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Reversing the Trend of Stunting in Sudan

Opportunities for Human Capital Development through Multisectoral Approaches

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Abstract

Stunting, measured using a height-for-age Z score [HAZ] and an indicator of chronic malnutrition, among 0–5-year-old Sudanese children has been on the rise—from 34 percent in 2010 to 38 percent in 2014. Although a multisectoral approach to tackling undernutrition may mask clarity and undermine specificity of sectors to prioritize, it can be a basis for designing evidenced-based and balanced multi-sectoral strategies to addressing stunting in Sudan. Overall, stunting is more prevalent in the early years of Sudanese children and among children from the poorest households and in rural areas where adequate access to the underlying drivers of nutrition also remains significantly low. Adequate access to nutrition drivers is strongly associated with a lower likelihood of being stunted. Among the nutrition drivers considered, adequate access to food security and care and health care (both individually and jointly) significantly lowers a child's probability of being stunted. In rural areas and poor households where stunting rates are highest, prioritizing food security and access to adequate health care can contribute toward lowering stunting. Poverty remains a central feature of stunting in Sudan and a main source of inequalities in adequate access to nutrition drivers.

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1. Introduction

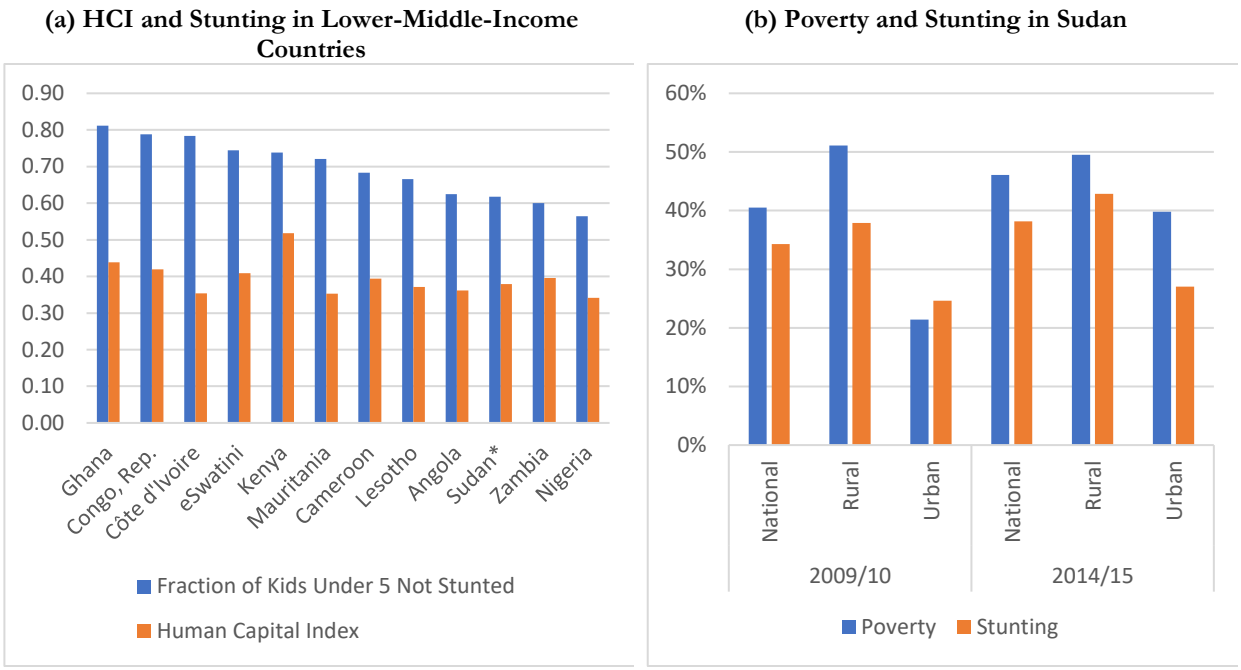
The Sudanese economy has experienced several events in the recent past. Following the secession of the South in 2011, the government experienced a significant decrease in total revenue, largely due to loss of oil revenue, thereby constraining its fiscal space. As a result of this and other macroeconomic shocks that emerged (notably rising prices and volatile exchange rates), the government faced immense challenge of instituting reforms to restore macroeconomic stability, spur growth, and improve the welfare of the Sudanese people. Recent poverty estimates obtained from the 2014/15 National Household Budget and Poverty Survey (NHBPS) and released in November 2017 indicate that 36.1 percent of Sudanese had per capita expenditure levels below the national poverty line. Measured against the World Bank's international poverty line of US$1.90 per day (based on the 2011 purchasing power parity [PPP]), 13.5 percent of Sudanese are deemed poor. These statistics are further marked by significant geographic heterogeneity. For instance, in the Northern State, about 12 percent of the population are estimated to be poor. In the state of Central Darfur and in Western Sudan, poverty is estimated at 67 percent. Similarly, states in the Kordofan and Darfur regions as well as the Red Sea and White Nile States have poverty rates higher than the national average.

Sudan's low ranking in the World Bank's 2018 Human Capital Index (HCI) may in part be driven by a high prevalence of stunting, an indicator of long-term malnutrition, and widespread poverty. Recent data from the World Bank's HCI, which measures the amount of human capital that a child born today is expected to attain by the time s/he reaches the age of 18 years, shows that the child will only be 38 percent as productive when s/he grows up as s/he could be if s/he enjoyed complete education and full health (World Bank Group 2018). At this level, Sudan ranks 139 out of 157 countries in the World Bank's 2018 HCI rankings—below its regional average (41 percent) and its income group average (49 percent). Among lower-middle-income countries in Sub-Saharan Africa, Sudan's level of HCI is only higher than Zambia and Nigeria (see Figure 1a). The HCI is constructed by combining measures of health (probability of survival to age 5, stunting among children ages 0–5 years, and probability of survival to age 60) and education (expected years of schooling and test scores). Among these indicators, stunting (an indicator of adverse undernutrition) among Sudanese children appears to be the main driver of its low HCI. For instance, while 94 percent of children born in Sudan are expected to live to age 5 and 78 percent of 15-year-olds are expected to live to age 60, 38 percent of children ages 0–5 years are stunted and face the risk of cognitive and physical limitations that can last

a lifetime (World Bank Group 2018).[2] Thus, Sudan's low performance in the HCI rankings can in part be explained by widespread stunting. Among its income group in Sub-Saharan Africa, Sudan has the third-highest level of stunting among under-five-year-old children (see Figure 1a. Central to the link between stunting and human capital accumulation is the extent of poverty. Inequalities in access to determinants of undernutrition such as quality and adequate diets, sanitation, and health care are often driven by poverty. Within Sudan, changes in poverty and stunting over time appear to mirror similar patterns (see Figure 1b). Poverty (defined using the international poverty line of US$3.20 for lower-middle-income countries) increased from 41 percent in 2009 to 46 percent in 2014/15. Similarly, stunting among under-five-year-old children increased from 34 percent in 2010 to 38 percent in 2014. This relationship is even more evident in rural areas where poverty is more widespread. Given that human development remains a central pillar in the drive to achieving the Sustainable Development Goals (SDGs) and the World Bank's twin goals to eliminate extreme poverty and boost shared prosperity by 2030, addressing the problem of stunting is crucial for a productive future labor force and for sustained economic growth.

[2] Another possible explanation for Sudan's low HCI is slow progress toward improving learning outcomes. For instance, while a Sudanese child who starts school at age 4 is expected to complete 7.3 years of school by age 18 and harmonized test scores in Sudan average 380 (where 625 represents advanced attainment and 300 represents the minimum attainment), learning-adjusted years of schooling is estimated at only 4.4 years—a learning gap of 2.9 years.

Figure 1: Human Capital, Stunting, and Poverty in Sudan



Source: Authors' calculation using the World Bank's HCI data in panel (a). In panel (b), stunting data presented are obtained from Sudan's Multiple Indicator Cluster Survey (MICS) 2010 and 2014 household survey data. Poverty data are obtained from Sudan's 2009 National Baseline Household Survey (NBHS) and 2014/15 National Household Budget and Poverty Survey (NHBPS) data.

Developing human resources through investments in human development to enhance population capabilities and better health is needed to reap the double dividends of improving productivity for growth and tacking inequality and hence forms a central pillar in Sudan's medium-term national development policy framework. Sudan's Poverty Reduction Strategy Paper (PRSP) was aimed at achieving sustainable development and poverty reduction in the medium term. Given the high prevalence of stunting, a measure of long-term malnutrition with large negative effects, these efforts can benefit from detailed insights into the underlying drivers of malnutrition. Furthermore, to reap the double dividends of improving productivity to spur growth and lower inequality, investments in human capital, particularly education and health care, among other things, are key.

This paper aims to inform these efforts by discussing the role of multisectoral approaches to tackling undernutrition (focusing on stunting) in Sudan. It provides country-specific insights into the extent to which inequalities in access to food security and care; health care; and water, sanitation, and hygiene (WASH) individually and collectively drive the prevalence of stunting among 0–23-month-old children. A multisectoral framework developed by the United Nations Children's Fund (UNICEF) for the identification of underlying determinants of undernutrition is adopted in this paper. These

determinants include indicators of food and care, WASH, and health care of children. We use two rounds of the MICS collected in 2010 and 2014 to examine the extent to which limitations in access to adequate levels of food security and care, WASH, and health care individually and jointly affect nutrition outcomes of Sudanese children ages between 0 and 23 months.

Furthermore, we examine the extent to which inequalities in access to the underlying drivers of nutrition exist as well as the varying degree to which adequate access to nutrition drivers influences nutritional outcomes among children across space (rural versus urban) and wealth (rich versus poor) in Sudan. Several studies on the determinants of undernutrition have highlighted the centrality of poverty—both as an indicator and a source of undernutrition. Thus, by considering the heterogeneity of stunting and the extent to which it is influenced by inadequate access to the underlying determinants of undernutrition across the wealth distribution, gaps in access to main drivers (which are likely to differ for rich and poor households) can be identified for reform. Similar insights can also be drawn from the comparisons of stunting and access to adequate levels of nutrition drivers in rural and urban areas.

The focus on 0–23-month-old children is motivated by empirical evidence that severe forms of undernutrition such as stunting are both more prevalent and have larger adverse effects in the early years of a child's life (Victora et al. 2010).[3] Recent data from Sub-Saharan Africa also show higher prevalence of stunting among younger children (Skoufias, Vinha, and Sato 2019, p49). Results from this paper will thus provide useful insights into recent trends in stunting across space (rural versus urban) and households (particularly those in the bottom of the wealth distribution). These insights will be useful for identifying the nutrition drivers that significantly influence stunting as well as gaps in access to these drivers to inform the design of effective policies to address the problem of stunting in Sudan.

