Wealth Inequality, Conflict and Population Health in Sudan

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ABSTRACT

Background: Researchers have demonstrated an association between income inequality and poor health outcomes over recent decades. We sought to understand the effects on health of both inequality and political armed conflict in Sudan, a northeast African country with seven international borders. Sudan's 31 million people represent diverse cultures, both Arabic and African. Sudan is a poor country, with a Human Development index of 0.41, ranking 171st of 187 countries. The country has suffered political instability since independence from Britain in 1956, with two revolutions and a 40-year civil war. Armed conflict in western Sudan and states bordering South Sudan are ongoing.

Methods: Data on 13,282 under five children were derived from the Sudan household survey round 2 (SHHS2), conducted between March and May 2010. The household assets index from that study was used as the indicator of living standards inequality. We also used data from the Sudan census conducted in 2008. We evaluated the role of both asset distribution and armed conflict in six health-related outcomes: life expectancy, infant mortality, teenage birth, height for age (stunting), vaccination coverage for children aged 12 to 23 months, and adequacy of food consumption.

Results: For four of our six measures of health in Sudan (food consumption, life expectancy, teen births and infant mortality), outcomes were significantly worse in the states with more skewness of wealth distribution, with correlation coefficients above .70 in all cases. For the two remaining health indicators, (height-for-age z scores or stunting, and vaccination coverage), we found weaker correlations with wealth skewness until we removed the conflict-affected states from the analysis. After removing those three states, the correlation coefficients on the stunting was significantly high again of .82 however there was no big difference for vaccination.

Conclusion: Wealth inequality and armed conflict are associated with poor population health in Sudan. Policies and public health strategies are required to address the distribution of resources and associated health problems. Wealth redistribution in the more unequal states, as well as a political resolution of conflict, may improve population health.

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DEDICATION

To the soul of my father Salahelddin Abdlgader Omer who loved me, believed in me and who taught me the meaning of life.

INTRODUCTION

This study hypothesizes a relationship between wealth inequalities and health outcomes in Sudan as measured by life expectancy, infant mortality, height for age, food consumption, teenage births and vaccination rates.

Inequality affects the health of millions of people globally, in both developed and developing countries. Inequality has been linked to physical and mental health problems, as well as broad social problems such as violence and crime. (1) The relationship between inequality and health captured researchers' interest decades ago. Rodgers studied income inequality as a determinant of health in 1979, concluding countries with more equal income distribution patterns enjoyed higher overall life expectancy. The average difference in life expectancy between more equal countries and less equal countries was as much as five to ten years. (2) Population health metrics, such as mortality, have been linked to social cohesion, trust and community support. Richard Wilkinson looked at British health during the two world wars and found British society was more egalitarian during the war periods. Life expectancy improved dramatically, two to three times greater than in other decades.(3, 4) Current researchers have built on this early work. Wilkinson and Pickett published a book in 2009 arguing that gross inequality undermines national life, kills trust, and generates a higher prevalence of frustration, depression and crime(1). Persons living in unequal societies or countries are inhibited from achieving their personal potential, which collectively inhibits their country's development and growth. Inequality also passes on health effects from one generation to the next; new generations can inherit poor health from previous generations who lived decades ago. Equality is a necessity for better life and better health outcomes. Emanuel *et al.* studied the relationship between grand-maternal and maternal factors in relation to maternal adult stature. Mother's stature was predicted partially by her own mother's stature, and partly by her birth weight. The study concludes, "some birth outcomes are already established before a prospective mother is conceived or born."(5)

Some researchers are arguing that even high levels of personal wealth do not protect the rich living in unequal societies. Biggs, *et al*, researched the effects of inequality and poverty on public health in low, middle, and high-income countries. They studied 22 countries in Latin America between 1960 and 2007, finding that while an increase in national gross domestic product (GDP) had a positive effect on population health, it was not sufficient to counter the effects of inequality and widespread poverty. With rising inequality, GDP had only modest effects on life expectancy and infant mortality rates. However, GDP had a large effect on population health when inequality was reduced. The authors concluded, "wealthier is indeed healthier, but how much healthier depends on how the increases in wealth are distributed" (6)

Similarly, Pop *et al* studied income inequality in relation to economic growth. Researchers studied life expectancy in 140 countries between 1987 and 2008. The study showed countries with higher levels of income inequality have lower levels of life expectancy in *both* low and middle-income countries. In high-income countries, the relationship was not significant. Authors suggest economic growth has a weaker benefit for population health in highly developed countries. (7)

The relationship between income and health is harder to study in low and middle-income countries, where measures of income are more difficult to approximate. Nowatzki studied the relationship between wealth inequality (rather than income inequality) and population health in 14 wealthy countries. She was able to use a wealth indicator in place of measures of monetary income, but still using the traditional "Gini coefficient," a measure of statistical dispersion of monetary income developed by the Italian statistician, Corrado Gini. Nowatzki confirmed wealth inequality was associated with life expectancy and infant mortality, and argued that relying on income instead of wealth is inadequate for addressing economic and health circumstances of individual and families in lower-income countries. (8)

Rasella *et al* studied income inequality on life expectancy in a highly unequal, but rapidly changing, developing country, Brazil (2000 to 2009). Authors concluded reducing income inequality in developing countries should be a first step towards increasing life expectancy(9). Olson *et al.* found a relationship between inequality and infant mortality rate in the US, highlighting the importance of the first 1,000 days of life and their effects on adult health. (10). In the Philippines, Kraft *et al.* showed wealth equity-markers were evident in relation to child mortality, and recent wealth-related inequalities were found to be strongly associated with many social factors (11). Another study in Ghana showed a strong association between childhood under-nutrition and inequality (12). "Stunting," a lower than expected body height for age, reflects childhood food insecurity and untreated infection. Elshibly and Schmalisch found a significant association between maternal body mass and newborn birth weight in Sudan. (13) Childhood growth failure is often used to measure the effects of health policies and health planning interventions over the long term.

Sudan, located in northeast Africa and covering 1.9 million square kilometers, borders seven countries. According to the 2008 census, Sudan's population was 31 million, with an equal sex ratio. Nearly two-thirds (63%) of the population live in rural settings, while 7% are nomads. The country is administratively divided into 17 states. Khartoum state, also the capitol of the country, has the largest population size, while the Northern state has the smallest. One in four Sudanese residents is under the age of five(14), and the adult literacy rate (population of 15 years and above) is 62%.(15) Sudan's diverse African and Arab cultures have clashed, with huge socio-economic differences between geographic regions. Much of the population (40%) lives below the poverty line of

approximately one dollar per day. The agricultural sector employs 80% of the workforce and contributes 33% to the GDP. Sudan faced a financial crisis in recent years, when the inflation rate rose to 16%, accompanied by an unemployment rate of 19%, and a public debt of 101% of the GDP. (16) In the context of rapid international gains in life expectancy, Sudan saw only a slight improvement in life expectancy over the last 20 years, reaching 63 years at birth. Sudan ranks 185th globally, 27 years of life expectancy behind Monaco and a nearly the same as Haiti (16) .

Sudan gained its independence from British colonizers in 1956, but political instability, generated by two revolutions and a 40-year civil war between the north and the south, have drained resources and compounded the economic and social effects of ethnic differences. In the western Darfur region, a conflict has raged since 2003, leading to the displacement of more than two million people and the killing of an estimated 400,000. (16) In 2005, North and South Sudan signed a peace agreement, which eventually led to South Sudan separating from the federal republic in July, 2011. Not long after independence, conflict commenced again between the two countries over oil rights. (17)

The annual rate of reduction in under-five mortality rate in Sudan for the recent 20-year period was only 1.7 %, a rate not on track to meet the Millennium Developmental Goals. Infant mortality in Sudan was reduced from 77 to 57 per 1000 live births in the same period (18), a number that is still unacceptably high. Sudan lags behind on Millennium Development Goals, with a prevalence of malnutrition at 32%. (19)

In this study we explore the correlation between wealth inequality and population health, using data from the nation's second Sudan Household Survey (SHHS2) conducted in 2010, and Census data from 2008. The health outcomes we measured included life expectancy, infant mortality, height for age, adequacy of food consumption, teenage birth and vaccination coverage.

METHODS

We analyze the relationship between wealth inequality and health outcomes in Northern Sudan, using data from a combination of Sudan's recently-released cross-sectional household health survey for most of our health outcomes data, as well as for our measures of wealth and its distribution. We used census sampling data for mortality data.

Data Sources

Sudan Household Health Survey-2

Data from the SHHS2, essentially equivalent to the internationally-known Demographic and Health Surveys (DHS), were released in early 2013. Carried out between March and May 2010, the survey was conducted by the Federal Ministry of Health and the Central

Bureau of Statistics (CBS). The effort was supported by Sudan's Government of National Unity's Ministry of Health and the Southern Sudan Commission for Census, Statistics and Evaluation. Financial and technical support to the SHHS2 were provided by the United Nations Children's Fund (UNICEF), the World Health Organization (WHO), U.S. and Japanese aid agencies, and several other United Nations agencies.

