad (4) \\ \frac{1}{\alpha(\alpha-1)}\left(\int_0^1 \left(\frac{Q(p)}{\mu}\right)^{\theta} dp - 1\right) & if\ \alpha \neq \{0,1\}, \quad (5) \end{cases}$$

where p is the percentage of population below a certain value of our outcome variable (y), μ is the mean of the distribution, $y = Q(p)$ is the quantile function, and $F(Q(p)) = p$. Moreover, $Q(p)$ is the outcome level below which we find p (i.e. the proportion of the population). This captures the outcome level (e.g. height-for-age) of a person whose percentile in the population distribution is p (Duclos and Araar, 2006). For instance, if the 50th percentile (median) value of this distribution is $Q(0.5)$, then at $ymax$, the proportion of the population $F(ymax) = 1$. The GE class of measures relies on a parameter α, which captures the weight specified for distances between outcomes at different elements of the distribution of outcomes.

The GE indices include GE(0), GE(1), and GE(2), where each one determines the degree of sensitivity of the index to differences in the outcome at different positions in the distribution (Duclos and Araar, 2006). GE(0) or Theil's L index can be interpreted as the mean logarithmic deviation between $Q(p)$ and μ. Because of the logarithmic transformation, it places more weight on divergences from the mean at the lower parts of the distribution. Compared with other decomposable inequality indices, GE(0) is the only measure considered to be path independent, indicating that the result of the decomposition is the same whether the direct or the residual method is adopted. On the other hand, GE(1), or Theil's T index, can be computed by multiplying what is inside the integral by $Q(p)/\mu$. Finally, the GE(2) index is computed as a half square of the coefficient of variation (SD/μ). GE(2) places more weight on deviations at higher parts of the distribution. For the purpose of comparison, we compute all GE classes, namely, GE(0), GE(1), and GE(2).

2.2.2. Decomposing Inequality

After measuring total inequality, the next step is to decompose the total inequality into within- and between-group inequality. Groups (types) refers to the collection of individuals with identical combination of circumstances. That is, children with the same observable circumstances C are grouped in the same type k. Hence, decomposing inequality allows us to split the observed inequality into a between-type inequality and a within-type inequality. Based on Roemer's framework, the share of between-type inequality to total inequality is a measure of inequality of opportunity. With k types, we decompose inequality as follows:

$$GE(\alpha) = \sum_{k=1}^{K} \phi(k) \left(\frac{\mu_k}{\mu}\right)^{\phi} GE(K;\alpha) + \bar{G}\bar{E}(\alpha), \tag{6}$$

where $\phi(k)$ denotes the fraction of the population in type k, μ_k is the mean height or weight of type k, and $GE(k;\alpha)$ is the GE index of type k. The first part in the right-hand side of the above equation reflects within-group inequality. On the other hand, $\bar{G}\bar{E}(\alpha)$ captures between-group component of inequality.

2.2.2.1. The path of decomposition

To measure the share of inequality of opportunity (i.e. between-type inequality) we can use either direct or residual method depending on the path of the decomposition, which relies on whether smoothed or standardized distribution is adopted. As explained in Equations (7) and (8), the smoothed distribution $\{\mu_i^k\}$ highlights the between-group variations by substituting the mean of each type k for y_i^k and the standardized distribution $\{v_i^k\}$ reflects within-group variations by replacing each y_i^k with $v_i^k = y_i^k \frac{\mu}{\mu_k}$. Following Ferreira et al.'s (2011) framework, the direct and residual measures of the share of inequality of opportunity can be specified by:

$$\theta_d = \frac{I(\{\mu_i^k\})}{I(\{y_i^k\})}, \tag{7}$$

$$\theta_r = 1 - \frac{I(\{v_i^k\})}{I(\{y_i^k\})}. \tag{8}$$

Equation (7) reflects the ratio of inequality in the smoothed distribution to the total inequality, which provides between-group inequality (i.e. the direct method). Equation (8) captures the residual method of computing between-group inequality, which is equal to one minus the ratio of inequality in the standardized distribution to the total inequality.

2.2.2.2. Parametric and non-parametric methods

To decompose the inequality measures, this study adopts both parametric and non-parametric methods for the purpose of comparison and robustness check. While the parametric method uses regression to link the observed circumstances to the outcome of interest, the non-parametric method measures the differences in outcome across the k circumstance groups (types). Due to lack of a large dataset, we adopt only the type specification of non-parametric decomposition.[2]

The parametric approach postulates a parametric equation that relates outcome variable y to a vector of observed circumstances C. Therefore, the parametric model can be described as follows:

$$y_i = C_i\gamma + \varepsilon_i. \tag{9}$$

Based on the vector of estimated coefficients (γ), the smoothed distribution can be estimated as follows:

$$\tilde{\tilde{Z}}_i = C_i\hat{\gamma}, \tag{10}$$

where $\tilde{\tilde{Z}}_i$ is the predicted value of y based on the estimated coefficients of Equation (10). This smoothed distribution relies only on the set of circumstances C_i, hence removing any within-type variability and keeping only between-type inequality. This also generates the direct parametric estimate of the contribution of inequality of opportunity θ_d as in Equation (7) by substituting $\tilde{\tilde{Z}}_i$ for μ_i^k.

On the other hand, the standardized distribution based on the residual method can be estimated as follows:

$$\tilde{\tilde{y}}_i = \bar{C}_i\hat{\gamma} + \hat{\varepsilon}_i, \tag{11}$$

where $\bar{C}$ is the vector mean of circumstances. Because differences in circumstances are controlled for, the remaining variability is entirely within-group inequality. Therefore, the residual parametric estimate of the share of inequality of opportunity θ_r can be calculated as revealed in Equation (8) by substituting $\tilde{\tilde{y}}_i$ for v_i^k (Ferreira and Gignoux, 2008).