Conceptually, the adopted framework is premised on the fact that at the heart of human development for sustainable growth is the need to ensure that nutrition levels (particularly of children) and other factors that influence it directly or indirectly are adequate. Achieving this objective requires a multisectoral approach to ensure food security, adequate care (including a clean and healthy environment), and access to health services. Deficiency in one or more of these factors, also referred

[3] In describing the nature of stunting in Sudan, we provide an overview of the prevalence of stunting across the age distribution of children under five years of age. Similar patterns of prevalence described by early papers are also observed- stunting rates among younger Sudanese children are higher. As a result, the analysis of the extent to which access to adequate levels of nutrition drivers influences stunting focuses on children ages 0–23 months.

to as the 'underlying determinants' of nutrition in the literature, may significantly affect nutrition outcomes and human capital formation. Although Sudan's low level of human capital as indicated by the World Bank's HCI rankings can be explained by several factors, current nutrition levels, particularly of children, highlight the centrality of nutrition quality in the human capital formation/development and sustainable growth nexus. Typically, underweight (having low weight), stunting (having low height-for-age), and wasting (having low weight-for-height) are considered standard indicators of nutrition quality. Data from the MICS collected in 2010 and 2014 indicate that stunting (measured as the percentage of children under age five who fall below −2 standard deviations of the median height-for-age of the World Health Organization [WHO] standard) increased from 35 percent in 2010 to 38.2 percent in 2014. Severe stunting (percentage of children under age five who fall below −2 standard deviations of the median height-for-age of the WHO standard) increased from 15 percent in 2010 to 18 percent in 2014. Other indicators such as underweight (which was 32.2 percent in 2010 and 33 percent in 2014) and wasting (which was 16.4 percent in 2010 and 16.3 percent in 2014) indicate that progress toward lowering prevailing levels of undernutrition in Sudan is slow. Similarly, across Sub-Saharan Africa, undernutrition remains a major challenge. A recent World Bank report estimates that in Sub-Saharan Africa, 58 million children under the age of five are stunted and 14 million are wasted (Skoufias, Vinha, and Sato 2019).

These statistics, particularly the high rates of stunting, highlight the urgency for action to avoid the large negative effects of undernutrition on individuals and their societies. Stunting, in particular, results in low cognitive development and human capital attainment, resulting in low future human capital formation and hence economic growth (Hoddinott et al. 2013). Effects of undernutrition on health outcomes are equally dire. In addition to increased vulnerability to diseases and likelihood of death from diseases, undernutrition has been identified as a major source of risk of chronic diseases in later life. Therefore, the analysis of the determinants of undernutrition serves as a tool to monitor progress in achieving targets such as the SDGs and highlight the possible negative effects of undernutrition on health and learning outcomes.

The paper is structured as follows: Section 2 provides an overview of the existing literature on undernutrition and its determinants. Section 3 describes the methodology used in this paper—the UNICEF conceptual framework and the MICS data collected in 2010 and 2014. The analysis section (Section 4) begins by describing the nature of stunting among 0–5-year-old children in Sudan highlighting differences in stunting rates across states, households, gender, and age groups. This

analysis is followed by an overview of the extent of inequalities in access to adequate levels of nutrition drivers among 0–23-month-old children. The second part of Section 4 examines the extent to which access to adequate levels of nutrition drivers influences stunting in Sudan. We estimate marginal effects of access levels (including individual and joint access) on the probability of being stunted to identify the main nutrition drivers that significantly affect stunting and the heterogeneity of their effects across space, wealth, and gender. Finally, Section 5 concludes by discussing the implications of the results on multisectoral responses to stunting in Sudan.

2. Stunting and Access to Nutrition Drivers

Undernutrition, particularly stunting among children, is widespread in developing countries and identified as a major challenge to sustained economic growth. In 2018, joint estimates by the WHO, UNICEF, and the World Bank Group indicated that globally 21.9 percent or 149 million children under five years were stunted (that is, too short for their age); 7.3 percent or 49 million children under five years were threatened by wasting (that is, too thin for their height); and 5.9 percent or 40 million children under five years were overweight (that is, too heavy for their height). More than one-third of stunted children (39 percent or 58.8 million children) live in Africa. Furthermore, between 2000 and 2018, Africa is the only region where the number of stunted children has risen—from 50.3 million to 58.8 million (UNICEF, WHO, and World Bank Group 2019). The widespread prevalence of stunting—an indicator of long-term undernutrition (particularly in Africa)—is alarming and calls for concerted efforts to confront it. There exists significant variability in the prevalence of undernutrition across countries (based on income group, Sahel versus non-Sahel, fragility, and so on) and within countries (rural versus urban, boys versus girls, the mother's level of education, the child's age group, and so on) in the region. One striking result from recent studies is the high prevalence of stunting among younger children (ages between 0 and 23 months) in Sub-Saharan Africa (Skoufias, Vinha, and Sato 2019, p49).

High rates of undernutrition are likely to have large negative effects on affected children and their societies in the immediate and long term. Undernourished children are less likely to develop cognitive abilities needed for improved learning outcomes and are more likely to be vulnerable to diseases, particularly chronic diseases in later life. As a result, children who are stunted in the early years of their lives are more likely to have lower learning attainment and wages and are less likely to escape poverty as adults (Fink et al. 2016; Hoddinott et al. 2008, 2011; and Martorell et al. 2010). Stunted women are likely to face obstetric complications because of a smaller pelvis and also face the risk of delivering low-birth-weight infants who in turn are more likely to be smaller adults, resulting in an intergenerational cycle of malnutrition (WHO 2010). Similarly, societies with high rates of undernutrition are less likely to be able to accumulate sufficient human capital for sustainable growth. As a result, countries' failure to address undernutrition (particularly in the early years of children) is likely to significantly undermine economic growth. The negative effects of stunting in particular have been identified to be particularly large. For instance, a recent World Bank report estimates the cost of a country's inability to eliminate stunting of today's workers when they were children at 7 percent of

gross domestic product (GDP) per capita. In Sub-Saharan Africa and South Asia, these effects are even larger—estimates are in the rage of 9 to 10 percent of GDP per capita (Galasso et al. 2017). Given the extent of undernutrition in developing countries and its potential impact on their growth, international organizations such as the World Bank, UNICEF, and so on are increasingly supporting efforts to overcome the challenge of undernutrition through the financing of nutrition-specific interventions and health sector reforms.

Identifying the drivers of malnutrition has been the subject of several studies—from sector-specific studies to multisectoral studies identifying constraints to improving nutritional outcomes. Many of the earlier contributions to the literature on determinants of child undernutrition focused on specific variables that are likely to affect child nutritional outcomes such as socioeconomic conditions of the household proxied by variables, including income, assets, and so on (Behrman and Deolalikar 1987) and the education level of the mother (see Barrera 1990; Behrman and Wolfe 1984; Skoufias 1999; and Webb and Block 2004; among others). In several of these types of studies, environment, health, and child care practices and other unobservable factors likely to affect child nutrition are controlled for using community and/or household fixed effects. Another strand of studies in the literature examined drivers of malnutrition through a sector-specific lens, particularly in nutrition and health. These studies examine the extent to which interventions in sectors such as nutrition (such as promoting breastfeeding, providing micronutrient fortified and enhanced complementary food) and health (such as increasing access to vitamins and minerals) improve nutrition outcomes (see Horton et al. 2010, among others). Later studies have adopted a broader multisectoral framework—incorporating various sectors considered by different strands of the literature on the determinants of undernutrition (nutrition, health, and environmental factors). Indicators of dietary quality and quantity, care and feeding practices, health care, and environmental factors such as water and sanitation have typically been identified and used in these studies to examine the extent to which these factors individually and interactively affect nutritional outcomes (Skoufias 2016).

UNICEF formalized these multisectoral determinants of undernutrition into a framework that continues to provide operational and analytical guidance for combating undernutrition. The UNICEF framework, which was first proposed in 1990, emphasized the interactions between food security, environment, health, and child care practices in influencing child nutritional outcomes (UNICEF 1990). The framework identifies **immediate causes** of undernutrition such as disease and inadequate dietary intake; **underlying causes** of undernutrition such as food insecurity, inadequate care,

unhealthy household environment, and inadequate access to health services; and **basic causes** of undernutrition such as structural differences in social, cultural, economic, and political factors and how they influence inequalities in the distribution of resources (financial, human, physical, and social capital) in the society (Skoufias, Vinha, and Sato 2019; UNICEF 1990). On the basis of this conceptual framework, basic causes of undernutrition trigger underlying causes by imposing constraints on households' ability to achieve food security and healthy environment, as well as access to care and health services. Where these constraints are binding, immediate causes such as inadequate dietary intake and diseases take effect. Although the framework captures the multisectoral nature of nutrition to a great extent, it is important to highlight some of the limitations in its categorization. Evidently, the central pillar of the determinants of undernutrition highlighted earlier is household poverty. Competing needs of households (particularly the poor) impose budget constraints on their ability to provide adequate and nutrient-rich food, proper care (including sanitation), and adequate access to health services for their children in the early years of the lives. As a result, the quantity, quality, and diversity of nutrition, as well as access to care and health services, are often low in these households, exposing their children to undernutrition. The fact that household income is explicitly not included in the UNICEF framework is one of its limitations. Other limitations, which have been cited in the literature, include the absence of prices, knowledge, and education—all of which have direct and/or indirect effects (through the categories identified by the framework) on nutrition (Skoufias 2016).

This framework (and modifications of it) has become the workhorse model used in the recent studies on the determinants of undernutrition. Despite several modifications to the UNICEF framework, the belief that poor diets, in terms of diversity, quality, and quantity resulting in micronutrient deficiencies and increased vulnerability to illness, and inequalities in access to health care, clean water and sanitation, proper care, and appropriate feeding practices play an individual and collective role in influencing nutritional outcomes is still central to its foundation (Skoufias, Vinha, and Sato 2019). Inadequate access to these determinants (particularly in the early years of a child's life) exposes children to various forms of malnutrition, including stunting. Typically, the framework is implemented by identifying indicators of three underlying determinants of undernutrition—food security and care, WASH, and health care. The indicators of food and care include the child's access to minimum acceptable diet (including exclusive breastfeeding for under-six-month-old children) and dietary diversity and quantity. The WASH component captures indicators relating to access to safe drinking water, handwashing facilities, and improved sanitation facilities (including the extent of open defection

in the community). The health component captures indicators relating to use of prenatal and postnatal services, vaccination compliance, and access to health care professionals during childbirth (UNICEF 1990). Several studies—including those by institutions such as the Food and Agriculture Organization (FAO) (2011), the U.S. Agency for International Development (USAID) (Riely et al. 1999), and the World Food Programme (WFP) (2009)—have adopted this framework to generate a wealth of knowledge on the extent and drivers of undernutrition and the identification of children and/or geographical areas where it is most prevalent and hence better targeting of interventions in specific countries. Similarly, other studies have adopted the framework to highlight cross-country differences in the prevalence and drivers of undernutrition—see Smith and Haddad (2015) for a study of 116 countries. The World Bank also recently produced a report on the state of stunting in Sub-Saharan Africa. The report, which also adopts the UNICEF framework, provides an important bridge of the knowledge gap in the understanding the nature of stunting in the region. It uses child-level data from the Demographic and Health Survey (DHS) collected in 2010 or later from 33 countries to provide a detailed analysis of the underlying determinants of undernutrition in Sub-Saharan Africa. The report also examined the extent of the heterogeneity in the prevalence of stunting across the subregion by looking at attributes such as income (both income level and variability), landlocked countries, the Sahel subregion, and fragility. Since DHS data from Sudan were not available for the period covered by the report, Sudan was not included in the analysis. The report documents substantial inequalities in access to the underlying determinants of stunting within countries—particularly between rural and urban and poor and wealthy households. It also highlights the significance of access to health in lowering the likelihood of a child being stunted—particularly when complemented with simultaneous access to food security and care or WASH.