The SHHS2 was intended to generate representative data at the national and state levels on population and health indicators, with an emphasis on child and maternal health outcomes. The target population for the survey was children aged 0 to 59 months, women aged 15 to 49 years and men aged 15 to 49 years (20). A two-stage cluster sampling design was employed to draw the sample in each state. Using traditional sample size calculations, it was determined 863 households per state would be representative at the .05 level. Survey conductors therefore chose a sample of 1,000 households in each state, structured as 40 clusters from each state, and 25 households in each cluster. Clusters were selected with probability proportional to the population size, and with urban and rural stratification. In cases where selected villages or quarters were not accessible for security or other problems, they were replaced by neighboring ones in the sampling frame. Each state sample was weighed so that collectively they are representative of the entire national population (20). A total of 240 interviewers and 60 supervisors were trained to collect data, and average field time (per state) was 33 days (20). Five questionnaires were used for each household: 1) household characteristics, 2) individual women (age 15-49), 3) children under five, 4) men (age 15-49) and 5) food security (20).

Of the 15,000 households selected for the sample, 14,921 were occupied, and 14,778 were successfully interviewed (response rate 99%). In those households interviewed, 18,614 women (aged 15-49 years) were identified, and 92% (17,174) were interviewed. In addition, 13,587 children under age five were found, and data were collected on 98% of these. Although 16,448 men were identified, only 5,573 men could be interviewed (34% response rate). Because of the low response rate, and likely resulting bias, data relating to men are not presented. Rural areas showed higher response rates than urban areas (20).

Census

The second source of data we used was Sudan's fifth population and housing census, generated from the long-form questionnaire of the 2008 population and housing census covering social, economic, demographic and housing characteristics, household ownership of durable goods, agricultural lands, livestock, and sources of livelihood of the household. The Census was conducted by the Ministry of the Cabinet and Central Bureau of Statistics, and serves the nation by providing population count and economic development indicators for planning, monitoring and evaluation purposes. (15) The census was conducted according to the United Nation standards, guaranteeing full

coverage and high accuracy. The *de facto* method was applied for the enumeration of the population, the "quick count" methodology for mapping purposes, and detailed questionnaires followed UN principles and recommendations for censuses. Data collectors were teachers from the enumeration areas where they worked, supplemented by qualified persons from the same tribes.

Measures of wealth and inequality

The SHHS2 surveyed households for indicators of wealth, and analysts subsequently used factor analysis to construct a consumption-based standard of living measure, also known as a household assets indicator. Calculating wealth involved three steps: 1) identify aggregate components of consumption, divided into durable goods and housing indicators, (2) adjust for cost of living differences, and (3) adjust for household size and composition (21). Durable goods elements include bicycle, motorcycle, car, animal drawn cart, boat with motor, sewing machine, refrigerator, TV, radio, clock, fan, animals, land phone, mobile phone, and farmland. Housing wealth indicators included type of floor and roof, type of drinking water and sanitation, and type of cooking and lighting fuel.(20). A similar study in Colombia, classified by the World Bank as another a lower-middle income country (like Sudan) (http://data.worldbank.org/about/country-classifications/country-and-lending-groups#MENA), used a similar household assets indicator as a determinant of socioeconomic inequality for contraceptive use(22).

Measures of health

Life expectancy

Life expectancy was calculated at the state level by the CBS using Census data. It is simply the average number of years a person can expect live from his or current age, based on national average life tables.(15)

Infant Mortality Rate (IMR); Source (Census)

Sudan's infant mortality rate was derived from Census data by the CBS. The probability of a child dying before its first birthday was calculated by dividing the number of live births in 2008 by the number of children who died that year.(15) We elected to use Census data for this calculation, rather than SHHS2 data, believing Census data to be more complete. (20)

Height for age

A standard international approach to measuring nutritional adequacy is to assess the proportion of the child population that endures "stunting," defined by UNICEF as inadequate height for age (measured as lower than two standard deviations from median height for age compared to a reference population). Height-for-age reflects chronic malnutrition, as failure to receive adequate nutrition over time results in recurrent infections that impair the body's ability to absorb or assimilate food (21). SHHS2

surveyors measured children's heights in each household and collected their age information (20)

Food consumption

A household "food consumption score" was available in the SHHS2, calculated by examining the number of times certain foods were eaten in the seven days preceding the survey, weighted by approximate nutrient density values. The food categories were fruits and vegetables (weighted 1), cereals and tubers (weighted as 2); beans, seeds and nuts (weighted 3); meat and dairy (weighted as 4); and oils, fats and sugar (weighted 0.5). The food consumption score was calculated by adding all the results of individual calculations and then multiplying the frequency of consumption by the score of food type. The number of times any particular item was eaten was capped at 7 per week. Household food consumption scores ranged up to 112. Households were then categorized as poor, borderline, or acceptable (below 21, 21 to 35, and more than 35.

Teen births

The SHHS2 data contained a measure of women in each household, aged 15-19, who reported they gave birth before age 15.

Vaccination

Vaccination data were obtained from the SHHS2, and measured by either the provision of a vaccine card or the mother's recall. Children in each household (between age 12 and 23 months) were assessed to determine whether they were fully immunized according to the national guidelines by their first birthday. The vaccine schedule includes protection from polio, tuberculosis, diphtheria, tetanus, pertussis, hepatitis B, mumps and measles.

Confounders, effect modifiers and possible biases

The effects of income inequality on health outcomes could be modified by the rural/urban status of households, as well as the location of the household in a conflict zone. Rural communities may have more social cohesion, but are also more distant from health services and opportunities for employment (1) While there are more deaths and injuries as a result of conflict, conflict regions also capture political interest. This attention can generate interventions that alter the natural distribution of human behaviors, health outcomes and resources, especially in relation to nutrition and vaccination.(6) We analyzed our results both with and without the four conflict states which are North Darfur, West Darfur, South Darfur and Blue Nile.

Although the survey has a high response rate from households visited, the decision to avoid sampling households in conflict zones was a source of possible bias. Further, all cluster studies suffer from sampling errors in populations that are not evenly distributed according to the characteristics of interest. Population enclaves can readily be missed.

(23) Cluster sampling can substantially increase standard errors. (21) Recall bias is another source of possible error, as not everyone can readily recall meal consumption, vaccination history, and other life events. Another source of bias stems from the time of day or day of week the house was visited (because of who was home to report then).

Data analysis

The variation in living standards across a population is an indicator of wealth inequality. The literature on the relationship between inequality and health has more traditionally used the "Gini coefficient." The Gini is based the Lorenz curve, which plots the proportion of the total income of a population against the cumulative earnings of the bottom x% of the population. A Gini coefficient of zero expresses perfect equality (everyone has an exactly equal income), and a value of 1 expresses maximal inequality (where only one person has all the income). The Gini coefficient, which is sensitive to small shifts in the mean, was of little practical use in ordering the equality of populations in our study(24). We did not have income data on a linear scale, but rather only a handful of asset indicators with a narrow range (-1.0 to 3.5) on the SHHS2 wealth index. Instead, we employed a skewness measure to assess inequality. There is literature supporting the use of asset measures as a better indicator of inequality, however, so we were convinced this was a reasonable approach. (24)

A file was created to ensure consistency of variables definitions across states. Summary descriptive statistics and frequencies were computed. The association between inequality measures and health outcomes measures were drawn in all states. Means and correlation statistics were estimated using SPSS 20, Excel and R program for analysis. All health outcome variables were analyzed at state level. The wealth measure was analyzed at household and state levels. Each state sample can be considered self-weighted. Sample weights were calculated for each state-level sample and these were used in the subsequent analyses of the survey data for national representativeness.(20)

Ethical review:

SHHS2 data collection procedures were approved by Sudan's national institutional review board. The University of Washington Human Subjects Institutional Review Board (IRB) exempts from review those studies based on national level data sets that contain no identifiable information on the subject participants.

RESULTS

Table (1) shows the populations studied in each of our two data sources, with total population in the census and total households in the SHHS2 survey. We present data on children under five separately, as they are the focus of several of our health measures (infant mortality, stunting, and proportion appropriately vaccinated). The SHHS2 was

able to obtain measurements on 13,587 children from 14,778 households in 15 states. The three states with the largest number of children per household (resulting in 1000 or more children in the sample for that state) were all in conflict regions.