The main advantage of parametric estimation is the possibility to determine the partial share of a group of circumstances such as parents' education and gender in inequality of opportunity. To compute the partial effect of a particular circumstance M, we can use the following standardized distribution model:

$$\tilde{\tilde{y}}_i^M = \bar{C}^M\hat{\gamma}^M + C_i^{m\neq M}\hat{\gamma}^{m\neq M} + \hat{\delta}_i. \tag{12}$$

This enables us to estimate the variation due to circumstance M while keeping the difference that emerges from other unobservable circumstances. Thus, the share of inequality due to circumstance M can be set as follows:

[2] Another approach of non-parametric analysis is the tranche method, but it cannot be applied in the present study due to smallness of dataset, particularly for the cross-region analysis.

$$\theta_r^M = 1 - \frac{I(\{\tilde{\tilde{y}}_i^M\})}{I(\{y_i\})}. \tag{9}$$

The non-parametric method also applies both direct and residual methods of estimating inequality of opportunity. The direct measure is captured by the ratio of inequality of a smoothed distribution across types over total inequality, as in Equation (7). Likewise, a residual measure of the share of inequality of opportunity is computed by the standardized distribution $\{v_i^k\}$ across all types, as in Equation (8).[3] The non-parametric type approach that adopted in this study is developed by Checchi and Peragine (2010), which splits the population into groups by circumstance categories, with the members of each group, called type, consisting of individuals with identical circumstances.[4]

In case of type specification of non-parametric decomposition, we categorized the sample of the under-five children into eighteen types based on three main circumstances, namely mother's education (3 variables), wealth groups (3 variables) and urban/rural residence (2 variables). Appendix C shows the combination of circumstances and number of observations in each cell.

2.3. Stimulating Most- and Least-Advantaged Child

To provide more insight into the role of circumstances in inequality of opportunity in child health, we used a variety of circumstance variables to simulate the "most-advantaged" and "least-advantaged" child. The most-advantaged reflects a state in which all the circumstance variables in their most advantageous level, while the least-advantaged captures a situation in which all circumstances at their least advantageous level. The difference between the most-advantaged and least-advantaged child captures the role of circumstances and therefore the significance of inequality of opportunity. The simulations are based on the regression analysis of the two outcomes (i.e. height-for age and weight-for-height), using the base parametric specifications. That

[3] In practice, producing standard errors for the estimated inequality indices and decompositions is not automatic. We therefore depend on bootstrapped standard errors, following the example of Ferreira and Gignoux (2008). This is done by estimating standard errors from the distribution of estimated inequality indices, which themselves are estimated from multiple sub-samples with a given number of replications. We used 300 replications to obtain the sub-samples.

[4] The disadvantage of the type approach is that with any realistic group of circumstances the number of cells *K* will become so large that the cell sizes would be inappropriate to obtain reliable estimates of the inequality measures. Hence, the main drawback of the non-parametric approach is that it requires large datasets. The greater the set of circumstances, the higher the number of cells in the partition and the higher the number of cells with zero or few observations. Moreover, this approach does not allow estimating partial effects of circumstances (Belhaj Hassine, 2011).

is, the probability of an outcome, for instance, height-for-age, is predicted based on the coefficients from the standard regression and the circumstances of the child (least or most advantaged). The least-advantaged child is one who lives in the poorest quintile of households in rural areas and whose mother and father have had no education. While the most-advantaged child is one who lives in the richest quintile of households in an urban area in Khartoum region and whose parents have had higher education. This comparison enables us to measure the impact of multiple circumstances simultaneously on child health outcome.

2.4. Data

Data for this study are sourced from the 2014 MICS, a nationally representative, cross-sectional, household survey. The survey is carried out by the Central Bureau of Statistics in Sudan, as part of a broader international household survey designed and implemented by the United Nations Children's Fund. The MICS includes anthropometric information (i.e. height and weight) for children under five and contains detailed information on health, social and economic circumstances of women, children and other household member characteristics that are needed in this study. The analysis in this research focuses on a sample of 12,923 children under five.

Circumstance variables

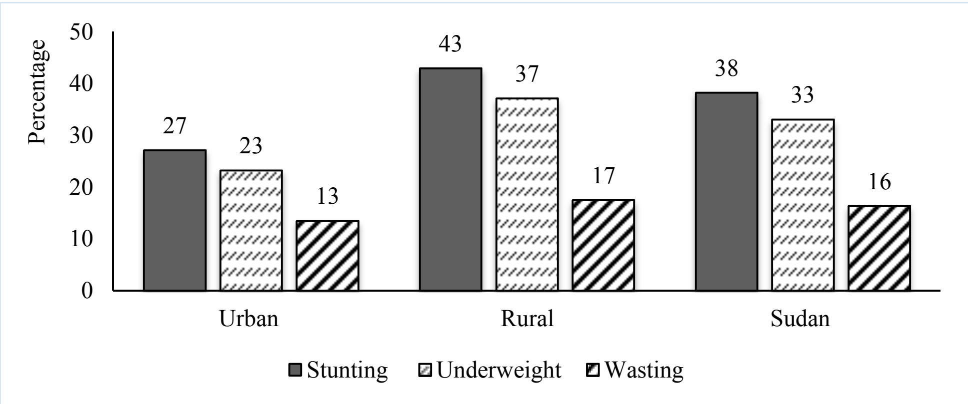
Circumstance variables include those variables that might determine early childhood access to good health. Following the recent literature on child health production and inequality (e.g. Krafft, 2015; Jemmali and Amara, 2015; Assaad et al., 2012; Pradhan et al., 2003; Blau et al., 1996; Kabubo-Mariara et al., 2008), the circumstance variables used in our analysis are categorized into five groups, namely, parents' education, parental wealth, geographic regions, public services, and demographic characteristics. Parents' education includes the education level of both mothers and fathers, while parental wealth involves the quintiles of household wealth. Regional variables consist of the main geographic zones of Sudan (Khartoum, Central, Northern, Eastern, Kordofan, and Darfur) and the residence location (i.e. urban/rural). Public services include access to clean water and improved sanitation services. Finally, the demographic characteristics consist of childbirth and mother's characteristics, such as order of the child in the household, whether the child is a twin or single, the sex of the child, and the mother's age. All these variables reflect conditions and behaviours that are largely beyond a child's control. The summary statistics of these variables are presented in Appendix B.

3. EMPIRICAL RESULTS AND DISCUSSION

This section is divided into two sub-sections. Sub-section 4.1 reports some descriptive statistics about child nutritional status in Sudan. Sub-section 4.2 presents empirical results pertaining to measurement and decomposition of inequality of opportunity in child health outcome across national and regional levels.