Understanding the underlying determinants of undernutrition is particularly important for designing appropriate multisectoral interventions to meet nutritional targets needed to overcome stunting, underweight, and wasting. With the increasing availability of rich data from DHSs and MICSs, the literature on the determinants of undernutrition is rapidly growing. This is further fueled by growing demand from policy makers as they seek to design appropriate interventions to address the rising challenge of undernutrition. While the recent World Bank report covers substantial ground on the state of stunting in Sub-Saharan Africa, it would be critical to have substantive country-specific insights that can inform the policy makers of individual countries. The UNICEF framework lends itself to this purpose by enabling researchers to capture the joint distribution of the underlying

determinants of undernutrition and thus identify the extent to which deficiencies in a single as well as multiple determinants influence the prevalence of stunting. These insights are important for identifying gaps in those determinant(s) that, if addressed through multisectoral interventions, can improve nutrition outcomes. Empirical evidence so far illustrates that these insights are useful for the design of nutrition-sensitive interventions that address issues of food insecurity, access to health services, provision of caregiving resources in households and communities, and so on and can strengthen other nutrition-related policies such as promoting adequate food and nutrient intake, optimum breast feeding, caregiving, and so on (Black et al. 2013).

This paper aims to contribute to the existing literature by providing in-depth country-specific evidence on the state of stunting in Sudan to inform policy. Drawing from the contributions in the literature, particularly the recent World Bank report on stunting in Sub-Saharan Africa (Skoufias, Vinha, and Sato 2019), this paper examines the prevalence of stunting in Sudan and the extent of the inequalities in access to the underlying determinants of stunting that are influenced by poverty to inform policy. Using two rounds of the MICS data collected in 2010 and 2014, this paper highlights geographic and socioeconomic (particularly wealth) heterogeneity in the prevalence of stunting among 0–23-month-old children in Sudan in both years. We use the UNICEF framework described earlier to identify indicators of food security and child care, WASH, and health care from the MICS data. We examine the extent to which these underlying determinants individually and collectively influence stunting among children in Sudan. The paper also highlights inequalities in access to these determinants and the extent to which such inequalities are driven by poverty. By providing detailed insights into the adequacy of these underlying determinants across states and households over time, gaps in access to drivers that significantly influence stunting can be identified to inform policy. Given recent macroeconomic and political changes in Sudan and ongoing efforts to formulate a national policy for sustained growth and poverty reduction such as the PRSP, results from these analyses will serve as inputs in the design and implementation of such policies by highlighting gaps in the underlying determinants that need to be addressed to improve nutrition outcomes.

3. Methodology

In this section, we describe the data used, the identification of stunted children, and the various indicators of the underlying determinants of stunting (food security and care, WASH, and health care) discussed in the previous section.

Data

This paper uses data from the MICSs collected in 2010 and 2014 by the Central Bureau of Statistics (CBS) of the Republic of Sudan in collaboration with UNICEF and the Ministry of Health.[4] The sample size was 14,778 households in 2010 and 16,801 households in 2014. The survey employed a two-stage stratified cluster design in which the enumeration areas (EAs) were selected in the first stage based on the 2008 population census, and individual households were randomly selected in the second stage following household listing exercise in the selected EAs. A total of 25 households were selected per EA. The sample was designed to be representative both nationally and at the level of all Sudan's states (15 states in 2010 and 18 states in 2014). Similar to the DHS, the MICS collects data at household, child, and women levels. In addition to information about households typically collected in household surveys such as demographics, socioeconomic status, livelihoods, and so on, the MICS collects comprehensive data on child-level health and nutrition (anthropometric indicators), maternal health, and WASH indicators. For this reason, it is easy to construct indicators of undernutrition such as stunting, underweight, and wasting using variables such as height-for-age, weight-for-age, and so on. Furthermore, the comprehensiveness of the data on child nutrition and care, access to health care, and WASH facilities makes it easy to examine the underlying determinants of undernutrition using the UNICEF framework.

Definitions

Stunting. A child who is too short for his/her age is referred to as being stunted. The WHO defines stunting as having a height-for-age Z score (HAZ) more than 2 standard deviations below the WHO Child Growth Standards median (WHO 2010). For this paper, it is expressed as a percentage of children ages 0–5 years whose HAZ falls below the WHO threshold. In discussing the general trend of stunting in Sudan (changes between 2010 and 2014, differences across space and households), we

[4] The 2010 MICS was labelled as the second wave of the Sudan Household Health Survey (SHHS); thus, we maintain the same nomenclature in the rest of the paper.

consider all children under five years of age. However, in analyzing the underlying determinants of stunting, we focus more on children ages 0–23 months.

Underlying determinants of stunting. In Table 1, we describe the underlying determinants of stunting based on the UNICEF conceptual framework. For each determinant, we discuss the indicators considered and the condition for a child to be considered to have an adequate level in the determinant. The adequacy definitions are constructed using thresholds based on accepted international standards (Skoufias, Vinha, and Sato 2019; UNICEF 1990). These determinants are constructed for children ages 0–23 months.

Table 1: Underlying Determinants of Stunting

Determinant	Component	Adequate When:
Food security and care	1. **Minimum acceptable diet.** This is an indicator of the child's level of food security. Under this component, children under 6 months old must be exclusively breastfed, children ages 6–8 months should be still breastfed and consume at least four food groups[5] at least twice a day, children ages 9–23 months and are still breastfed must consume at least four food groups at least three times a day, and children ages 6–23 months who are not being breastfed must consume at least four food groups at least four times a day. 2. **Early initiation of breastfeeding.** This component captures child care and is met when a child was breastfed within hours after birth. 3. **Age-appropriate feeding.** This is another indicator of child care. Under this component, children under 6 months old must be exclusively breastfed and those ages 6 and 24 months in addition to consuming other food, must also be still breastfed.	A child is considered to have an adequate level of food security and child care if the condition for minimum acceptable diet is met with one of the two indicators of child care: early initiation of breastfeeding or age-appropriate breastfeeding.
WASH	1. **Access to safe drinking water.** The child lives in a household with access to pipe-borne water or water obtained from tube well or bore well, protected well or spring, or rainwater. 2. **Access to improved sanitation facilities.** The child lives in a household with a flush toilet, ventilated or slabbed pit latrine, or a composting toilet. 3. **Community-level sanitation.** This indicator captures the extent of open defecation in a child's community/primary sampling unit (PSU), that is, households who do not have access to any toilet facility and thus resort to open defecation. Typically, appropriate community-level sanitation is reached when less than 25 percent of a households in the community use open defecation.	A child is considered to have adequate WASH if s/he meets at least three of the five components.

[5] The food groups are defined to capture the extent of dietary diversity; these include grains, roots, and tubers; legumes and nuts; dairy products; flesh foods including organ meats; eggs; vitamin A-rich fruits and vegetables including orange and yellow vegetables; and other fruits.

Determinant	Component	Adequate When:
	4. **Access to hand washing facilities.**[6] A child lives in a household with handwashing facilities along with water and soap or detergent, as observed by the interviewer. 5. **Feces disposal.** A child's stools are disposed into improved sanitation facilities.	
Health care	1. **Antenatal visits.** This indicator is adequate when a child's mother had at least four antenatal visits during pregnancy. 2. **Birth assisted by health care professional.** The childbirth was assisted by health care professionals such as a doctor, nurse, birth attendant, midwife, and so on. 3. **Immunization compliance.** This indicator captures a child's compliance with his/her vaccines as and when they are due based on the WHO vaccination schedule:[7] tuberculosis- BCG (at birth); diphtheria, pertussis, and tetanus DPT/PENTA (at 2, 3, and 4 months), polio (at birth, 2, 3, and 4 months), and measles (at 9 months). Typically, a leeway of 2 months is added to the vaccination schedule after which a child is considered to be noncompliant with the vaccination requirement.	A child is considered to have adequate health care if s/he meets all three indicators. In other studies, an indicator of access to mosquito net is included in the health care component. However, since this was not available in the MICS data set, we restrict the health care component to the three indicators.

[6] This indicator was not available in the 2010 data.
[7] See https://tinyurl.com/y3gykpr9 for Sudan's vaccination schedule.

4. Analysis

This section aims to provide a description of the state of stunting in Sudan by highlighting differences in stunting levels across space and over time (between 2010 and 2014). We complement this description with a basic analysis of the relationship between stunting and the drivers discussed earlier. These analyses focus on highlighting the correlation between inequalities in individual and/or joint determinants of stunting and observed levels of stunting.

In the second part of the analysis,

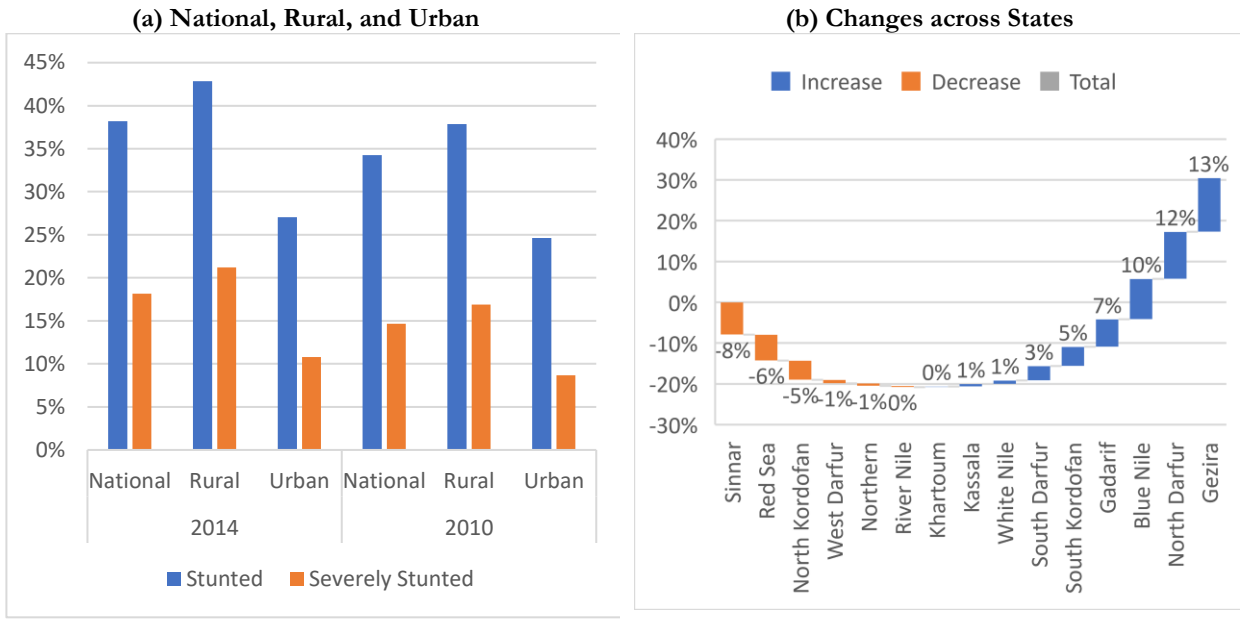
- We estimate the effect of access to adequate levels of nutrition drivers on stunting of 0–23-month-old children;
- We consider the effect of individual and joint access to adequate levels of nutrition drivers on stunting;
- For each component of nutrition driver, we also examine the effect of the individual indicators that form these components on stunting to identify the main drivers of nutritional outcomes among Sudanese children; and
- We also consider differences in the effect of the drivers of stunting across space (rural versus urban), households (rich versus poor), and gender.