Skewness

We calculated the wealth skewness in each state, and portray a histogram of the distribution of wealth assets for each state in figures 1-15. Where wealth is fairly symmetrically distributed, with a proportionally equal number of rich and poor, the histogram will resemble a traditional bell curve, with skewness of zero, or close to it. In Sudan, Northern State is our least skewed, and therefore the state where wealth is most symmetrically distributed. The 637 households in Northern state had an average wealth score of .88, with a standard deviation of .77. The skewness score was 0—that is, the mean is equal to the median, implying relatively symmetric though uneven distribution of assets across households. See Figure 1. By contrast, the 975 households in West Darfur State had an average wealth index score of - 0.66, with a standard deviation of 0.65. The histogram is skewed to the right, illustrating that most people are poor, while a few are very rich. The skewness score is 2.4, implying a very asymmetric distribution of wealth within the state. See Figure 15. Figures 2 through 14 illustrate the wealth distribution skewness for each of the other 13 states.

Table (2) offers a compilation of all the skewness coefficients for each state, ranging from 0 in Northern to 2.38 in West Darfur, and an average 1.095 for the nation.

Life expectancy

Life expectancy in Sudan is an average 60 years, with a range of 57 in West Darfur to 65.5 years in Gezira State. The four conflict states have the lowest life expectancy in the country. See Table 2. We found states with skewed wealth distribution were more likely to have lower life expectancy. Figure 17 illustrates life expectancy plotted on the y-axis and skewness on the x-axis, with a correlation of -.84. The four conflict states (North Darfur, South Darfur, Blue Nile, and West Darfur) portray the lowest life expectancy and most skewed wealth index.

Infant mortality

Sudan's infant mortality rate is an average 79 per 1,000 live births, with a range of 38 per 1,000 live births in Northern State to 349 in South Darfur. There are six states with double-digit infant mortality rates, and nine states with triple digit figures (the latter ranging from 104 to 349). See Table 2. States with skewed wealth distribution were more likely to have higher infant mortality rates, with a correlation coefficient of 0.715. The three conflict states (South Darfur, Blue Nile, and West Darfur) suffer the highest infant mortality and the most skewed wealth indices. See Figure 18.

Height for age (stunting)

International World Health Organization (WHO) norms for height-for-age z scores are 1.10 to 1.30 (25), but Sudan's scores in 2010 ranged from -.93 in Northern State to -1.92 in Red Sea, according to the SHHS2. WHO has established that scores between -2 and -3 represent "moderate stunting." The majority of children under age five in Sudan show stunted growth (low height for age in comparison to the WHO reference population). The correlation coefficient for the association between wealth skewness and stunting was only 0.476 (relatively weak). The conflict states had stunting scores in the middle of the distribution of states, unlike other measures of health where the conflict states performed relatively poorly. When we removed these states from the analysis, we found a strong correlation (.82) between stunting and wealth index skewness in the remaining 11 states. See Table 2 and Figure 19.

Food consumption

The food consumption situation in Sudan is relatively good. Overall, 90 percent of households in Sudan reported acceptable food consumption, with a range between 99 percent in River Nile state and 76.6 percent in West Darfur state. States with skewed wealth indices were more likely to have lower percent food consumption scores, with a correlation coefficient of -0.85. The three conflict states (North Darfur, Blue Nile, and West Darfur) reported the lowest food consumption scores and the highest wealth index skewness. See Table 2 and Figure 20.

Teen births

The SHHS2 study found ten percent of young women in Sudan were married before age 15. About 16 percent of women aged 15 to 19 years began bearing children before age 15, with a range of 7.9 percent in Northern State to 30 percent in West Darfur. States with skewed wealth distribution were more likely to have higher teenage birth rates, with a correlation coefficient of 0.79. The three conflict states (South Darfur, Blue Nile, and West Darfur) portrayed the highest teenage birth rates and highest wealth index skewness. See Table 2 and Figure 21.

Proportion vaccinated

Only about half (49.4%) the children aged 12-23 months in Sudan had completed the recommended vaccine schedule at the time of the SHHS2 survey, with range of 34 percent (South Darfur) to 65 percent (Blue Nile). In contrast to findings on other health status measures in this study, Blue Nile, a conflict state, was among the top two performing states on vaccine coverage for children under age two. The correlation coefficient between vaccine coverage and wealth skewness was - 0.038, statistically not significant. The same applied for non-conflict states, where four states had vaccine rate of 60-65 percent and five states have vaccine rate of 35-40 percent. See Table 2, Figure 22.

DISCUSSION

For four of our six measures of health in Sudan (food consumption, life expectancy, teen births and infant mortality), outcomes were significantly worse in the states with more skewness of wealth distribution, with correlation coefficients above .70 in all cases. For the two remaining health indicators, (height-for-age z scores or stunting, and vaccination coverage), we found weaker correlations with wealth skewness until we removed the conflict-affected states from the analysis. After removing those three states, the correlation coefficients on the stunting was significantly high again at .82 however there was no big difference for vaccination.

Previous authors (Nowatzki and Rodgers) have reported life expectancy and infant mortality to be associated with inequality. (8)(2) In relation to food consumption and stunting, a study based on the Nigeria 2003 Demographic and Health Survey found considerable pro-rich inequalities in the distribution of stunting, as well as malnutrition associated with socioeconomic inequality generally.(26) Similar findings come from other sub-Saharan countries, (27)(28)(29, 30) Vietnam (31) and China (32). Sudan's Ministry of Health and UN agencies, mainly UNICEF, have focused vaccine and food supplementation interventions on conflict regions, leading to improvements in height for age in children aged 18 to 24 months. This could explain the weaker correlation we found between stunting and wealth skewness overall. After removing conflict states from the analysis, though, stunting was again highly correlated with skewness of wealth. This is consistent with findings from the Biggs paper (6).

Other researchers have also found income inequality to be associated with higher birth rates among teens, as we did for wealth skewness. A possible explanation is that greater income inequality undermines social capital (social cohesion, civic engagement, and mutual trust in a community). In a U.S. study, teen birth rates were affected by both poverty and income inequality, though income inequality appeared to affect teen birth rate primarily through its affect on social capital (33).

The relationship between vaccine coverage and income inequality from other studies is more nuanced. A 2012 study from Japan demonstrated that while higher income inequality was associated with lower measles vaccine coverage rates in more rural areas, larger municipalities could overcome this problem with social capital development (34). In relation to vaccination during conflict, Parameswaran and Wijesinghe found no differences in vaccination coverage in the war-affected Kilinochchi district of Sri Lanka. (35)

We conclude from our findings, supported by research from others who have published in this area, that an unequal distribution of wealth, as approximated by skewness in this study, is associated with worse health outcomes. Our countervailing finding that vaccine

coverage in conflict-afflicted states is not predicted by skewness of wealth distribution is consistent with observations that vaccine campaigns are typically conducted in war zones by various authorities as a public health measure. (36) (37) A measles campaign in camps for internally displaced persons and neighboring communities in Darfur aimed to vaccinate all children aged 9 months-15 years, and resulted in a reduction in reported measles cases.(38) Conflict areas are the focus of more political interest and health interventions, which may mask some of the effects of inequality. Another confounder could be that higher infant mortality rates in the three conflict states led to the deaths of unvaccinated children, thus artificially elevating the vaccination rate because it was inflated by survivors. Sample bias may also be a problem, because serious security issues forced SHHS2 to replace clusters in war zones with those in safer areas to protect the surveyors.

It's possible that the mechanism by which income inequality undermines health is through the erosion of social capital, since both teen births and vaccine coverage seem to have demonstrated this association. The fact that the conflict states in Sudan have the most wealth skewness supports this hypothesis. On the other hand, the conflict states also share the characteristics of poor infrastructure and rugged geography with few roads. Certain conflict state sites could be inaccessible for months during the rainy season. By comparison, the most equal states are closer to the capital, with good infrastructure, as well as more job and education opportunities. The chicken and egg are difficult to differentiate here, as the more equal states have no history of conflict. Is it the inequality that leads to conflict, or the conflict that leads to inequality?

Racism in Sudan is a significant problem that can also explain some portion of inequality. Northern region people are known to discriminate against those from western Sudan in term of color and tribal affiliation, also reflected in marriage choices (39). All these issues relate to social capital, as well. The effect of conflict on health, regardless of income inequality, is incontrovertible, however. It's been reported that half a million people may have died in the Darfur conflict, and 2 million people displaced.(6, 16)

Our study has limitations. Household wealth was estimated by the SHHS2 tallies of cumulative quantity and quality of household assets. While this is an indicator of living standards, it doesn't produce results comparable to those obtained from direct measures of income. Further, cross-sectional data allow calculations of association, but do not provide evidence for causal inferences because of the lack of temporal sequence, among other reasons. Vaccine measures and other variables based on respondent recall are subject to bias. The SHHS2 avoidance of surveying in high-conflict zones certainly undermines the measures of association with the affects of conflict.