3.1. Child Malnutrition in Sudan: An Overview

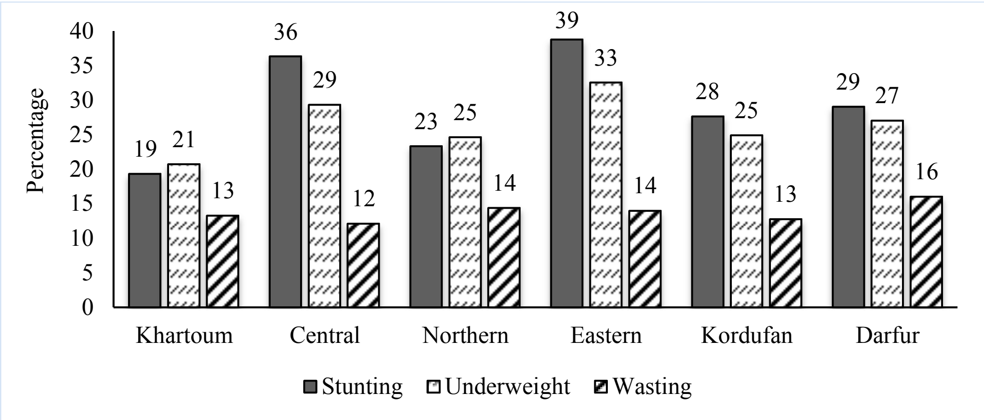
To understand child nutritional status in Sudan, this section examines the three main nutritional indicators, namely, stunting, underweight and wasting, for children under five by region and gender. Stunting, underweight, and wasting are defined as having, respectively, a height-for-age, weight-for-age, and weight-for-height z-scores that are below two standard deviations from the median of the relevant CDC's healthy child reference distribution. Figure 1 presents the anthropometric measures of children by region. The figure indicates that there is a regional disparity in child health, as those residing in rural areas are more underweight, stunted, and wasted than those living in urban areas. The prevalence of underweight is 23.2 per cent in urban areas and 37.1 per cent in rural areas. About 17.4 per cent of children living in rural areas are stunted compared with 13.4 per cent in urban areas. In addition, the difference in prevalence of child stunting between rural (42.9 per cent) and urban (27.1 per cent) areas is very wide. Regarding nutritional indicators at the national level, the figure indicates that about 38.2, 33, and 16.3 per cent of the total number of children under five are stunted, underweight, and wasted, respectively. This implies a high prevalence of poor nutritional status among children under five in Sudan.



Source: The 2014 MICS in Sudan (see Central Bureau of Statistics, 2016).

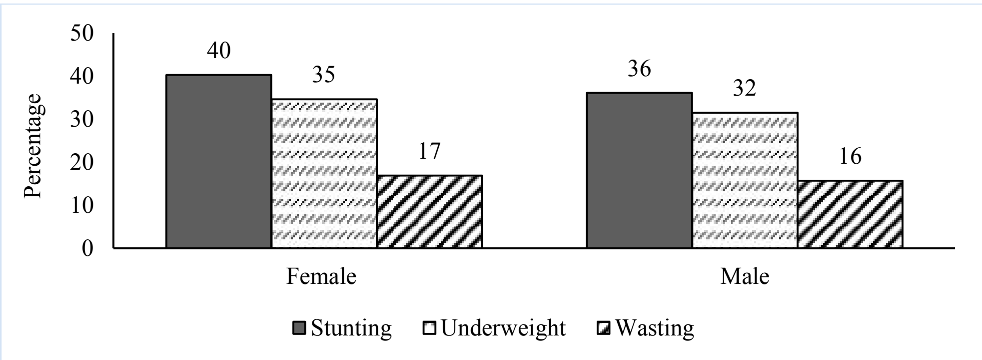
Figure 1. Nutritional Status of Children under Five by Place of Residence in Sudan (%)

To understand the situation of child health across geographic zones in Sudan, Figure 2 plots the three nutritional indicators by the main geographic regions. The figure depicts that Khartoum and the Northern region have lower percentages of malnutrition indicators. Expectedly, the Eastern region reports the highest percentages of stunting and underweight compared with other regions, exceeding the national level. Darfur is ranked second after the Eastern region in terms of poor nutritional status. The high incidence of undernutrition in the Eastern region and Darfur can be explained by the high rate of poverty and inequality in these regions. Moreover, Darfur suffers from long civil conflict and disadvantaged economic situations.



Source: The 2014 MICS in Sudan (see Central Bureau of Statistics, 2016).

Figure 2. Nutritional Status of Children under Five by Geographic Regions in Sudan (%)



Source: The 2014 MICS in Sudan (see Central Bureau of Statistics 2016).

Figure 3. Nutritional Status of Children under Five by Gender in Sudan (%)

Finally, Figure 3 presents the child nutritional status by gender. The figure shows that boys are more exposed to nutritional problems than girls. In all indicators male children exhibit higher incidence of nutritional deficiencies. These findings are in line with the findings documented in other studies in Sub-Saharan Africa, which report lower stunting rates for girls than for boys (e.g. Wamani et al., 2007).

Regarding the descriptive statistics of the circumstances used in the analysis, Appendix B describes the summary statistics of circumstance variables. The high standard deviation of standardized height and weight-for-height implies a high disparity in nutritional status among children under five, confirming the results reported in Figures 1-3. The descriptive statistics also reveals that the average of secondary and higher education for both mothers and fathers is very low, indicating that most of the rural population has a lower level of educational attainment. The high mean of illiterates for both mothers and fathers also signifies the prevalence of illiteracy in Sudan. Interestingly, the summary statistics indicates that the mean of piped water and improved sanitation is very low, confirming the poor housing environment, which may affect child health status.

3.2. Empirical Results: Inequality Measurement and Decomposition

This section presents the results of estimating and decomposing inequality of opportunity in child health in Sudan. First, we present the results of total inequality and the contribution of inequality of opportunity to total inequality at both national and regional levels. Second, we report the results of contribution of each group of circumstances to inequality of opportunity. Finally, we present the simulation results of health outcome for the least- and most-advantaged children.

3.2.1. Total Inequality in Child Health Outcome

Table 1 presents the results of estimated total inequality in standardized height-for-age and weight-for-height of children under five. The table reports the results of GE(0), GE(1), and GE(2) indices for the national level. For all general entropy indices, the estimated inequality in height-for-age (stunting) is higher than inequality in weight-for-height (wasting). The table also shows that all inequality measures are statistically significant at all significance levels.