Overview Stunting in Sudan

Overall, the number of stunted children who are five years old or younger increased in Sudan between 2010 and 2014, driven largely by an increase in rural areas. In 2010, 34 percent of children under five years were stunted, 15 percent of whom were severely stunted. In 2014, it is estimated that 38 percent of under-five-year-olds were stunted with 18 percent being severely stunted. In rural Sudan, stunting is more prevalent and continues to rise—from 38 percent in 2010 to 43 percent in 2014 compared to 25 percent in 2010 and 27 percent in 2014 in urban areas. Across states, there appears to be significant spatial heterogeneity in the prevalence of stunting. In some states, the number of stunted children decreased between 2010 and 2014, but in most states, it increased. For instance, the largest decreases in the prevalence of stunting were observed in Sinnar, Red Sea, and North Kordofan where the percentage of stunted children decreased by 8 percent, 6 percent, and 5 percent, respectively. On the

other hand, in Gezira, North Darfu, and Blue Nile, the percentage of stunted children increased by 13 percent, 12 percent, and 10 percent, respectively, between 2010 and 2014.

Figure 2: Prevalence of Stunting among Under-Five-Year-Old Children in Sudan: National, Rural, and Urban as well as Changes across States



Source: Authors' calculation using MICS 2010 and 2014 data.

Stunting is more prevalent among children from poorer households. Using a composite indicator of household wealth, it can be observed that stunting is more prevalent among households in the bottom of the wealth distribution and remained high in 2014. More than 40 percent of children in the poorest, poor, and middle wealth quintiles were stunted in 2014—more than 20 percent of these children were severely stunted. Although the prevalence of stunting increased across the wealth distribution between 2010 and 2014, children from households at the bottom of the distribution remain disproportionately affected. These statistics highlight the centrality of household poverty in the prevalence of stunting. Understanding the extent to which poverty influences undernutrition, particularly its role in driving inequalities in access to the underlying determinants of nutrition, is a crucial first step in designing and implementing needed reforms. This paper aims to make a contribution in this regard- by highlighting the role of multisectoral approaches. There also appears to be significant heterogeneity in the prevalence of stunting across households based on the education level of mothers. In both 2010 and 2014, moderate and severe stunting were more prevalent among children whose mothers had no formal education compared to those whose mothers had some primary, secondary, or higher education. For instance, in 2014, the percentage of moderately and severely stunted children whose

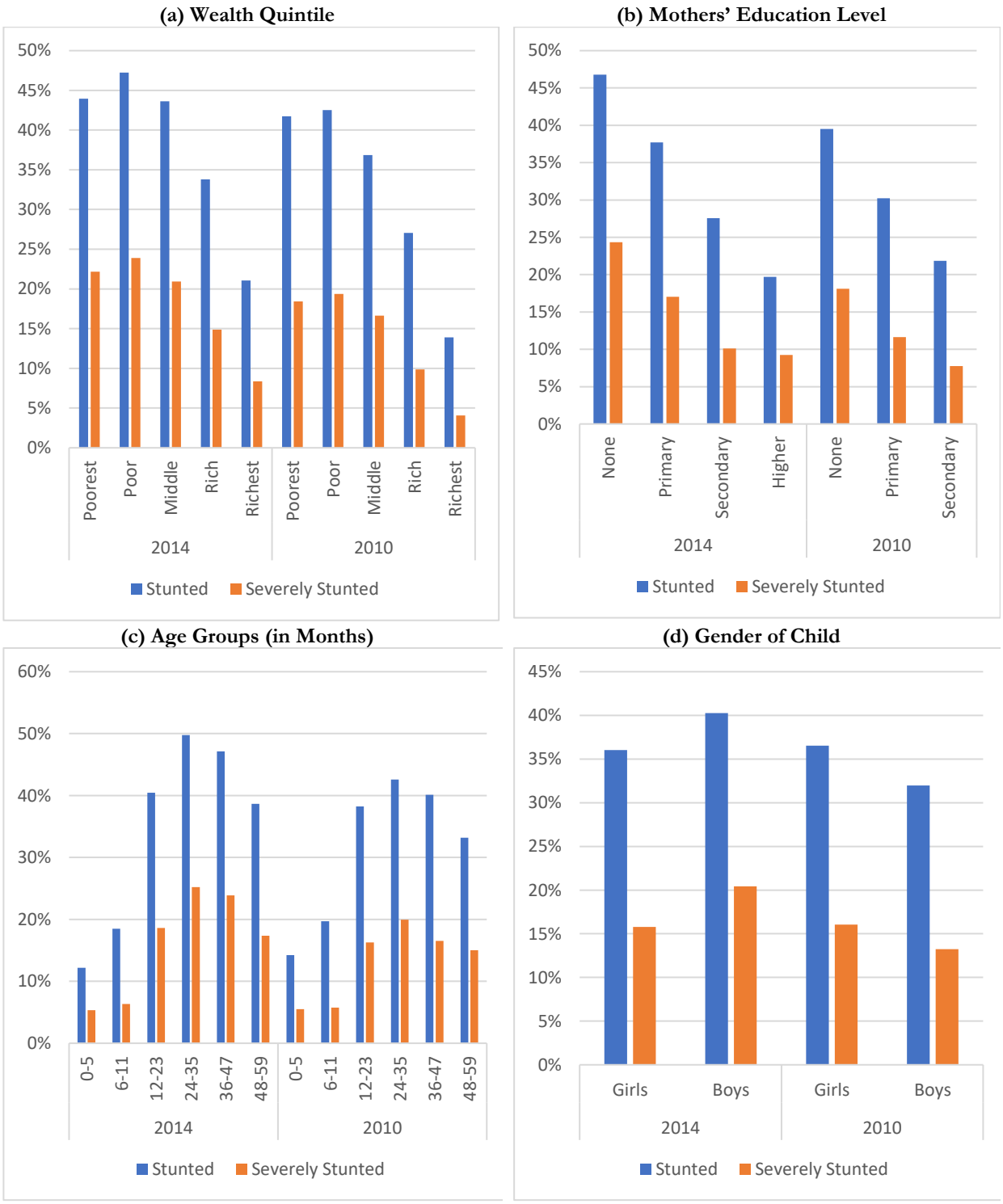
mothers had no formal education was 47 percent and 24 percent, respectively—more than double the prevalence of stunting among children whose mothers had higher education.

Gender patterns in the prevalence of stunting in Sudan have changed between 2010 and 2014, with more boys being stunted in 2014 than girls. Although stunting (both moderate and severe) was more prevalent among female children in 2010, the reverse was observed in 2014. In 2010, 37 percent of female children were stunted compared to 32 percent of male children. Similarly, 16 percent of female children were severely stunted compared to 13 percent of male children. However, in 2014, 40 percent of boys were stunted compared to 36 percent of girls, and 20 percent of boys were severely stunted compared to 16 percent of girls. Although the prevalence of stunting fell among girls between 2010 and 2014, the rate of progress was slow. High prevalence of stunting among girls has significant long-term implications. Small female adults are more likely to give birth to low-birth infants who in turn face significant risk of being smaller adults tomorrow, resulting in an intergenerational cycle of malnutrition. Thus, addressing the problem of stunting through a gender lens is crucial for tackling the intergenerational cycle of undernutrition.

Within the 0–5 age group, the prevalence of stunting continues to be high among the youngest children, including those under 24 months. High prevalence of stunting in the early years of Sudanese children continues to be a major concern. In both 2010 and 2014, the highest rates of stunting were observed among children ages 24–35 month, 35–47 months, and 12–23 months. Furthermore, the recent data show an increase in the prevalence of stunting in these age groups. Stunting among children ages 24–35 months increased from 43 percent in 2010 to 50 percent in 2014, from 40 percent in 2010 to 47 percent in 2014 for children ages 35–47 months, and from 38 percent to 40 percent for children ages 12–23 months. The rates of severe stunting also mirror similar patterns. Another indicator of the high prevalence of stunting in the early years of Sudanese children is the prevalence rate among children under 24 months since this period falls within the traditional first 1,000-day threshold. Moderate stunting rates did not significantly change for this age category in Sudan between 2010 and 2014. In both periods, an estimated 27 percent of children under 24 months were stunted, more than 10 percent of whom were severely stunted; modest reductions in stunting among children ages 0–5 and 6–11 months have been overshadowed by an increase in stunting among children ages 12–23 months. Nutritional deprivation in the early years of a child's life (particularly the first 1,000 days) resulting in stunted growth exposes the children to the risk of delayed cognitive and physical development, illness, and death. If not addressed, stunting in the early years of a child's life implies

that such children are less likely to live to be adults or more likely to grow into less productive adults, leaving societies with lower or less productive human capital and slower growth.

Figure 3: Prevalence of Stunting in Sudan: Wealth Quintile, Mothers' Education Level, Age Group, and Children Gender



Source: Authors' calculation using MICS 2010 and 2014 data.

Overview of the Underlying Determinants of Nutrition (0–23-month-old Children)

Adequate access to the underlying determinants of stunting remains low in Sudan. In 2014, only 5 percent of children ages 0–23 months had adequate levels in all three determinants of stunting considered in this paper: food security and care, WASH, and health care.[8] Although the percentage of 0–23-month-old children with adequate levels of these determinants has increased from 4 percent in 2010, this is largely driven by increases in access for children from rich and urban households. Figure 4a and Figure 4b illustrate the extent of the deficiencies in the access to the underlying determinants of nutrition in Sudan in 2014 and 2010, respectively. Low access to these underlying determinants of nutrition among children in Sudan highlights the urgency for holistic and multisectoral approaches in nutrition and care, WASH, and health to address the widespread prevalence of stunting in Sudan. In the following sections, we identify and discuss the indicators driving these deficiencies in each component to inform the needed responses.