We conclude skewed wealth distribution to be associated with poorer population health in Sudan on four measures: food consumption, life expectancy, teen births and infant mortality, where better outcomes favored the less skewed states. For vaccination and stunting, conflict-zone interventions organized by public health organizations may have masked the effects of inequality. The harms to social capital created by or through both inequality and conflict may be the causes of the causes of poor health. Public health officials may want to consider interventions to prevent both war and economic inequality as equally important to vaccination and food supplementation.

Living in an equal society could be the best medicine for a healthier and better life.

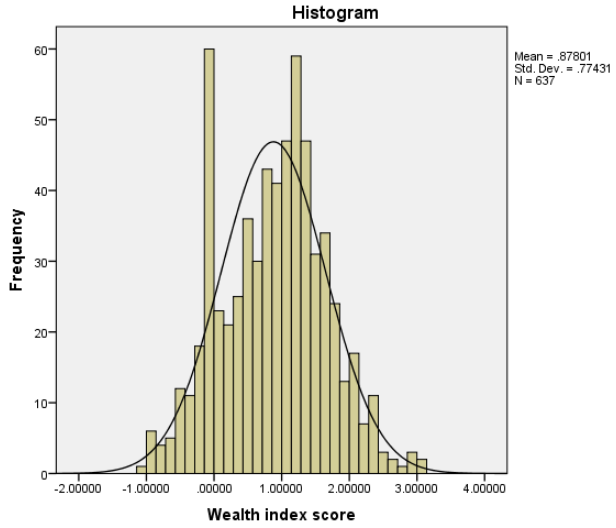
TABLES AND FIGURES

Table 1: Sample sizes in each Sudanese state for data collected on children under age five (Sudan Household Survey 2010), in relation to population estimates from the 2010 Sudan Census.

State	Census data		SHHS data	
	Population	Under- five population	Sample size of Children under five Eligible	Sample size of children under-five Mother/Caretaker Interviewed
Northern	686,098	80,344 (11.7%)	637	607 (95%)
River Nile	1,097,356	145,560 (13.3%)	789	765 (97%)
Gezira	3,549,026	511,776 (14.4%)	843	839 (99.5%)
Khartoum	5,181,186	650,463 (12.6%)	862	828 (96%)
White Nile	1,713,360	267,270 (15.6%)	889	856 (96%)
Sennar	1,272,766	203,041 (16%)	853	843 (99%)
Red Sea	1,368,330	155,127 (11.3%)	641	625 (97.5%)
South Kordufan	1,389,076	260,172 (18.7%)	1031	1020 (99%)
Kassala	1,769,887	220,488 (12.5%)	824	818 (99%)
Gedarif	1,334,947	230,165 (17%)	935	901 (96%)
North Kurdufan	2,888,969	494,197 (17%)	910	902 (99%)
North Darfur	2,089,801	313,592 (15%)	1067	1034 (97%)
Blue Nile	816,048	156,404 (19%)	1257	1234 (98%)
South Darfur	4,054,603	625,560 (15.4%)	1074	1034 (96%)
West Darfur	1,292,714	220,946 (17%)	975	967 (99%)
National total/ averages	30,504,166	4,535,105 (15%)	13587	13282 (97.8%)

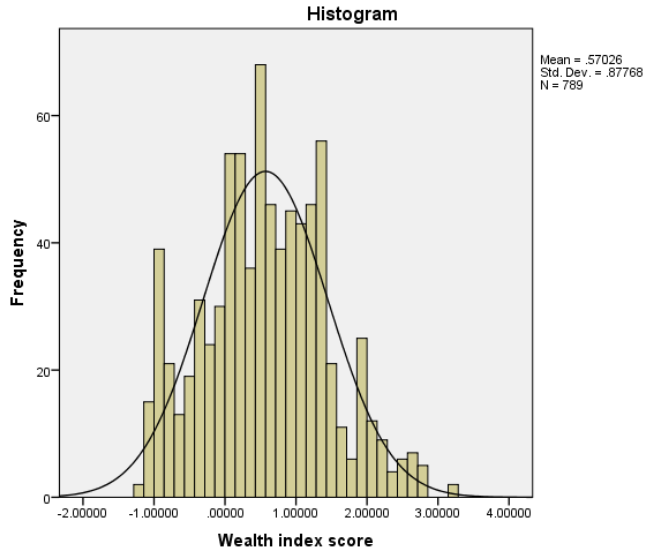
Sources of data: Sudan Household Survey 2010, conducted between March and May 2010, by the federal Ministry of Health and the Central Bureau of Statistics, and the Sudan Census, generated from the long-form questionnaire of the 2008 population and housing census.

Figure 1: Skewness measures for household standard of living (wealth) distribution in the Northern State



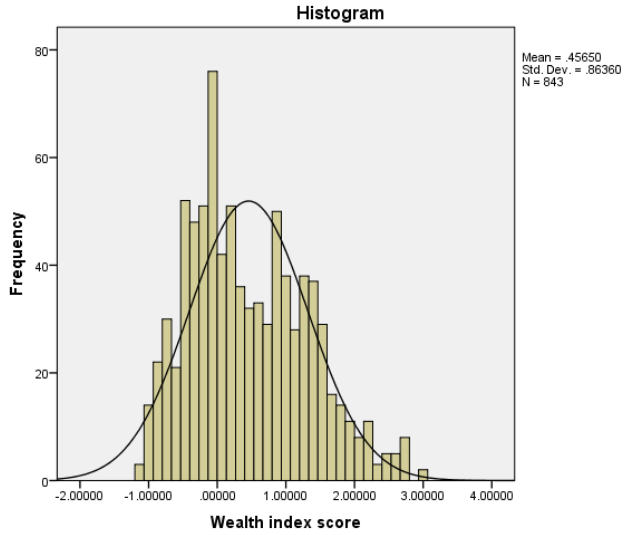
Source of data: Sudan Household Survey 2010, conducted between March and May 2010, by the federal Ministry of Health and the Central Bureau of Statistics.

Figure 2: Skewness measures for household standard of living (wealth) distribution in the River Nile State



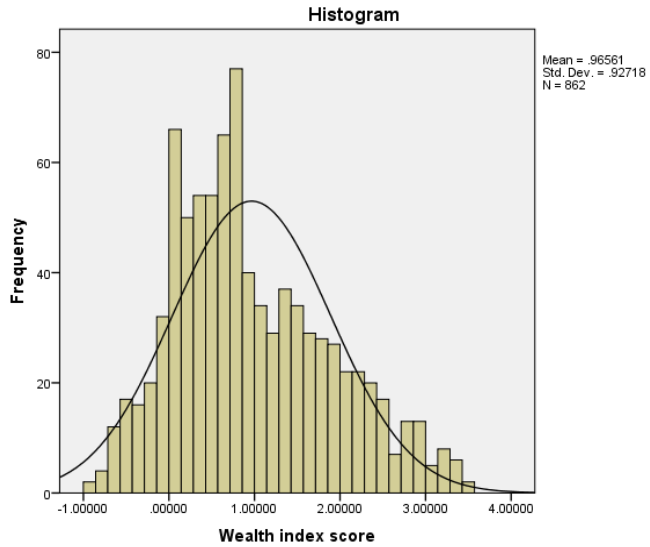
Source of data: Sudan Household Survey 2010, conducted between March and May 2010, by the federal Ministry of Health and the Central Bureau of Statistics.

Figure 3: Skewness measures for household standard of living (wealth) distribution in Gezira State



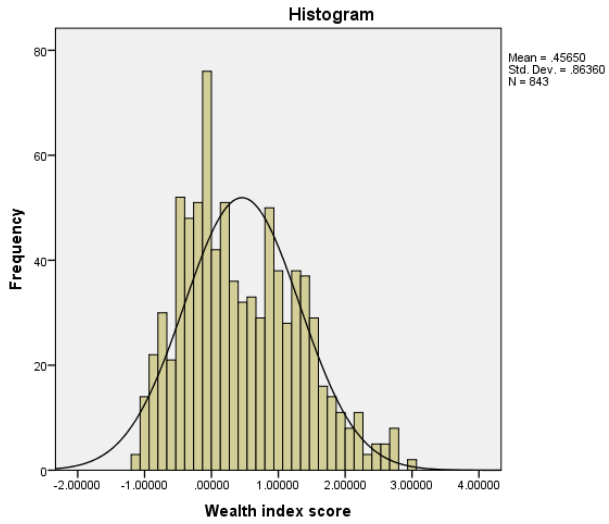
Source of data: Sudan Household Survey 2010, conducted between March and May 2010, by the federal Ministry of Health and the Central Bureau of Statistics.