Regarding total inequality in child health by gender of the child and place of residence, Table 2 reports some variations in inequality for both height-for age and weight-for-height. The table points out that while the overall inequality in child health for both male and female children exhibits the same pattern of inequality at the national level, inequality measures among male children are slightly higher than that among female counterparts. This finding confirms the disparity in nutritional status across gender as presented in the descriptive statistics section (Section 4.1). Moreover, the table shows that inequality in both height-for age and weight-for-height in rural areas is higher than that in urban areas and at the national level. These findings confirm high disparity in child health across place of residences in Sudan.

Table 1. Total Inequality: Height-for-Age and Weight-for-Height at the National Level

Indicator	$GE(0)$	$GE(1)$	$GE(2)$
Height-for age (stunting)	0.01100*** (0.00017)	0.01160*** (0.00017)	0.01240*** (0.00018)
Weight-for-height (wasting)	0.00681*** (0.00022)	0.00699*** (0.00024)	0.00724*** (0.00026)

Note: Standard errors in parentheses. *p<0.01, **p<0.05, ***p<0.001.
Source: Author's compilation based on the 2014 MICS in Sudan (see Central Bureau of Statistics, 2016).

Table 2. Total Inequality: Height-for-Age and Weight-for-Height by Gender and Place of Residence

Indicator	$GE(0)$	$GE(1)$	$GE(2)$	$GE(0)$	$GE(1)$	$GE(2)$
Gender of child	Female			Male		
Height-for-age	0.0109*** (0.0003)	0.0115*** (0.0003)	0.0123*** (0.0003)	0.0110*** (0.0002)	0.0116*** (0.0002)	0.0125*** (0.0002)
Weight-for-height	0.0064*** (0.0001)	0.0066*** (0.0002)	0.0068*** (0.0002)	0.0070*** (0.0001)	0.0071 (0.0001)	0.0074*** (0.0001)
Place of residence	Urban			Rural		
Height-for-age	0.0093*** (0.0002)	0.0099*** (0.0002)	0.0106*** (0.0003)	0.0115*** (0.0002)	0.0122*** (0.0002)	0.0131*** (0.0002)
Weight-for-height	0.0065*** (0.0002)	0.0066*** (0.0002)	0.00686*** (0.0002)	0.00681*** (0.00015)	0.0069*** (0.00016)	0.00724*** (0.00018)

Note: Standard errors in parentheses. *p<0.01, **p<0.05, ***p<0.001.
Source: Author's compilation based on the 2014 MICS in Sudan (see Central Bureau of Statistics, 2016).

To examine the pattern of child health inequality across regions, Table 3 presents the results of generalized entropy classes of inequality for the six geographic regions of Sudan. The results indicate that there is a remarkable variation in inequality measures across regions, signifying the geographic disparity in child health outcome in Sudan. The table shows that Khartoum has very low inequality measures for both height and weight indicators. This can be justified by the fact that Khartoum is the more urbanized area in the country with low child malnutrition. However, the Eastern region, Kordofan, and Darfur report the highest inequality indictors for both height and weight. It is worth mentioning that these regions are home to a big portion of population who suffer from poverty, conflict, and food insecurity. This finding, therefore, implies that child health inequality is dominant in poor and conflict-affected regions. This result also confirms the large regional disparity in access to public services in Sudan.

Table 3. Total Inequality: Height-for-Age and Weight-for-Height by Geographic Regions

Indicator	Height-for-age			Weight-for-height		
	GE(0)	*GE*(1)	*GE*(2)	*GE*(0)	*GE*(1)	*GE*(2)
Khartoum	0.00447***	0.00476***	0.00511***	0.00494***	0.00491***	0.00492***
	(0.00075)	(0.00081)	(0.00088)	(0.00029)	(0.00029)	(0.00029)
Northern	0.00684***	0.00722***	0.00771***	0.00623***	0.00631***	0.00646***
	(0.00059)	(0.00062)	(0.00067)	(0.00024)	(0.00025)	(0.00028)
Central	0.00881***	0.00937***	0.0101***	0.00722***	0.00742***	0.00771***
	(0.00050)	(0.00053)	(0.00057)	(0.00025)	(0.00027)	(0.00030)
Eastern	0.0135***	0.0142***	0.0152***	0.00760***	0.00780***	0.00809***
	(0.00068)	(0.00068)	(0.00068)	(0.00034)	(0.00037)	(0.00042)
Kordofan	0.0138***	0.0145***	0.0153***	0.00684***	0.00700***	0.00723***
	(0.00049)	(0.00048)	(0.00048)	(0.00028)	(0.00030)	(0.00032)
Darfur	0.0106***	0.0112***	0.0120***	0.00693***	0.00709***	0.00734***
	(0.000187)	(0.000192)	(0.000199)	(0.000117)	(0.000127)	(0.000142)

Note: Standard errors in parentheses. *p<0.01, **p<0.05, ***p<0.001.

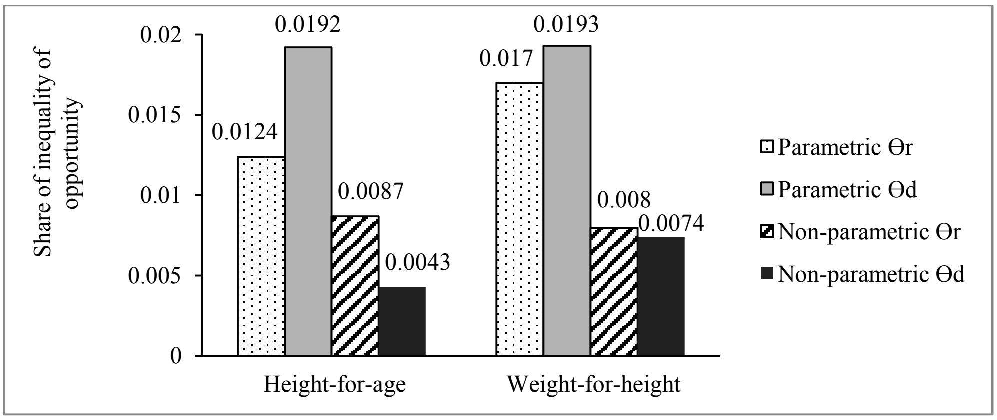
Source: Author's compilation based on the 2014 MICS in Sudan (see Central Bureau of Statistics, 2016).

3.2.2. Contribution of Inequality of Opportunity: Parametric and Non-Parametric Specifications

After measuring total inequality, the next step is to identify the contribution of inequality of opportunity (between-group inequality) to overall inequality. Because some circumstances are not observable due to lack of data, the share of inequality of opportunity that we measure must be interpreted as lower bound estimates, while unobserved factors are absorbed into the unexplained component, such as natural variations across children.