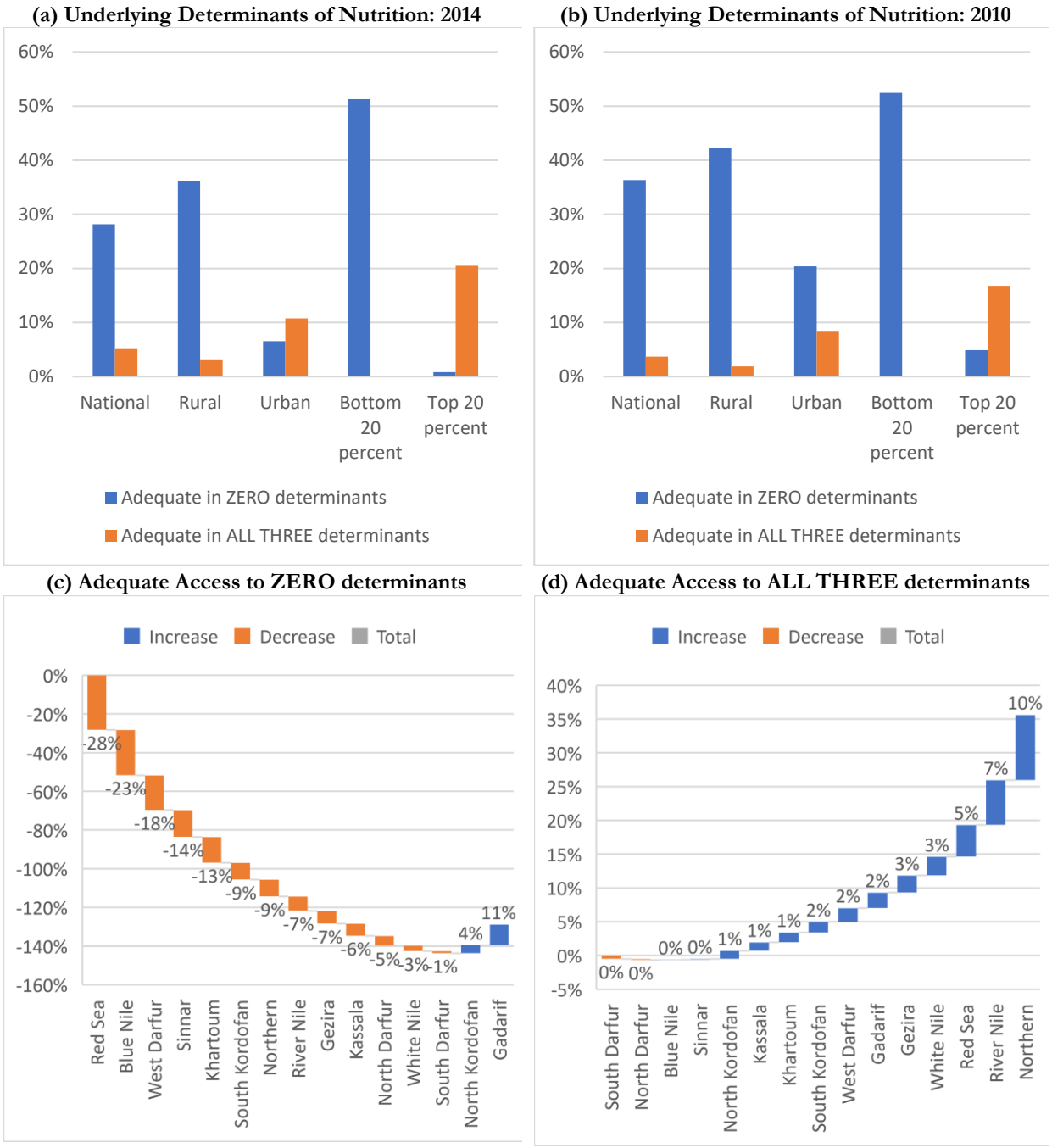
Inequalities in access to adequate levels of the underlying determinants of stunting, particularly between rich and poor as well as rural and urban households, are widespread in Sudan. Most 0–23-month-old children without access to any of the underlying determinants of stunting are from poor or rural households. In both 2010 and 2014, more than 50 percent of children from households in the bottom 20 percent of the wealth distribution and more than 30 percent of those in rural areas did not have adequate levels in any of the three determinants of stunting. On the other hand, the percentage of children from the richest households with inadequate access to all three determinants of nutrition decreased from 5 percent in 2010 to 1 percent in 2014. Similarly, in urban areas, children without adequate access to all three determinants decreased from 20 percent in 2010 to 7 percent in 2014. At face value, these figures illustrate that the increase in the prevalence of stunting in Sudan between 2010 and 2014 was likely driven by inadequate access to adequate levels of the underlying determinants of nutrition for children from poor and rural households. Inequalities in access between these children and those from rich and urban households widened between 2010 and 2014, driving the increase in the prevalence of stunting in poor and rural households.

Although occurring at varying degrees, some states registered significant progress in improving access to the underlying determinants of nutrition between 2010 and 2014. Figure 4a and Figure 4b show the changes between 2010 and 2014 in the percentage of children ages 0–23 months without access and

[8] See Table 1 for the description of the different indicators considered in each component and the definition of adequacy levels.

with access to all three underlying determinants of nutrition across states in Sudan. Most states experienced a decrease (increase) in the percentage of children without (with) access to all three determinants of nutrition between 2010 and 2014. For instance, in the Red Sea and Blue Nile States, the percentage of children without access to any of the three determinants decreased by more than 20 percent between 2010 and 2014. However, in other states such as Gadarif and North Kordofan, the reverse is observed—the percentage of children without access to any of the three determinants increased by 11 percent and 4 percent, respectively. Changes in the percentage of children with adequate access to all three determinants were moderate across Sudan. The largest improvements were registered in the Northern, River Nile, and Red Sea States, where the percentage of children ages 0–23 months with access to all three determinants increased by 10 percent, 7 percent, and 5 percent, respectively.

Figure 4: Access to the Underlying Determinants of Nutrition of 0–23-month-old Children



Source: Authors' calculation using MICS 2010 and 2014 data.

Access to Individual Indicators of Nutrition Drivers

Low adequate access to the underlying determinants of undernutrition appears to be largely driven by low access to adequate health care. Less than 15 percent of children ages 0–23 months had adequate access to health care in both 2010 and 2014. Children in the poorest households continue to have the lowest access to health care in both 2010 and 2014. Compared to the other determinants,

adequate access to health care remains a major challenge to improving nutrition outcomes of Sudanese children. Despite the inequalities in access to food security and care as well as WASH between poor and rich and rural and urban households, access to these determinants is much higher than access to health care—55 percent of 0–23-month-old children had access to adequate levels of WASH in 2014 (an increase from 35 percent in 2010). Although access to food security and care decreased by 6 percent between 2010 and 2014, 36 percent of children had adequate access to food security and care in 2014.

Access to adequate levels of food security and care decreased between 2010 and 2014, driven largely by increased food insecurity. Across Sudan, 36 percent of 0–23-month-old children had adequate levels of food security and care in 2014, a slight decrease from 42 percent in 2010 (see **Error! Not a valid bookmark self-reference.**a and **Error! Not a valid bookmark self-reference.**b). Inequalities in access to adequate food security and care between rural and urban as well as poor and rich households widened between 2010 and 2014. The gap in the percentage of 0–23-month-old children with adequate access to food security and care between poor and rich households was 4 percentage points in 2010 and 12 percentage points in 2014. Similarly, between rural and urban households, this gap increased from 1 percentage point in 2010 to 3 percentage points in 2014. A closer look at the individual components of food security and care shows a decrease in food security and significant improvements in indicators of care such as early initiation of breastfeeding—59 percent of children were breastfed within hours after birth in 2014 compared to 37 percent in 2010. Similarly, more than 80 percent of children met the age-appropriate breastfeeding thresholds in both 2010 and 2014. Food security (an important determinant of nutrition outcomes and measured through the lens of minimum acceptable diets) remains low and unequal between households. The percentage of children with adequate minimum acceptable diets decreased from 43 percent in 2010 to 36 percent in 2014. The gap between rich and poor households also widened from 4 percentage points in 2010 to 12 percentage points in 2014. Increased food insecurity, particularly among the poorest households, is likely to be a major driver of the increased prevalence of stunting in Sudan.

Access to adequate WASH albeit high is masked by large inequalities, particularly between rich and poor households. The percentage of 0–23-month-old children with adequate WASH increased from 35 percent in 2010 to 55 percent in 2014 but was largely driven by increase in access for children from rich and urban households (see **Error! Not a valid bookmark self-reference.**c and **Error! Not a valid bookmark self-reference.**d). The gap in the percentage of children with adequate WASH

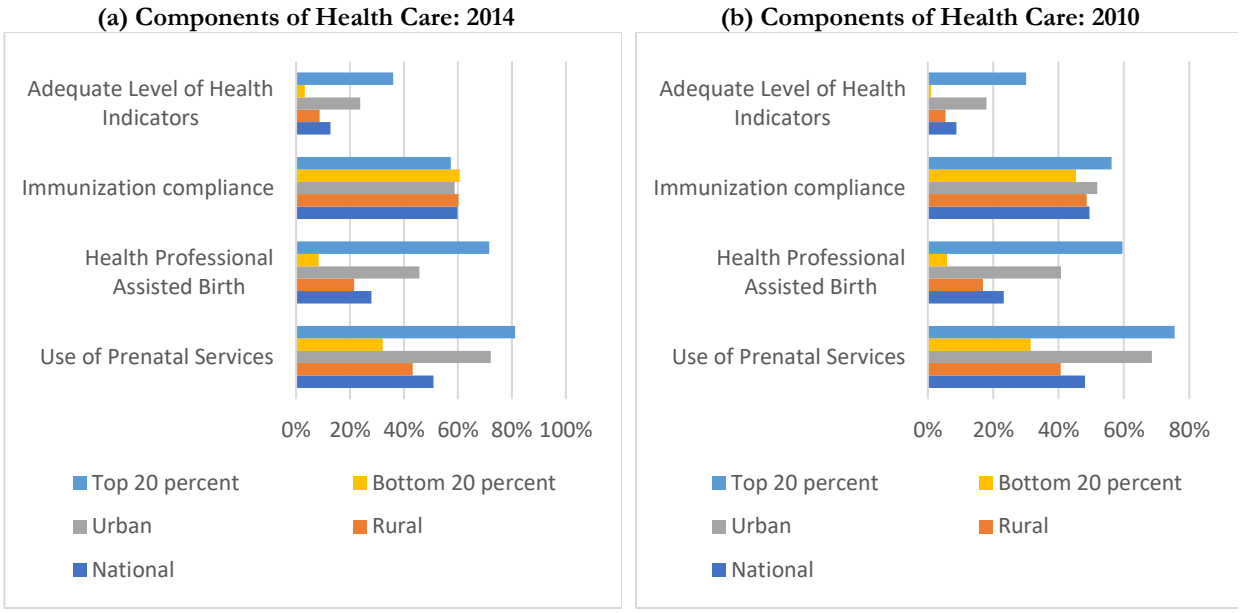
between rich and poor households remains disproportionately high—more than 70 percentage points in both 2010 and 2014. Nearly all children under 24 months old from households in the top 20 percent of the wealth distribution have adequate access to WASH whereas slightly above 20 percent of similar children from the bottom 20 percent of the wealth distribution have adequate access to WASH. Access to the individual components of WASH is equally marked by significant inequalities between rich and poor households. Access to safe drinking water and improved sanitation (both at household and community level) improved between 2010 and 2014. However, children from households at the bottom of the wealth distribution continue to have low access levels to these components of WASH. Availability of handwashing facilities is relatively low in Sudan, particularly in poor households.