Figure 4: Skewness measures for household standard of living (wealth) distribution in Khartoum State



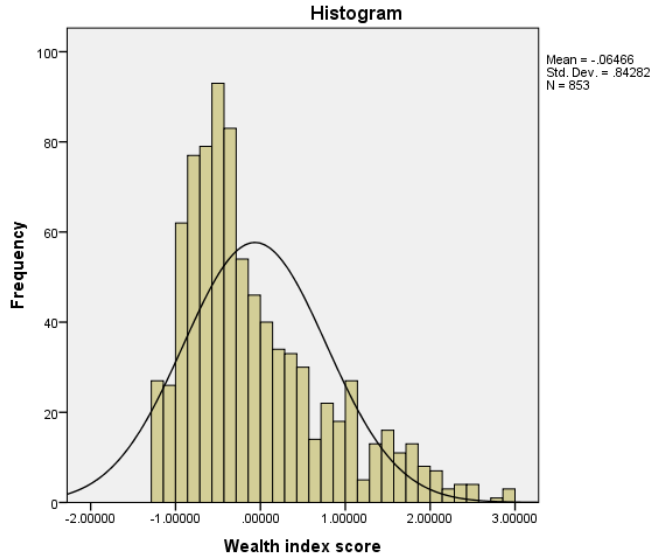
Source of data: Sudan Household Survey 2010, conducted between March and May 2010, by the federal Ministry of Health and the Central Bureau of Statistics.

Figure 5: Skewness measures for household standard of living (wealth) distribution in White Nile State



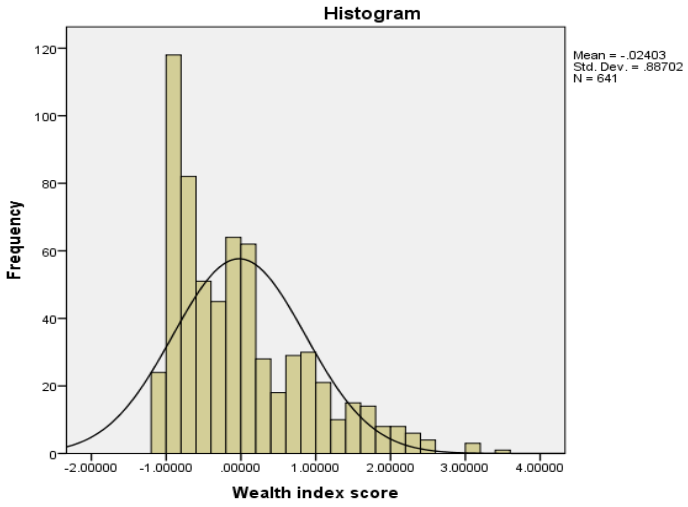
Source of data: Sudan Household Survey 2010, conducted between March and May 2010, by the federal Ministry of Health and the Central Bureau of Statistics.

Figure 6: Skewness measures for household standard of living (wealth) distribution in Sennar State



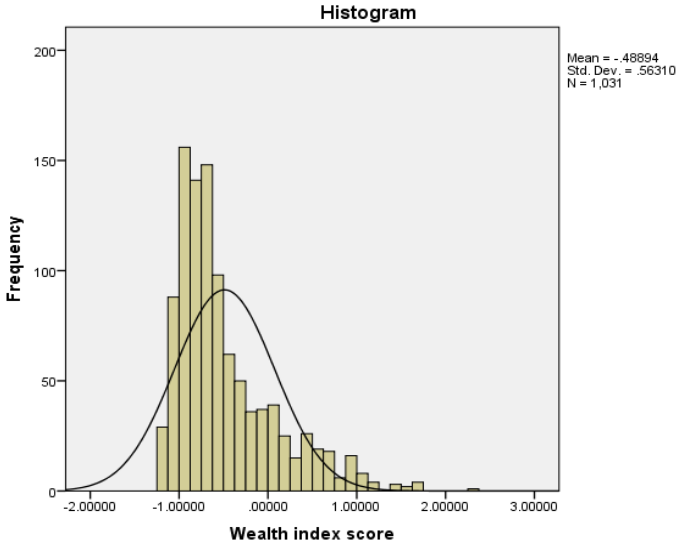
Source of data: Sudan Household Survey 2010, conducted between March and May 2010, by the federal Ministry of Health and the Central Bureau of Statistics.

Figure 7: Skewness measures for household standard of living (wealth) distribution in Red Sea State



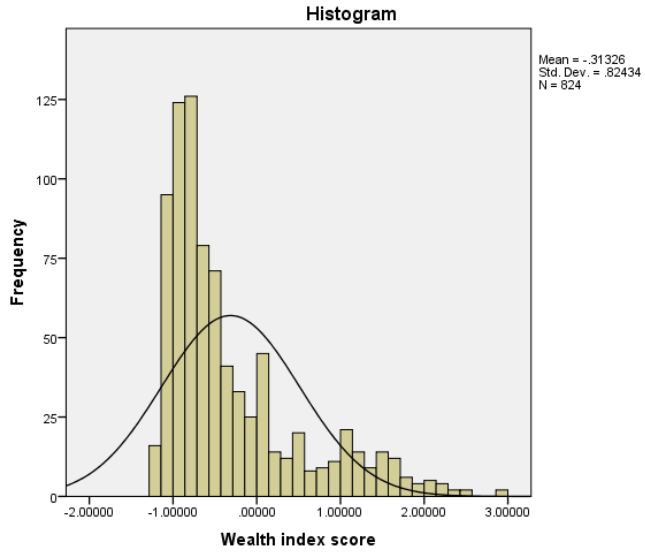
Source of data: Sudan Household Survey 2010, conducted between March and May 2010, by the federal Ministry of Health and the Central Bureau of Statistics.

Figure 8: Skewness measures for household standard of living (wealth) distribution in South Kurdufan State



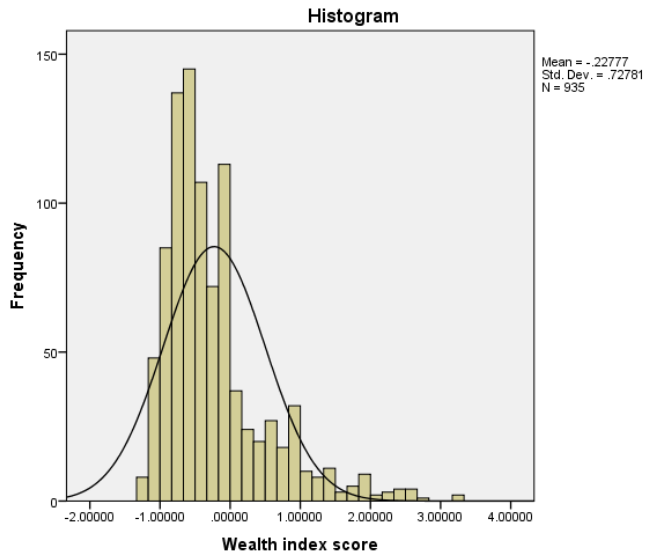
Source of data: Sudan Household Survey 2010, conducted between March and May 2010, by the federal Ministry of Health and the Central Bureau of Statistics.

Figure 9: Skewness measures for household standard of living (wealth) distribution in Kassala State



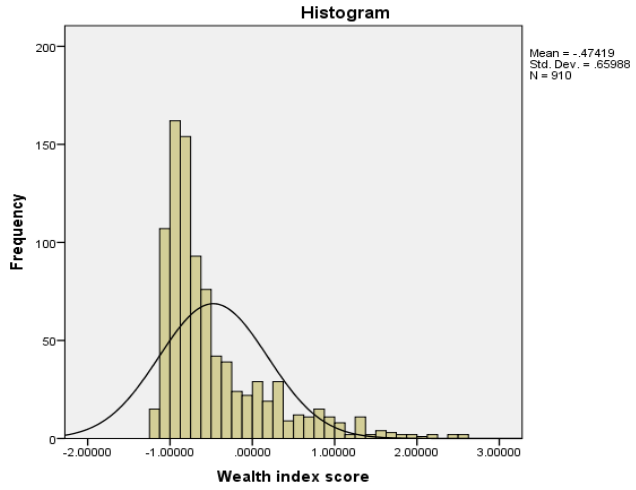
Source of data: Sudan Household Survey 2010, conducted between March and May 2010, by the federal Ministry of Health and the Central Bureau of Statistics.