Figure 4 shows the results of direct (θ_d) and residual (θ_r) measures of inequality using parametric and non-parametric approaches. The results are based on $GE(0)$ class of generalized entropy measure.

As shown in Figure 4, the estimated share of inequality of opportunity in total inequality varies according to the method of inequality. The parametric method reports higher estimates of inequality of opportunity with both direct and residual approaches, whereas the non-parametric specification produces lower inequality estimates for both height and weight measures. For both parametric and non-parametric estimates, the results of residual and direct measures are presented in Appendix D. The results indicate that all estimates are statistically significant, implying that the share of inequality of opportunity to total inequality in child health is significant. Since inequality of opportunity in child health is a result of circumstances that are out of a child's control, these findings suggests that circumstances play an essential role in influencing inequality of opportunity in child health in Sudan. However, the contribution of inequality of opportunity to total inequality is less than that reported in other empirical studies (e.g. Assaad et al., 2012; Hussien and Ayele, 2016). The low share of inequality of opportunity to total inequality can be justified by the fact there are potential factors (circumstances) affecting inequality of opportunity were not able to include in our analysis due lacking these variables in MICS survey. Thus, our results are likely a lower bound on the true inequality of opportunity. Indeed, many empirical studies indicate that the estimates of parametric or non-parametric of IOP can be higher if more circumstance variables used in the analysis (Ferreira and Gignoux, 2008; Brunori et al., 2013).



Source: Author's construction based on parametric and non-parametric specifications.

Figure 4. Share of Inequality of Opportunity to Total Inequality, $GE(0)$

To examine the regional disparities in contribution of inequality of opportunity to total inequality, Table 4 presents the share of inequality of opportunity to total inequality by region. Due to smallness of sample sizes across regions, we adopt only the parametric estimate in the regional analysis. The table shows that Khartoum has the highest share of inequality of opportunity to total inequality compared to other regions, using both direct and residual measures. This can be justified by the fact that since inequality of opportunity is attributed mainly to circumstances, Khartoum is home to the most well-off households with improved socio-economic situation, hence circumstances contribute significantly to total inequality in the region. However, for the other regions, the contribution of inequality of opportunity to total inequality is relatively low and varies across regions. This is because children in these regions live in unfortunate economic and social circumstances, as most of them belong to households with poor education and social background. This finding also confirms unequal circumstances across regions.

Table 4. Share of Inequality of Opportunity to Total Inequality by Region, $GE(0)$

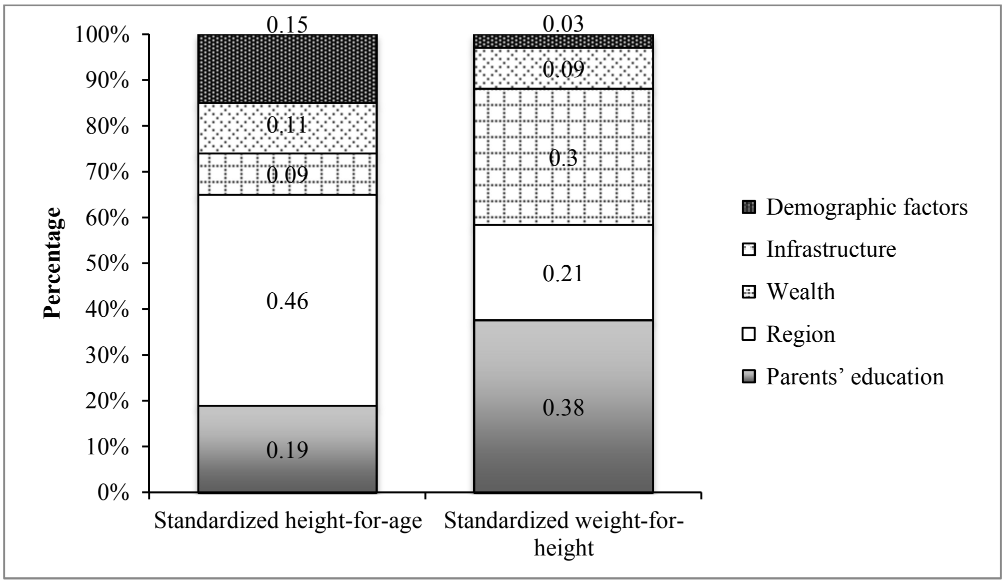
	Height-for-age		Weight-for-height	
	Parametric θ_r	Parametric θ_d	Parametric θ_r	Parametric θ_d
Khartoum	0.0501***	0.0841***	0.0583**	0.0618***
	(0.0112)	(0.0260)	(0.0203)	(0.0201)
Northern	0.0543***	0.0705***	0.0643***	0.0607***
	(0.0166)	(0.0215)	(0.0148)	(0.0149)
Central	0.0176**	0.0378***	0.0152***	0.0200***
	(0.0070)	(0.0102)	(0.0032)	(0.0037)
Eastern	0.0862***	0.0452***	0.0357***	0.0346***
	(0.0020)	(0.0103)	(0.0070)	(0.0080)
Kordofan	0.0961	0.0170**	0.0154***	0.0189***
	(0.0672)	(0.0075)	(0.0043)	(0.0055)
Darfur	0.0143***	0.0267***	0.0154***	0.0169***
	(0.0023)	(0.0038)	(0.0027)	(0.0030)

Note: Standard errors in parentheses. *p<0.01, **p<0.05, ***p<0.001.
Source: Author's compilation based on GE(0) measure of inequality.

3.2.3. Contribution of Circumstance Groups to Inequality of Opportunity

For further insight into the contributors of inequality of opportunity in child health, we estimate the partial effect of circumstances in inequality of opportunity across national and regional levels. These results are derived from the parametric method, which enables measuring the contribution of individual or group of circumstances to inequality of opportunity. To focus our discussion on the main circumstance groups, we grouped circumstance variables with similar characteristics into five categories. We grouped father's education and mother's education as 'parents' education', toilet facility and drinking water quality as 'infrastructure', and geographic region dummies as 'region', and wealth quintiles as 'wealth'. In the regional analysis, we used the place of residence (urban/rural) instead of geographic region. Finally, we grouped the demographic characteristics of the child and the mother as 'demographic factors'.