Access to adequate health care remains low and unequal in Sudan despite improvements in immunization compliance. Less than 15 percent of under-24-month-old children in Sudan had access to adequate health care in 2010 and 2014 (see Figure 6a and Figure 6b). Among poor and rural households, access to health care was much lower in both 2010 and 2014; less than 5 percent of children in poor households and less than 10 percent of those in rural areas had adequate access to health care. In rich and urban households, moderate improvements in access to health care were observed between 2010 and 2014. Nationally, immunization compliance rates increased from 49 percent in 2010 to 60 percent in 2014 and are less unequal between rich and poor as well as urban and rural households. Inequalities in the use of prenatal services and health professional assisted delivery remain wide between poor and rich as well as rural and urban households. It is thus surprising that while immunization compliance has improved, which illustrates increased use of postnatal services, the use of health centers for prenatal visits and/or delivery remains low in Sudan. Therefore, addressing the inadequate access to health care requires interventions to improve access to and use of health centers, particularly in poor and rural households.

Figure 5: Components of Food Security and Care and WASH for Children Ages 0–23 Months

Source: Authors' calculation using MICS 2010 and 2014 data.

Figure 6: Components of Health Care for Children Ages 0–23 Months



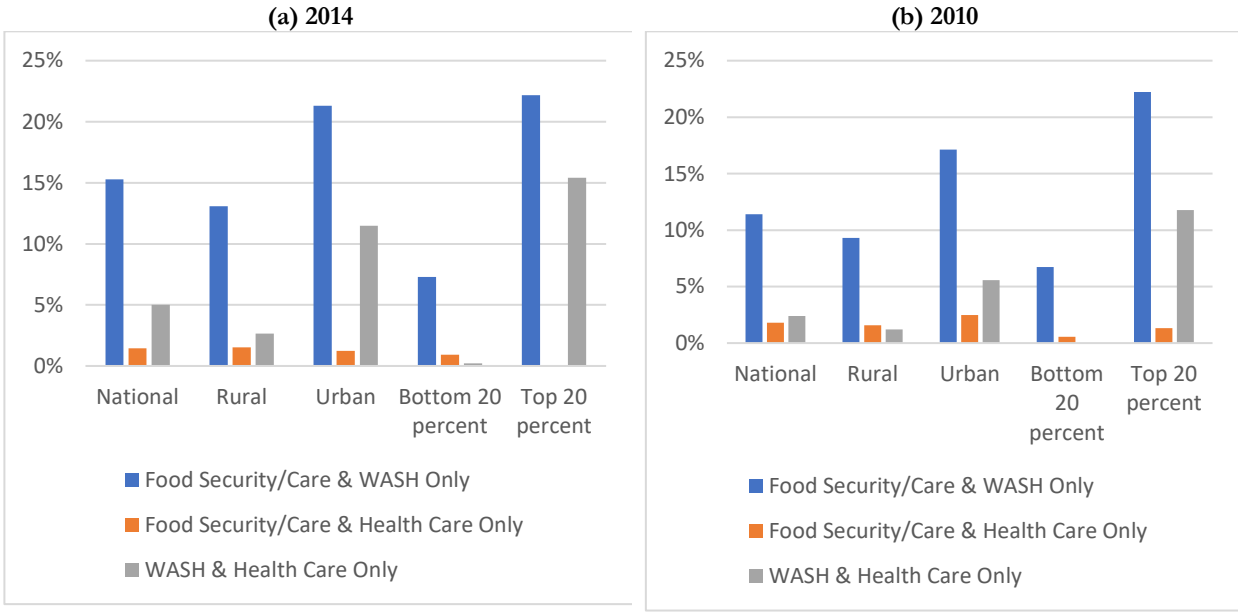
Source: Authors' calculation using MICS 2010 and 2014 data.

Joint Access to the Underlying Determinants of Nutrition

Of the three nutrition drivers considered in this report, access to adequate health care continues to be low for Sudanese children (particularly those in rural areas and from households in the bottom 40 percent of the wealth distribution). Figure 7 shows that in both 2010 and 2014, more children ages between 0 and 23 months had joint access to adequate levels of food security and WASH indicators only than food security and health care only or WASH and health care only. For instance, across Sudan, in 2010, 15 percent of 0–23-month-old children had adequate access to food security and care and WASH only (and inadequate access to health care). On the other hand, only 1 percent and 5 percent of children had adequate access to food security and care and health care only as well as WASH and health care only, respectively. In 2014, 11 percent of children ages 0–23 months in Sudan had adequate access to both food security and care and WASH only, but only 2 percent of 0–23-month-old children had joint access to adequate levels of food security and care and health care or WASH and health care. In rural areas and among households in the bottom 20 percent of the wealth distribution, joint access to adequate levels of the underlying determinants of nutrition are lower, particularly when access to health care is considered. In both 2010 and 2014, less than 5 percent of children from rural areas or households in the bottom 40 percent of the wealth distribution had adequate joint access to food security and care and health care or WASH and health care. Access to adequate food security and care and WASH for these children remains below the national average and

decreased between 2010 and 2014. These results highlight the extent to which low access to adequate health care remains a main driver of inadequate access to the underlying determinants of undernutrition.

Figure 7: Joint Access to Nutrition Drivers



Source: Authors' calculation using MICS 2010 and 2014 data.

The description of the nature of stunting in Sudan above provides an overview and several insights to inform responses. The heterogeneity in the prevalence of stunting of across states and between rural and urban shows the degree to which rural children remain most vulnerable to stunting. Similarly, across households, poor households (particularly those in the bottom 20 percent of the wealth distribution) and children whose mothers have no formal education remain disproportionately stunted. Large inequalities in access to adequate levels of the underlying determinants of undernutrition exist between rural and urban and rich and poor households. More rural and poor households have inadequate access to all the three determinants, food security and care, WASH, and health care, than their urban and rich counterparts. Access to adequate health care remains significantly low for most households in Sudan, particularly rural and poor households. A closer look at joint access to these determinants shows that inadequate access to health care remains a main barrier for poor and rural households' access to the adequate levels of these underlying determinants of undernutrition. These features of the nature of stunting in Sudan are fairly consistent with observed trends from recent data from Sub-Saharan African countries (Skoufias, Vinha, and Sato 2019).

Stunting and Children's Access to the Underlying Determinants of Undernutrition

This section examines the relationship between stunting and the number of determinants of undernutrition accessed at the same time. By means of probability density functions (PDFs) and cumulative density functions (CDFs) of children's HAZ and access to different numbers of the underlying determinants of undernutrition, we examine the relationship between having access to one, two, or all three drivers of nutrition and stunting. Figure 8 presents the CDFs and PDFs for 2010 and 2014 and for various access levels to the underlying determinants of undernutrition: zero, one, two, and three. The black vertical line in each graph at −2 shows the WHO threshold of HAZ used to define stunting. The intersection of this line with each CDF, denoted by the dotted/dashed lines, represents the prevalence of stunting among children with that access level. Similarly, in the PDFs, the area under the curve and left of the −2 threshold represents stunting.

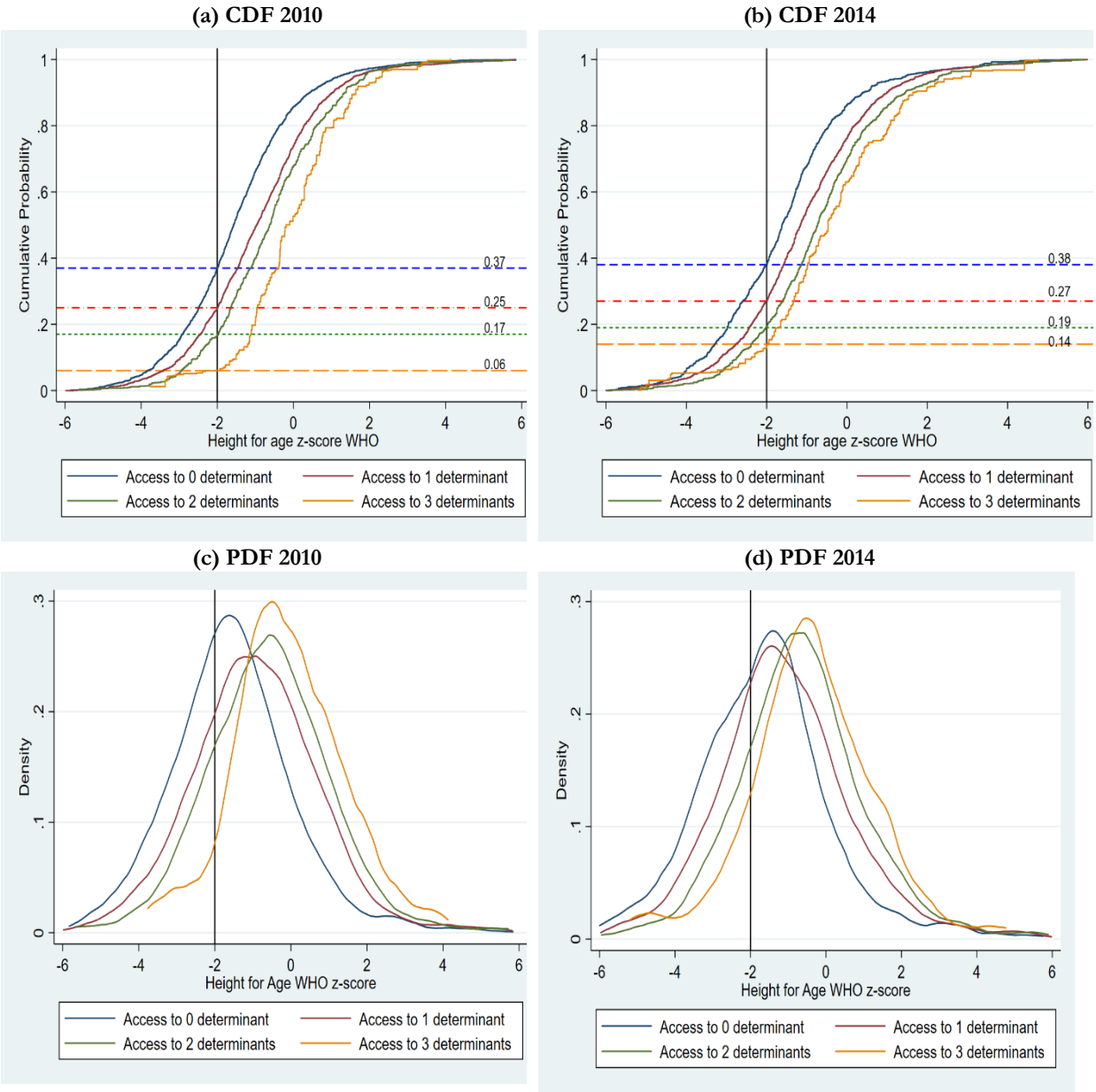
The prevalence of stunting is higher among children with access to zero underlying determinants and lower among children with access to all three underlying determinants of undernutrition. The CDFs of HAZ for children with access to zero, one, two, and three determinants of undernutrition presented in Figure 8a and Figure 8b illustrate correlations between stunting and access to the drivers of nutrition. In both 2010 and 2014, the prevalence of stunting was significantly lower among children with access to more drivers of nutrition. For instance, 37 percent children under 24 months of age without access to any of the underlying determinants of undernutrition were stunted in 2010, compared to only 6 percent of children in the same age group with access to all three determinants of undernutrition. Similarly, in 2014, 38 percent of children without access to any of the underlying determinants were stunted compared to 14 of children with access to all three. It can also be observed from the CDFs that the largest reductions in stunting are associated with increases in access from none (0) to any one nutrition driver and from any one driver to simultaneous access to any two drivers of nutrition. For instance, in both 2010 and 2014, stunting rates were lowest among children with access to all three nutrition drivers (6 percent and 14 percent, respectively), followed by children with simultaneous access to any two nutrition drivers (17 percent and 19 percent, respectively) and children with access to any one nutrition driver (25 percent and 27 percent, respectively). Stunting rates were highest among children without access to any nutrition driver (37 percent and 38 percent, respectively).