Figure 10: Skewness measures for household standard of living (wealth) distribution in Gedarif State



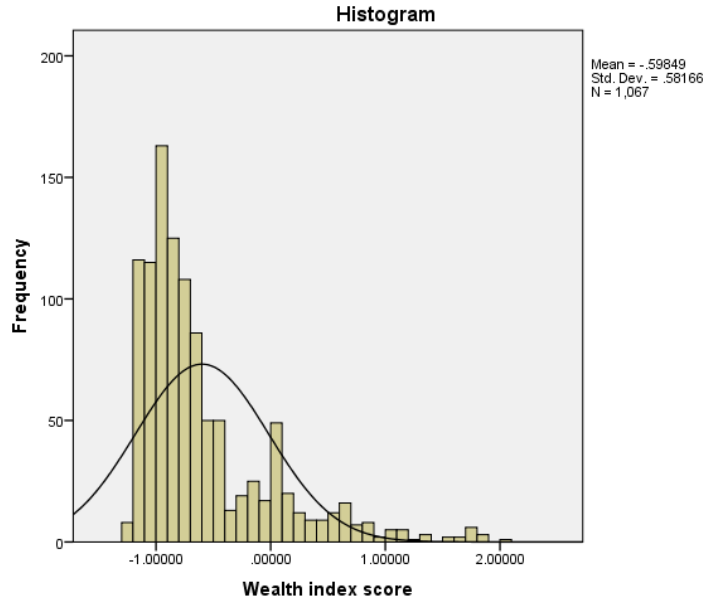
Source of data: Sudan Household Survey 2010, conducted between March and May 2010, by the federal Ministry of Health and the Central Bureau of Statistics.

Figure 11: Skewness measures for household standard of living (wealth) distribution in North Kurdufan State



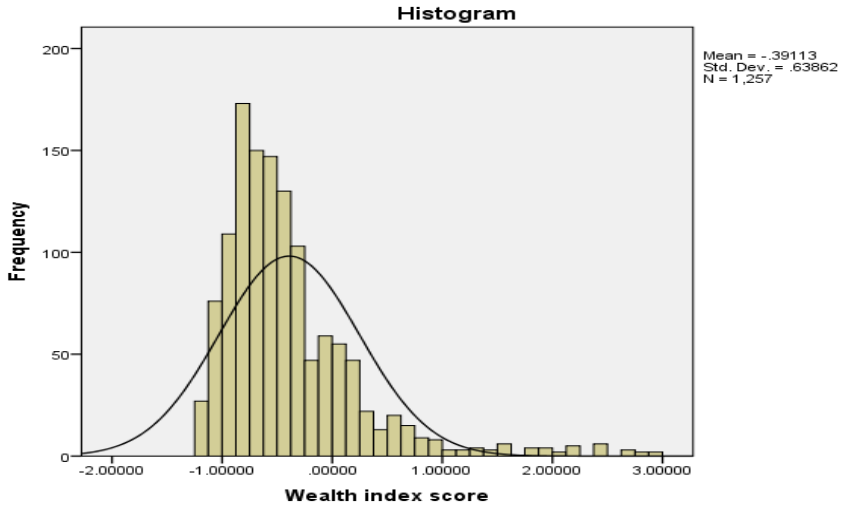
Source of data: Sudan Household Survey 2010, conducted between March and May 2010, by the federal Ministry of Health and the Central Bureau of Statistics.

Figure 12: Skewness measures for household standard of living (wealth) distribution in North Darfur State



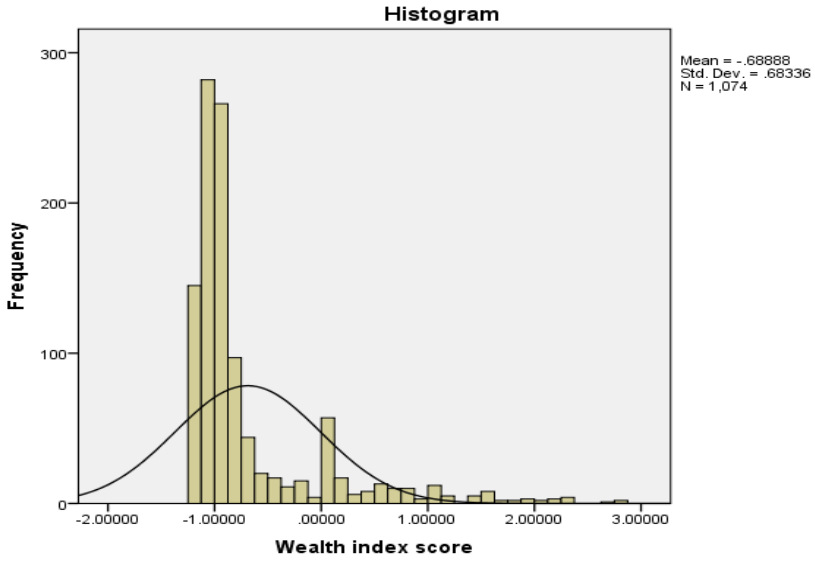
Source of data: Sudan Household Survey 2010, conducted between March and May 2010, by the federal Ministry of Health and the Central Bureau of Statistics.

Figure 13: Skewness measures for household standard of living (wealth) distribution in Blue Nile State



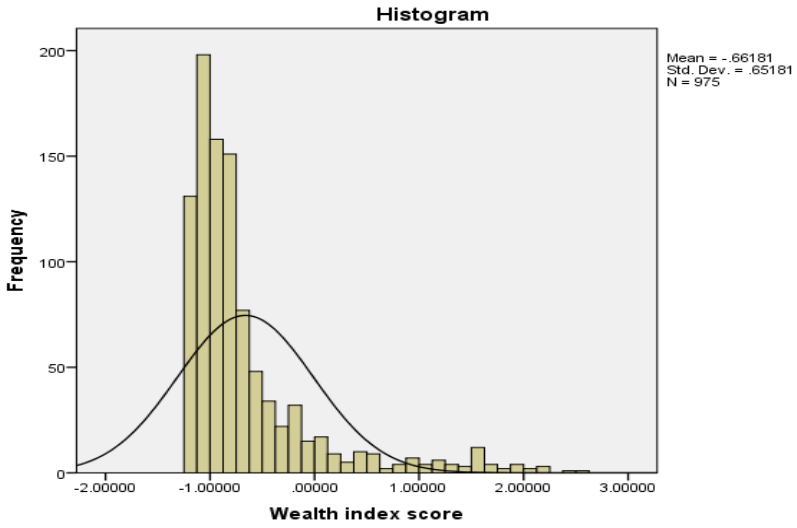
Source of data: Sudan Household Survey 2010, conducted between March and May 2010, by the federal Ministry of Health and the Central Bureau of Statistics.

Figure 14: Skewness measures for household standard of living (wealth) distribution in South Darfur State



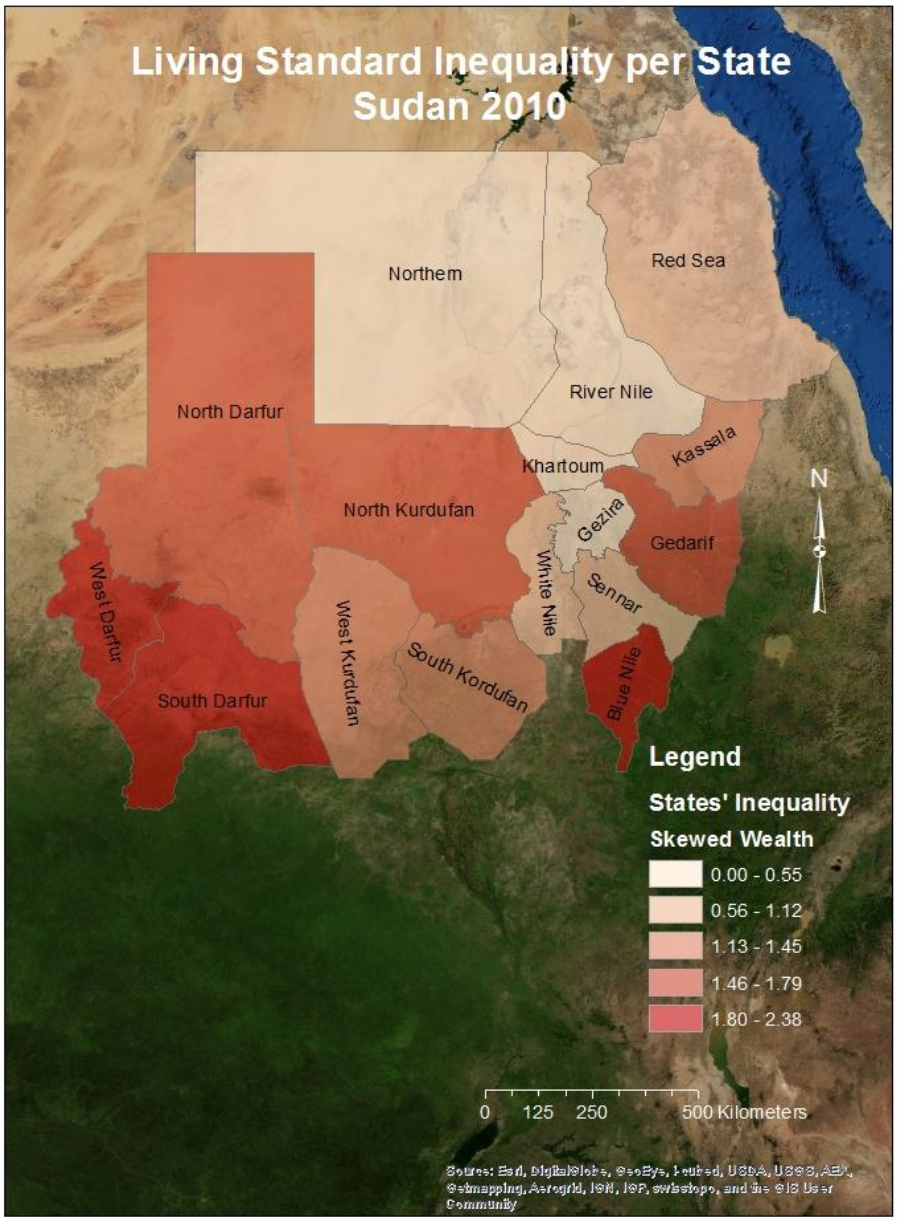
Source of data: Sudan Household Survey 2010, conducted between March and May 2010, by the federal Ministry of Health and the Central Bureau of Statistics.