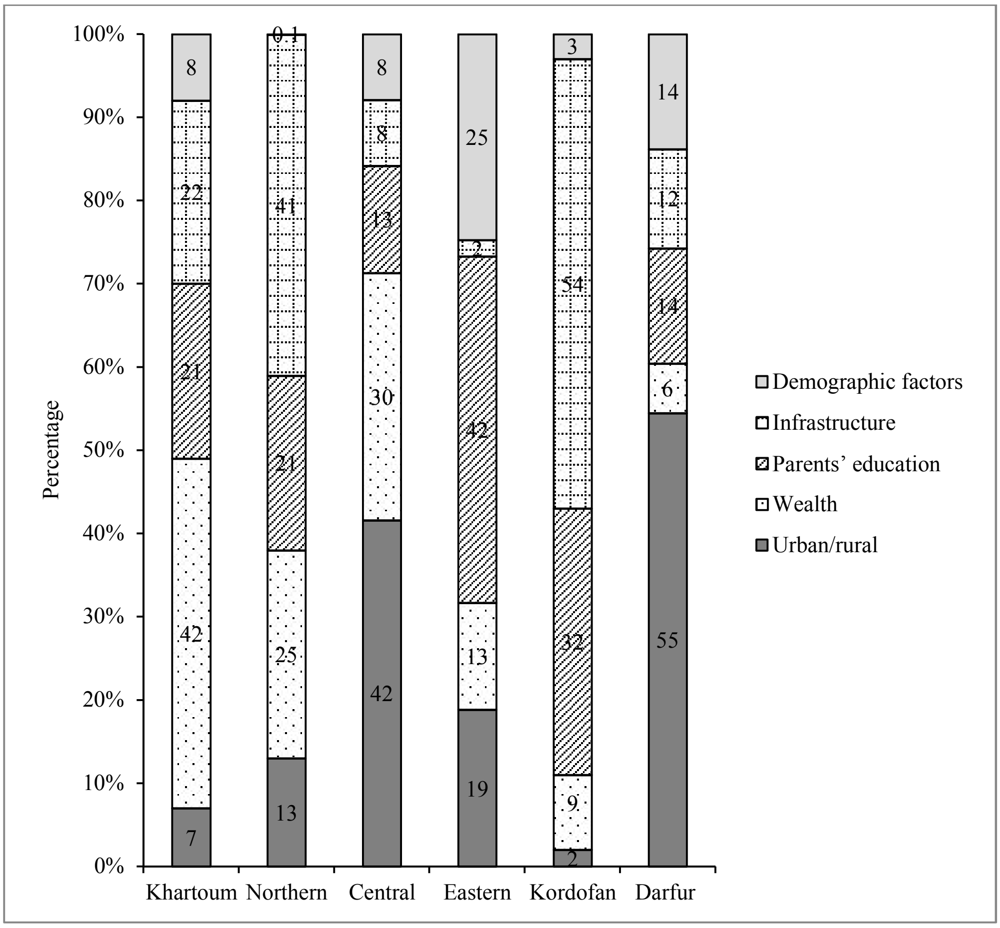
The results in Figure 5 of national level reveal that geographic location is the largest contributor to inequality of opportunity in height-for-age, signifying the role of regional disparity in inequality of opportunity. Parents' education comes in second as the main driver of inequality in height. The figure also indicates that for weight-for-height, parents' education accounts for the biggest contributor to inequality, whereas parental wealth is the second largest contributor to inequality of opportunity in weight-for-height. These findings imply that regional disparity and parents' education are the predominant contributors to inequality of opportunity in child health in Sudan. Infrastructure and demographic factors are found to have small contribution to inequality of opportunity in both height and weight-for-height variables. These findings are consistent with previous studies (e.g. Assaad et al., 2012; Hussien and Ayele, 2016;Amara and Jemmali, 2017).



Source: Author's construction based on $GE(0)$ measure of inequality.

Figure 5. Partial Effects of the Contribution of Different Sets of Circumstances to Inequality of Opportunity in Standardized Height and Weight-for-Height (Percentage)

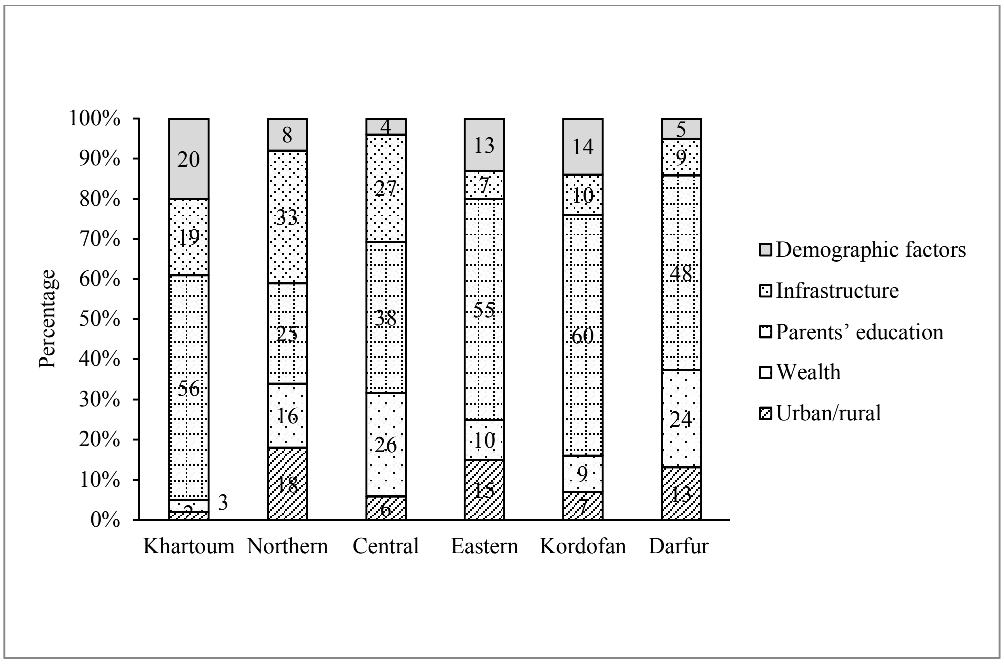
Regarding the regional level, Figures 6 and 7 show the share of sets of circumstance in inequality of opportunity for height and weight-for-height, respectively. For inequality of opportunity in height, Figure 6 shows that there is high variation in the contribution of circumstances across regions. For example, in Khartoum, parental wealth is the largest contributor to inequality of opportunity in health, while for the other regions, parental wealth has less contribution. Interestingly, for most regions parents' education is the second or third contributor to inequality in child health. For the Northern region and Kordofan, infrastructure is the largest share in inequality of opportunity in child health. In Darfur and the Central region, the urban/rural residence accounts for the biggest share in inequality of opportunity.