The PDFs (in Figure 8c and Figure 8d) summarize the same information in a different way. Children with better access to the underlying determinants of undernutrition have a higher mean HAZ (the PDF shifts right) and most of the differences in the PDFs for different access levels are in the lower

left tail of the bell-shaped curve, which represents stunting. It is easy to observe that in both 2010 and 2014, stunting was higher among children without access to any nutrition driver and lowest among children with access to all three drivers; in Figure 8c and Figure 8d, the area under the blue PDF and to the left of the −2 threshold is larger than the area under the orange PDFs and to the left of the −2 threshold. Similarly, stunting is lower among children with simultaneous access to any two drivers than children with access to only one nutrition driver.

In both the PDFs and CDFs, it can be observed that differences in the prevalence of stunting due to inequalities in access to the underlying determinants of undernutrition were larger in 2010 than in 2014. Fewer children with adequate levels in all three determinants were stunted in 2010 than in 2014. Furthermore, the difference in the prevalence of stunting between children with adequate levels in all three determinants and children with adequate levels in only two determinants was larger in 2010 than in 2014. In 2010, only 6 percent of children with adequate levels in all three drivers of nutrition were stunted compared to 14 percent in 2014. The difference in the prevalence of stunting between children with adequate levels in all three drivers and those with adequate levels in only two was 9 percentage points in 2010 and 5 percentage points in 2014. The PDFs also illustrate a similar story—the area under the curve and left to the −2 threshold for children with adequate level in all three determinants is smaller in 2010 than in 2014 and much smaller than for children with adequate access to only two determinants in 2010 than in 2014.

Figure 8: Cumulative and Probability Density Functions of HAZ and Nutrition Drivers



Source: Authors' calculation using MICS 2010 and 2014 data. Estimates are based on children under 24 months of age.

Estimating the Impact of the Underlying Determinants of Undernutrition on Stunting

The preceding sections describe the nature of stunting and access to drivers of nutrition in Sudan by highlighting differences in the prevalence of stunting across states and households in Sudan as well as the relationship between stunting and access to nutrition drivers. The figures presented summarize patterns of stunting and changes between 2010 and 2014. In particular, the CDFs and PDFs (Figure 8) illustrate the correlation between stunting and access to nutrition drivers. However, these analyses ignore the potential influence that individual child, parental, and regional characteristics may have on the relationship between stunting and access to one or more determinants of nutrition. In this section, we complement the description of the nature of stunting by estimating the extent to which the underlying determinants of undernutrition individually and jointly affect stunting among 0–23-month-old children in Sudan while controlling for these attributes. It is important to highlight that the estimated parameters from the following models capture correlations between stunting and having adequate levels of access to one or more of the underlying drivers of nutrition identified by the UNICEF framework. The additional controls included are aimed at minimizing the influence of confounding factors on the relationship between having adequate access to the underlying determinants of undernutrition and stunting.[9] Thus, we interpret the results with these caveats in mind. The methodology adopted closely follows the work of Skoufias, Vinha, and Sato (2019).

In the first specification, we examine the effect of varying access to nutrition drivers on stunting by fitting the following logit model:

$$Stunted_{\iota s} = \beta_0 + \beta_1 Any1_{\iota s} + \beta_2 Any2_{\iota s} + \beta_3 All3_{\iota s} + X_{\iota s} + \mu_s + \varepsilon_{\iota s}, \qquad (1)$$

where the dependent variable $Stunted_{\iota s}$ is a binary variable taking the value of 1 if child ι in state s age between 0 and 23 months is stunted (that is, has a HAZ less than -2 standard deviation for the reference WHO population) and 0 otherwise. The variables, $Any1_{\iota s}$, $Any2_{\iota s}$, and $All3_{\iota s}$, are binary variables that take the value of 1 if the child has adequate level in any one, any two, or all three nutrition drivers, respectively; $X_{\iota s}$ captures a set of control variables relating to child characteristics (gender, birth month, birth order, and so on); parental characteristics (mother's age, education level, marital status, and so on); and household characteristics (number of household members, number of children

[9] Some studies estimate reduced form models that capture budget constraints and so on (see Barrera 1990).

under five years of age, location of household [rural or urban], and wealth of household). μ_s is state-level fixed effects, and ε_{is} is the error term.

In the specification described earlier, the constant term β_0 provides an estimate of the probability of being stunted for children in the reference group, that is, children without access to adequate levels in any of the three nutrition drivers. The other parameters, β_1, β_2, and β_3, provide estimates of the marginal decline in the probability of being stunted for children with access to any one, any two, or all three nutrition drivers, respectively, relative to children in the reference group. It is important to state that the parameter estimates from this specification do not imply causal inference on the impact of access to nutrition drivers on stunting. The possibility of omitted variable bias cannot be entirely ruled out. It is for this reason that additional control variables and state fixed effects are included to minimize such biases.

In a second specification, we examine the effect of joint access to nutrition drivers on stunting. Figure 7 shows that simultaneous access to nutrition drivers is associated with a decline in the prevalence of stunting. It is thus important to identity which of these drivers is associated with a more significant decline in stunting rates. Insights from such analysis are particularly important for policy targeting, especially for governments such as Sudan facing constrained fiscal space. We examine this using the following logit model:

$$Stunted_{is} = \beta_0 + \beta_{FC}FC_{is} + \beta_W W_{is} + \beta_H H_{is} + \beta_{FCW}FC\_W_{is} + \beta_{FCH}FC\_H_{is} + \beta_{WH}W\_H_{is} + \beta_{FCWH}All3_{is} + X_{is} + \mu_s + \varepsilon_{is} \quad (2)$$

The dependent variable $Stunted_{is}$, the set of control variables X_{is}, state fixed effects μ_s, and error term ε_{is} are as defined in equation (1). The effect of having adequate access to one nutrition driver or a combination of two or all three nutrition drivers on the probability of being stunted (assuming child, parental and household characteristics are constant) is captured by the β parameter estimates (except β_0 which captures the probability of being stunted of children in the reference category, that is, those who have inadequate access to all three nutrition drivers). For instance, the estimated value of β_{FC} represents the estimated decline in the probability of being stunted among children who have adequate access to food security and care only (FC = 1) but inadequate access to WASH and health care, relative to the probability of a child in the reference group being stunted. The estimated values of β_W and β_H have similar interpretations for adequate access to WASH only and health care only, respectively.

Similarly, the effect of having simultaneous access to any two and all three nutrition drivers on the probability of being stunted is obtained from parameter estimates of β_{FCW}, β_{FCH}, β_{WH}, and β_{FCWH}.

We estimate these specifications for each round of data, 2010 and 2014, separately using a logit model. It is important to highlight that fixed effects estimators on pseudo panel data constructed using the two rounds of cross-sectional data[10]. Such techniques will allow us estimate the effects of the underlying determinants on nutrition with better precision. However, the recent changes in Sudan's geopolitical landscape between 2010 and 2014, particularly the secession of the South in 2011, makes the assumptions underpinning a pseudo panel hard to justify in this case.

Empirical Results

Having access to adequate levels of nutrition drivers is associated with lower probability of stunting. In both 2010 and 2014, children under 24 months old with access to all three underlying determinants of nutrition were, respectively, 23.4 percent and 17.4 percent less likely to be stunted than children without adequate access to any of the three determinants. Furthermore, having adequate access to some nutrition drivers is better than having adequate access to none; children who have access to adequate levels to some (one or two of the three) of the nutrition drivers are significantly less likely to be stunted than those without adequate access to any of the three drivers. For instance, in 2014, children with adequate access to at least one determinant were 7.5 percent less likely to be stunted than those without adequate access to any of the three determinants. Similarly, children with adequate access to any two determinants were 13.4 percent less likely to be stunted than those without adequate access to any. Similar effects are observed from the 2010 data. These estimates are robust to state fixed effects as well as child, mother, and household covariates.

Table 2: Marginal Effects: Adequate Access to Underlying Determinants of Nutrition

Variables	2010			2014		
	(1)	(2)	(3)	(1)	(2)	(3)
Adequate in 1 determinants	−0.123*** (0.0167)	−0.114*** (0.0162)	−0.0733*** (0.0170)	−0.109*** (0.0216)	−0.0964*** (0.0213)	−0.0750*** (0.0220)
Adequate in 2 determinants	−0.201*** (0.0227)	−0.187*** (0.0235)	−0.125*** (0.0257)	−0.187*** (0.0256)	−0.163*** (0.0279)	−0.134*** (0.0304)
All three determinants	-0.310*** (0.0294)	-0.294*** (0.0343)	−0.234*** (0.0437)	−0.243*** (0.0440)	−0.213*** (0.0493)	−0.174*** (0.0587)
State Fixed Effects	**—**	**Yes**	**Yes**	**—**	**Yes**	**Yes**
Additional Controls			**Yes**			**Yes**
Observations	4,846	4,846	4,769	4,580	4,580	4,273

Note: (1) All specifications are estimated for children under 24 months old.

[10] See (Christiaensen & Subbarao, 2005) for an application of such techniques.