Figure 15: Skewness measures for household standard of living (wealth) distribution in South Darfur State



Source of data: Sudan Household Survey 2010, conducted between March and May 2010, by the federal Ministry of Health and the Central Bureau of Statistics.

Figure 16: Map of Sudan, portraying standard of living skewness in each of the 15 states.



Sources of data: SHHS2 data portrayed on map obtained from DIVA GIS 2012, ESRI 2012, Sudan Household Survey 2010.
Note darker shaded states are the most skewed by wealth distribution. Blue Nile, West Darfur and South Darfur are the conflict states.

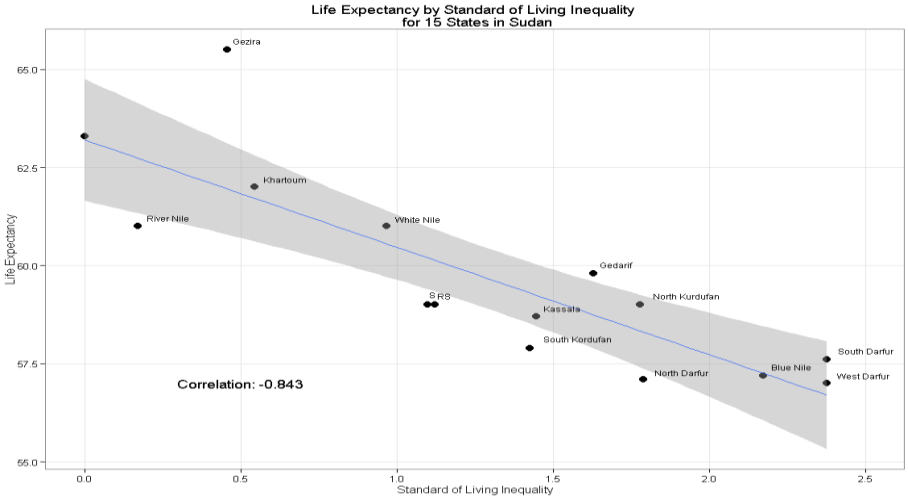
Table 2: Wealth Skewness and health outcomes in Sudan.

state	Inequality, Independent variable	Health outcomes measures, dependent variables			Factors affecting health outcomes, explanatory variables		
	Wealth skewness coefficient	Life expectancy	IMR	Mean height for age (z score)	Percent with adequate food consumption	Percent teenage birth	Percent vaccinated
Red Sea	1.121	59	145	-1.9232	85	12	35.1
Kassala	1.446	58.7	227	-1.872	89.3	14	46.6
North Kurdufan	1.778	59	104	-1.7273	83.5	17.1	37
Sennar	1.099	59	62	-1.6744	90.6	15.2	65.1
Gedarif	1.63	59.8	79	-1.6492	90.5	21	58.8
White Nile	0.966	61	70	-1.5344	95.1	18.2	54.9
Blue Nile	2.173	57.2	336	-1.4805	81.8	27.7	64.7
South Kordufan	1.427	57.9	90	-1.444	83.9	18.8	42.7
West Darfur	2.378	57	318	-1.3973	76.6	30.1	38.6
North Darfur	1.79	57.1	145	-1.3652	80.9	15.6	43.4
South Darfur	2.377	57.6	349	-1.3515	88.7	22.2	34.1
River Nile	0.171	61	42	-1.1904	99.1	16.5	40
Gezira	0.457	65.5	154	-1.1207	96.3	13.2	62.6
Khartoum	0.545	62	170	-0.9476	97	9.5	60.9
Northern	0	63.3	38	-0.9349	98.3	7.9	60.4

Sources of data: Sudan Household Survey 2010, conducted between March and May 2010, by the federal Ministry of Health and the Central Bureau of Statistics, and the Sudan Census, generated from the long-form questionnaire of the 2008 population and housing census.

Note Blue Nile, West Darfur and South Darfur are the conflict states.

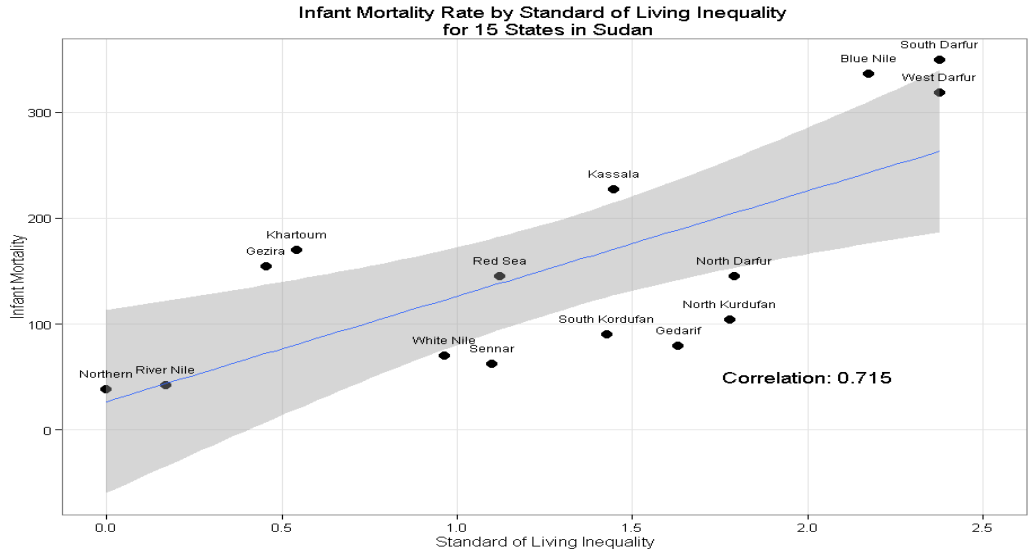
Figure 17: Life expectancy in relation to wealth skewness in Sudan.



Source of data: Sudan Household Survey 2010, conducted between March and May 2010, by the federal Ministry of Health and the Central Bureau of Statistics.

Note the strong negative correlation between wealth skewness and life expectancy (coefficient is - 0.843).

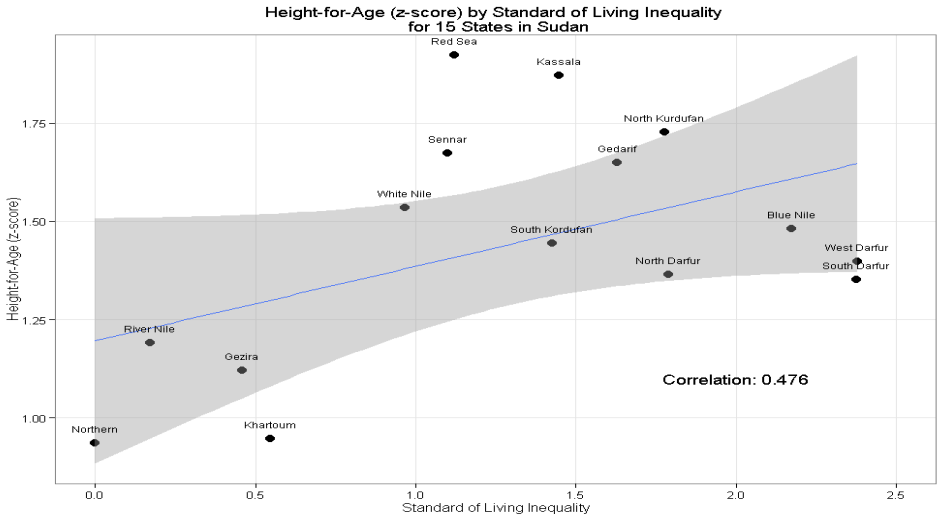
Figure 18: Infant mortality in relation to wealth skewness in Sudan.