Source: Author's construction based on $GE(0)$ measure of inequality.

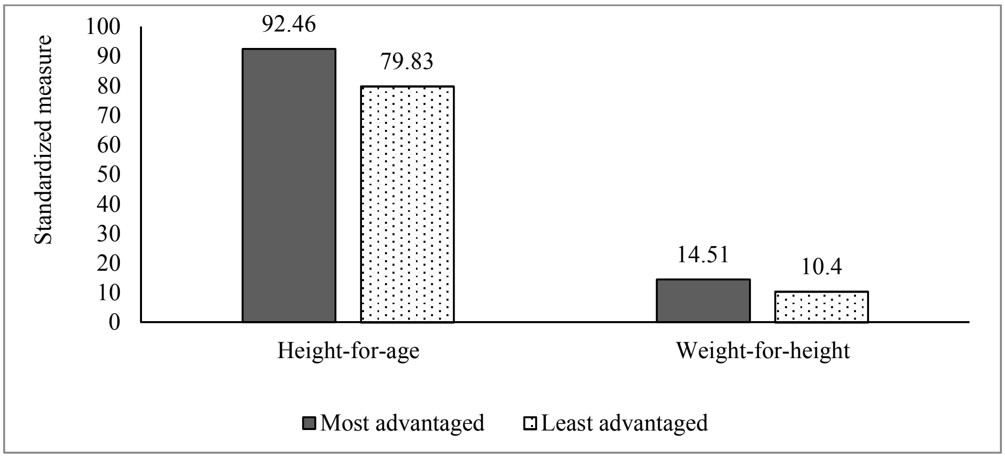
Figure 6. Contribution of Circumstances to Inequality of Opportunity in Standardized Height (Percentage)

Figure 7 presents the contribution of circumstances to inequality of opportunity in standardized weight-for-height. The figure indicates that for most regions parents' education accounts for the largest share in inequality of opportunity, confirming the results of the national level. The figure also reports a disparity in the contribution of other factors to inequality of opportunity in child weight across regions. These regional variations in the contribution of circumstances to inequality of opportunity signify the economic and social disparities across regions. Therefore, addressing inequality of opportunity requires special attention to distribution of public services across regions.



Source: Author's construction based on $GE(0)$ measure of inequality.

Figure 7. Contribution of Circumstances to Inequality of Opportunity in Standardized Weight-for-Height (Percentage)



Source: Author's construction based on simulation process.

Figure 8. Simulations of Standardized Height and Weight-for-Height for Most- and Least-Advantaged Children

4.2.4. Most- and Least-Advantaged Child Simulations

Finally, the simulation results of height and weight of children in terms of the circumstances for a least-advantaged child versus a most-advantaged child are presented in Figure 8. The figure shows the predicted height and weight for most- and least-advantaged children. The results reveal that there is an obvious gap between the most- and least-advantaged children in terms of both height and weight-for-height, indicating that circumstances have an effective impact on child health outcome.

4. CONCLUDING REMARKS

Motivated by the obvious disparity in child health outcome across regions in Sudan, this study examines inequality in child health outcome due to unequal circumstances. The study used the 2014 MICS, measuring and decomposing inequality via parametric and non-parametric approaches. Taking a different approach from Roemer's framework of inequality, we explain inequality of opportunity in child health by observable circumstances, while considering genetic variation and luck as residual inequality, which is not attributable to differences in opportunities.

The study results show that there is high inequality in child health outcome in Sudan as expected. The results also indicate high variations in health inequality across regions, and the estimated share of inequality of opportunity in total inequality is substantial and varies across regions. Moreover, circumstances are found to contribute significantly to inequality of opportunity in child health, but their effects vary across regions as well. Specifically, parental wealth, geographic region, and parents' education represent primary factors contributing to inequality of opportunity in both height-for-age and weight-for-height. Therefore, unequal distribution of household wealth and education across regions plays a critical role in inequality in child health outcome. Thus, we conclude that child health outcome is dependent on the region where a child lives, parental wealth, and parents' education. However, infrastructure and demographic factors have less impact on inequality of opportunity. Finally, to assess differences between the best and worst circumstances, we used the parametric estimates of the effects of circumstances on child health outcome to simulate height and weight outcomes for a most- and least-advantaged child. The simulation results reveal a considerable gap between the most- and least-advantaged group particularly in height outcome, signifying the importance of circumstances in health inequality.

In light of the above findings, serious interventions should be adopted to reduce inequality of opportunity in child health in Sudan. Circumstances that are causing inequality of opportunity should gain more attention. Specifically, measures that reduce wealth inequality and improve access to public health and services, such as education and clean water, should be on the top of policy agendas. Considering the high inequality of opportunity within poor and conflict-affected regions, special attention should be paid to equal distribution of public services across regions to enhance fair chances for child health within and between regions.

This study has some limitations. First, other potential factors (circumstances) affecting inequality of opportunity in child health may exist, which we were unable to investigate due to lack of data. For example, the distance to healthcare facilities may influence the provision of healthcare, hence resulting in disparities in child health. Thus, our results are likely a lower bound on the true inequality of opportunity. The actual estimates would be much higher if data for more circumstance variables were available and if other indicators of economic welfare, such as household income and parents' occupation, were included in the analysis. Second, the data we used were drawn from the 2014 MICS (Central Bureau of Statistics, 2016), which is the only available survey of such type; hence unavailability of other MICS prevented us from investigating the trend of inequality of opportunity over time.

APPENDIX

Appendix A. Transforming Height-for-Age and Weight-for-Height into Standardized Values: An Example

To elaborate the process of transforming height-for-age and weight-for-height into standardized values, Appendix A presents an example. For instance, from the MICS data we observe that a 52-month-old male who is 97.7 cm in height. Using the 2000 CDC growth charts for a 52-month-old male following Kuczmarski et al., 2002, we calculate his z-score to be −1.56. We then use this relative position to determine what his height would be if he were a 24-month-old female, which is 83.6 cm. This 52-month-old for male with a height of 97.7 cm thus maintains his relative position but has a standardized height that can be compared with standardized heights for other children at different ages and sex.

Table A1. Height-for-Age and Weight-for-Height Transformation Example

Original value from the MICS survey	*z*-score	Standardized height/weight
Height for a 52-month-old male: 97.7 cm	−1.56	83.6 cm
Weight for a male with a height of 100 cm: 13 kg	−1.70	8.9 kg

Source: Author's compilation based on the 2014 MICS in Sudan (see Central Bureau of Statistics, 2016).

Appendix B. Descriptive Statistics of Variables Used in the Analysis

Table A2. Descriptive Statistics of Variable

Variable	Definition	Mean	Std
Nutritional indicators			
Standardized HAZ	Standardized height-for-age measure	85.8085	12.5344
Standardized WHZ	Standardized height-for-weight measure	10.8412	1.2965
Mother's education			
No education	1=if mother is illiterate	0.4375	0.4961
Primary	1=if mother completed primary level	0.3467	0.4760
Secondary	1=if mother completed secondary level	0.1534	0.3604
High	1=if mother completed high education level	0.0623	0.2417
Father's education			
No education	1=if father is illiterate	0.4150	0.4927
Primary	1=if father completed primary level	0.3268	0.4691
Secondary	1=if father completed secondary level	0.1911	0.3932
High	1=if father completed high education level	0.0671	0.2502
Wealth quintile			
Poorest	1=if child belong to a poorest household	0.2033	0.4025
Poorer	1=if child belong to a poor household	0.2491	0.4325
Middle	1=if child belong to a middle-class household	0.2300	0.4208
Richer	1=if child belong to a rich household	0.1684	0.3742
Richest	1=if child belong to a richest household	0.1379	0.3448
Region			
Khartoum	1=if reside in Khartoum region and 0=otherwise	0.0532	0.2244
Central	1=if reside in the Central region and 0=otherwise	0.2639	0.4407
Northern	1=if reside in the Northern region and 0=otherwise	0.0851	0.2791
Eastern	1=if reside in the Eastern region and 0=otherwise	0.1445	0.3516
Kordofan	1=if reside in Kordofan and 0=otherwise	0.1759	0.3807
Darfur	1=if reside in Darfur and 0=otherwise	0.0532	0.2244
Residence			
Urban	1=if reside in urban region	0.2896	0.4536
Rural	1=if reside in rural region	0.7184	0.4497
Infrastructure/public services			
Piped water	1=if household has access to piped water and 0=otherwise	0.2853	0.4516
Public water	1=if household has access to public water and 0=otherwise	0.2941	0.4557
Water: other	1=if household has no access to safe water and 0=otherwise	0.4206	0.4937
Flush toilet	1=household has flushed toilet and 0=otherwise	0.0660	0.2483
Pit toilet	1=household has pit toilet and 0=otherwise	0.5859	0.4926
Toilet: other	1=household has no safe toilet and 0=otherwise	0.3481	0.4764
Demographic factors			
Twin birth	1=if the child is twin and 0=otherwise	0.0316	0.1751
Mother age	Age of mother in years	28.4145	7.4720
Birth order	Birth order	2.5287	0.9618
Child sex	1=if child is female	0.4865	0.4998

Source: Author's compilation based on the 2014 MICS in Sudan (see Central Bureau of Statistics, 2016).

Appendix C. Cell Sizes (Combination of Circumstances) Used in the Types Non-Parametric Estimates

Table A3. Cell Size

	Group/cell			No of observation
NO	Urban/rural	Mothers' education	Fathers' education	
1	rural	none	none	64
2	rural	none	prim&sec	426
3	rural	none	high	171
4	rural	prim&sec	none	3,530
5&6	rural	prim&sec	prim&sec & high	1,860*
7	rural	high	none	1,161
8	rural	high	prim&sec	1,882
9	rural	high	high	117
10	urban	none	none	33
11	urban	none	prim&sec	711
12	urban	none	high	377
13	urban	prim&sec	none	272
14&15	urban	prim&sec	prim&sec &high	184*
16	urban	high	none	545
17	urban	high	prim&sec	1,346
18	urban	high	high	97

Note: none, prim&sec and high denotes illiterate, primary & secondary and high education level, respectively.
* indicates combining two groups due to small number of observations.

Appendix D. The share of Inequality of Opportunity

Table A4. The Share of Inequality of Opportunity (θ) Using Parametric and Non-Parametric Methods and $GE(0)$ - Full Sample

	Parametric		Non-Parametric (type)	
Indicator	$\theta Pr1$	$\theta Pd1$	$\theta Pr1$	$\theta Pd1$
Height-for age (stunting)	0.0124*** (0.00164)	0.0193*** (0.00234)	0.0087*** (0.0032)	0.0043*** (0.0007)
Weight-for-height (wasting)	0.0170*** (0.00250)	0.0193*** (0.00294)	0.0083*** (0.0018)	0.0074*** (0.0027)

Note: Standard errors in parentheses. *** p<0.001.

Table A5. The Share of Inequality of Opportunity (θ) Using Parametric and $GE(0)$ – Male and Female Sample

	Females		Males	
Indicator	$\theta Pr1$	$\theta Pd1$	$\theta Pr1$	$\theta Pd1$
Height-for age (stunting)	0.00979***	0.0175***	0.0179***	0.0269***
	(0.00253)	(0.00379)	(0.00258)	(0.00353)
Weight-for-height (wasting)	0.0200***	0.0230***	0.0172***	0.0197***
	(0.00422)	(0.00471)	(0.00370)	(0.00414)

Note: Standard errors in parentheses. *** p<0.001.

Table A6. The Share of Inequality of Opportunity (θ) Using Parametric and $GE(0)$ – Urban and Rural Sample

	Urban		Rural	
Indicator	$\theta Pr1$	$\theta Pd1$	$\theta Pr1$	$\theta Pd1$
Height-for age (stunting)	0.0145***	0.0244***	0.0108***	0.0138***
	(0.00216)	(0.00319)	(0.00389)	(0.00433)
Weight-for-height (wasting)	0.0138***	0.0165***	0.0226***	0.0247***
	(0.00262)	(0.00315)	(0.00446)	(0.00505)

Note: Standard errors in parentheses. *** p<0.001.

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Mailing Address: Ebaidalla M. Ebaidalla, Qatar University, P.O. Box 2713, Doha, Qatar, Email: ebaidalla@qu.edu.qa

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