Source of data: Sudan Household Survey 2010, conducted between March and May 2010, by the federal Ministry of Health and the Central Bureau of Statistics.

Note the strong positive correlation between wealth skewness and infant mortality (coefficient is 0.715). The three conflict states have the highest infant mortality rates.

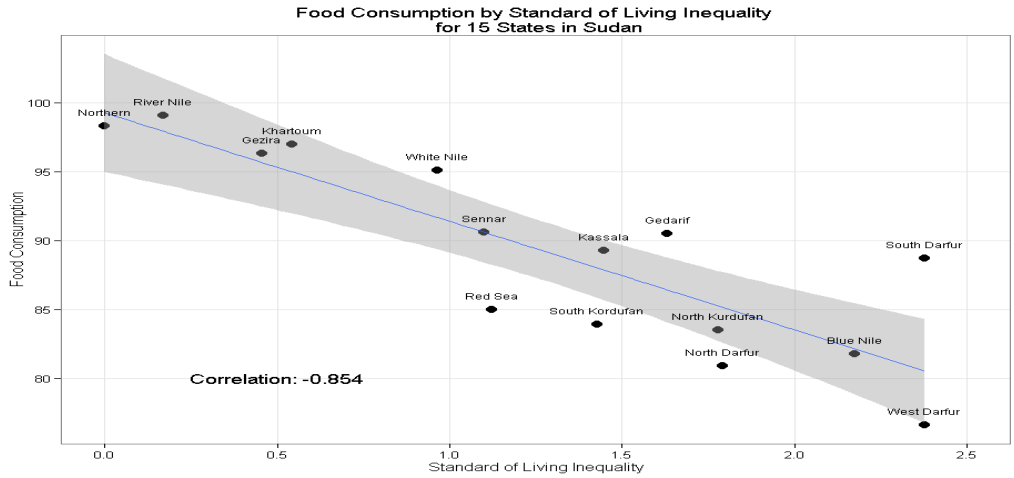
Figure 19: Height for age (z scores in relation to international norms) in relation to wealth skewness in Sudan.



Source of data: Sudan Household Survey 2010, conducted between March and May 2010, by the federal Ministry of Health and the Central Bureau of Statistics.

Note the weak but positive correlation between wealth skewness and stunting. The least skewed states have the least stunted children, while in conflicts zone there is no correlation. In separate analysis (not graphed), we found skewness and stunting in the eleven non-conflict states to be significant at 0.82.

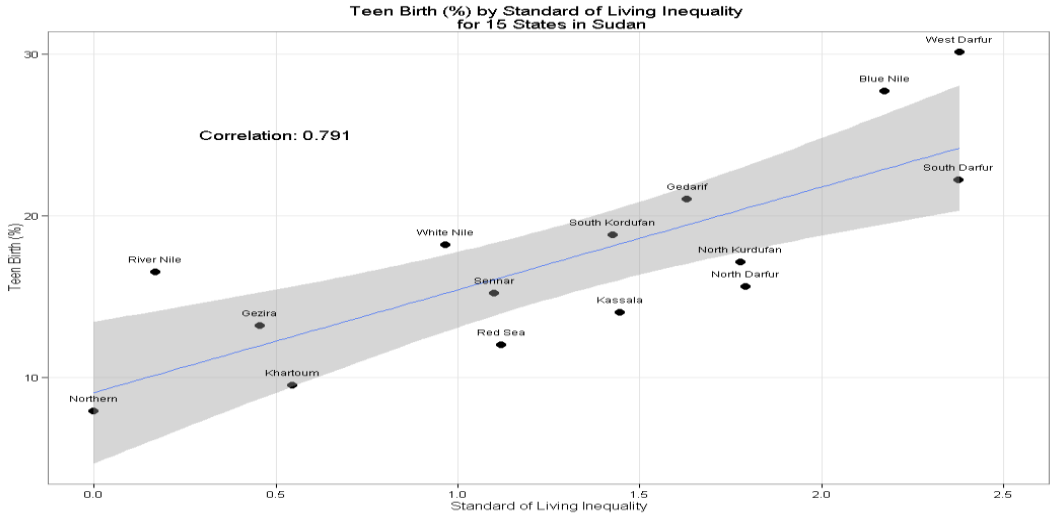
Figure 20: Adequacy of food consumption in relation to wealth skewness in Sudan.



Source of data: Sudan Household Survey 2010, conducted between March and May 2010, by the federal Ministry of Health and the Central Bureau of Statistics.

Note the positive correlation between wealth skewness and poor food consumption scores. The most skewed states had the poorest food consumption scores, with a strong negative correlation of - 0.854.

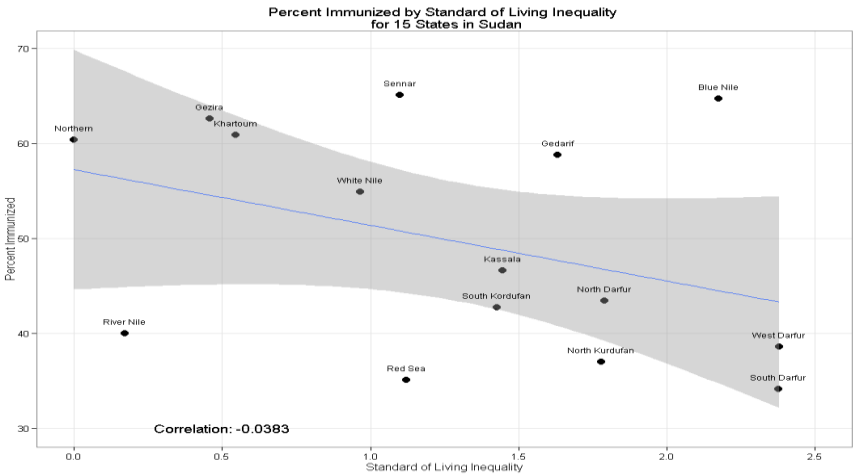
Figure 21: Teen births in relation to wealth skewness in Sudan.



Source of data: Sudan Household Survey 2010, conducted between March and May 2010, by the federal Ministry of Health and the Central Bureau of Statistics.

Note the positive correlation between wealth skewness and higher teen birth rates, with a strong positive correlation of 0.791.

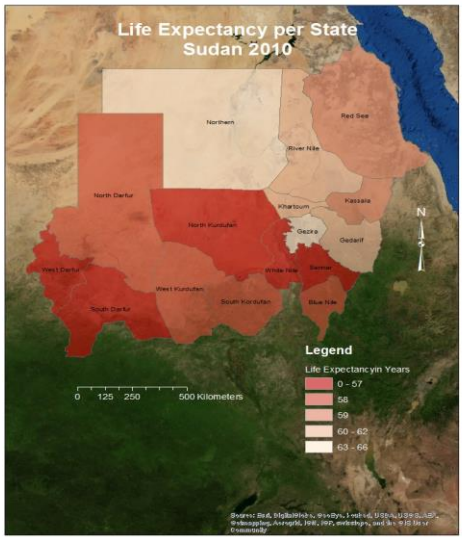
Figure 22: Vaccination rates in relation to wealth skewness in Sudan.



Source of data: Sudan Household Survey 2010, conducted between March and May 2010, by the federal Ministry of Health and the Central Bureau of Statistics.

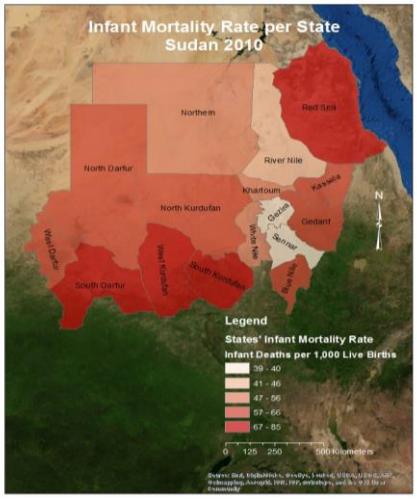
Note the weak but negative correlation between wealth skewness and proportion of children appropriately vaccinated. The vaccination rates in the three conflict zones were variable, with Blue Nile performing well but West and South Darfur performing relatively poorly.

Figure 23: Map of Sudan, portraying life expectancy in each of the 15 states.



Sources of data: Census data portrayed on map obtained from DIVA GIS 2012, ESRI 2012, Sudan Household Survey 2010.
Note darker shaded states have the lowest life expectancies. Blue Nile, West Darfur and South Darfur are the conflict states.

Figure 23: Map of Sudan, portraying infant mortality in each of the 15 states.



Sources of data: Census data portrayed on map obtained from DIVA GIS 2012, ESRI 2012, Sudan Household Survey 2010.
Note darker shaded states have the highest infant mortality rates. Blue Nile, West Darfur and South Darfur are the conflict states.

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