(2) Marginal effects are based on coefficient estimates obtained from the logit model in equation (1).
(3) Base category in each specification is children with inadequate access to all three determinants.
(4) Additional controls include child-level characteristics (such as birth month, gender of child, birth order except in 2010); mother-level characteristics (such as age, education level, marital status, and so on); and household characteristics (such as household size, number of children under five, wealth quintile, gender of head, and so on).
(5) Household weights applied.
Robust standard errors clustered in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

The effects of access to adequate levels of nutrition drivers on stunting described earlier are masked by significant heterogeneity across space (rural/urban), income (bottom 40 and top 20 of the wealth distribution), and gender (male and female children). Using both 2010 and 2014 rounds of data, we draw some insights on the extent of the heterogeneity in the effect of access to adequate levels of nutrition drivers on stunting across households and over time as shown in Table 3. Estimates from both rounds of data show that patterns between rural and urban children, bottom 40 and top 20 percent of wealth distribution, as well as boys and girls have changed overtime. For instance, the effect of adequate access to all three determinants on the likelihood of stunting was higher among rural children than urban children in 2010 (30.7 percent compared to 26.2 percent), while the reverse was observed in 2014. Among urban children, adequate access to all three determinants is associated with a 18.5 percent decrease in the probability of stunting relative to those without adequate access to any of the three determinants in 2014. In rural areas, adequate access to one or two nutrition drivers yields significantly more reduction in the probability of stunting—these children are on average 8.5 percent and 13.4 percent, respectively, less likely to be stunted than children without adequate access to any nutrition driver. Access to some nutrition drivers has a larger effect on stunting outcomes for rural children than urban children.

Overall, adequate access to the underlying determinants of nutrition yields larger effects on the stunting outcomes of children from the poorest households than those of children from the richest households. For children from households in the bottom 40 percent of the wealth distribution, access to nutrition drivers significantly lowers their probability of stunting. This is true for children with access to all as well as those with access to some of the nutrition drivers. In 2014, children from these households with adequate access to one nutrition driver decrease their probability of stunting by 9.6 percent, access to two is associated with a 17.7 percent decrease in their probability of stunting, and children with access to all three nutrition drivers were 28.8 percent less likely to be stunted compared to children without adequate levels of access to any of the nutrition drivers. Compared to their counterparts from households in the richest 20 percent of the wealth distribution, differences in access

to the underlying determinants of nutrition do not appear to have a statistically significant effect on stunting outcomes.

Among both boys and girls, better access to adequate levels of nutrition drivers lowers their probability of being stunted with the gains from improved access being larger for girls in 2014. In 2010, gains from adequate access to nutrition drivers were larger for boys than girls—boys with adequate access in one, two, and all three nutrition drivers were 8.8 percent, 16.1 percent, and 25.8 percent, respectively, less likely to be stunted than boys without adequate access to any of the nutrition drivers. For girls, on the other hand, adequate access to one, two, and three nutrition drivers was only associated with 6.2 percent, 9.1 percent, and 21 percent reductions, respectively, in the likelihood of stunting, compared to girls without adequate access to any nutrition driver. However, estimates from the latest round of data show that girls are gaining more from having access to nutrition drivers. Girls with adequate access to all three nutrition drivers are on average 23.4 percent less likely to be stunted than girls without adequate access to any nutrition driver. The effect on the comparable category of boys is statistically insignificant. Similarly, girls with access to any one or any two nutrition drivers are also 7.2 percent and 13.6 percent, respectively, less likely to be stunted. For boys with similar access levels, the effect on their probability of stunting is 7.5 percent and 12.9 percent, respectively. Gains from improvements in access to adequate levels of nutrition drivers appear to be larger for girls than boys, particularly in 2014. Girls with adequate access to all three nutrition drivers gained an additional 9 percentage point reduction in their probability of being stunted compared to girls with adequate access to only two nutrition drivers.

Table 3: Marginal Effects: The Heterogeneity of the Effects of Adequate Access to Underlying Determinants of Nutrition

Variables	2010						2014					
	Rural	Urban	Bottom 40	Top 20	Boys	Girls	Rural	Urban	Bottom 40	Top 20	Boys	Girls
Adequate in 1 determinant	−0.0662***	−0.0768***	−0.0813***	−0.0353	−0.0881***	−0.0623***	−0.0848***	-0.0534	−0.0961***	0.0623	−0.0754**	−0.0721**
	(0.0186)	(0.0285)	(0.0253)	(0.0739)	(0.0247)	(0.0238)	(0.0249)	(0.0657)	(0.0315)	(0.0665)	(0.0313)	(0.0308)
Adequate in 2 determinants	−0.131***	−0.113***	−0.141**	−0.0328	−0.161***	−0.0905***	−0.134***	−0.131**	−0.177***	0.0444	−0.129***	−0.136***
	(0.0388)	(0.0368)	(0.0593)	(0.0763)	(0.0359)	(0.0345)	(0.0384)	(0.0651)	(0.0536)	(0.0542)	(0.0431)	(0.0395)
All 3 determinants	−0.307**	−0.262***		−0.113	−0.258***	−0.210***	−0.133	−0.185**	−0.288***		−0.105	−0.234***
	(0.148)	(0.100)		(0.0947)	(0.0723)	(0.0457)	(0.0918)	(0.0803)	(0.0871)		(0.0932)	(0.0533)
State fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,446	1,323	2,059	601	2,407	2,362	3,082	1,191	1,942	543	2,177	2,096

Note: Robust standard errors clustered in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0$.

Although adequate access to food security and care significantly lowers the probability of stunting, the effect is larger when combined with access to health care. Holding, child, parental, household, and state-specific factors constant, having adequate access to food security and care only yields large reductions in a child's probability of being stunted (see Table 4). Children with access to adequate levels of food security and care only were 9.7 percent and 20.4 percent less likely to be stunted in 2010 and 2014, respectively, than those without adequate access to any of the nutrition drivers. Compared to the effects of having adequate access to WASH only or health care only, the effect of having adequate access to food security and care only is larger and statistically significant on the probability of being stunted. The effect of food security and care on stunting is larger when combined with access to adequate health care, although the magnitude decreased between 2010 and 2014. The probability of being stunted associated with having simultaneous access to adequate food security and care and health care was 22.6 percent and 21.2 percent in 2010 and 2014, respectively. This implies that the marginal decline in the probability of being stunted associated with adding access to adequate health care for children with adequate access to food security and care was 12.9 percentage points in 2010 $[(-0.226) - (-0.0965) = -0.129]$ and about 1 percentage point in 2014 $[(-0.21) - (-0.20) = -0.01]$. The gains from adding adequate access to WASH for children with adequate access to food security and care are not as large. Similarly, children with joint access to adequate WASH and health care were 16.6 percent less likely to be stunted in 2010 than those without adequate access to any of the underlying nutrition drivers. The effect in 2014 was statistically insignificant once child, mother, household, and state-specific fixed effects are accounted for.

The large nutritional gains from having adequate food security and care offer one possible explanation for the increase in the rate of stunting in Sudan between 2010 and 2014. Adequate access to food security and care decreased significantly in rural areas (from 42 percent in 2010 to 35 percent in 2014) and among the poorest households (from 39 percent in 2010 to 33 percent in 2014), thereby resulting in large increases in stunting. One possible policy implication of these results, particularly in a country such as Sudan where the government faces constrained fiscal space, is that in identifying priority sectors for responses to tackle stunting, ensuring access to adequate food security and care for deprived children should be a primary one. For children who already have adequate access to food security and care only, resources can be directed toward ensuring that they have simultaneous access to health care to further improve their nutritional outcomes.

Table 4: Marginal Effects: Joint Access to Underlying Determinants of Nutrition

Variables	2010			2014		
	(1)	(2)	(3)	(1)	(2)	(3)
Adequate food security/care only	−0.120*** (0.0177)	−0.122*** (0.0173)	−0.0965*** (0.0177)	−0.208*** (0.0267)	−0.209*** (0.0268)	−0.204*** (0.0315)
Adequate WASH only	−0.0984*** (0.0220)	−0.0798*** (0.0227)	−0.0220 (0.0256)	−0.0706*** (0.0227)	−0.0510** (0.0231)	−0.0236 (0.0246)
Adequate health care only	−0.148* (0.0815)	−0.133 (0.0829)	−0.102 (0.0824)	0.0844 (0.0542)	0.0891* (0.0531)	0.136** (0.0595)
Adequate food security/care and WASH only	−0.173*** (0.0285)	−0.160*** (0.0290)	−0.0933*** (0.0301)	−0.181*** (0.0319)	−0.160*** (0.0331)	−0.133*** (0.0356)
Adequate food security/care and health care only	−0.293*** (0.0803)	−0.289*** (0.0787)	−0.226*** (0.0809)	−0.215** (0.0863)	−0.214** (0.0861)	−0.212** (0.0944)
Adequate WASH and health care only	−0.309*** (0.0801)	−0.268*** (0.0767)	−0.166** (0.0773)	−0.176*** (0.0483)	−0.113** (0.0536)	−0.0558 (0.0551)
Adequate all 3 determinants	−0.427*** (0.0867)	−0.389*** (0.0894)	−0.281*** (0.0896)	−0.261*** (0.0654)	−0.215*** (0.0665)	−0.166** (0.0721)
State fixed effects	**—**	**Yes**	**Yes**	**—**	**Yes**	**Yes**
Additional controls			**Yes**			**Yes**
Observations	4,846	4,846	4,769	4,580	4,580	4,273

Note: (1) All specifications are estimated for children under 24 months old.
(2) Marginal effects are based on coefficient estimates obtained from the logit model in equation (2).
(3) Base category in each specification is children with inadequate access to all three determinants.
(4) Additional controls include child-level characteristics (such as birth month, gender of child, birth order except in 2010); mother-level characteristics (such as age, education level, marital status, and so on); and household characteristics (such as household size, number of children under five, wealth quintile, gender of head, and so on).
(5) Household weights applied.
Robust standard errors clustered in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

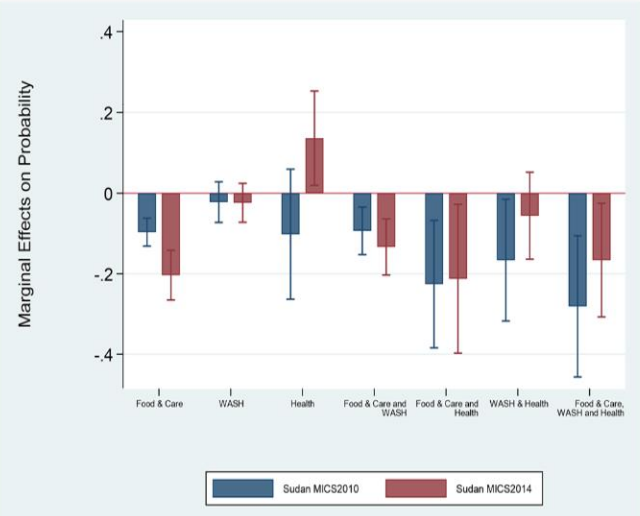
Gains from adequate access to food security and care have improved and were larger for girls, children in rural areas, and those from poorer households in 2014**.** While adequate access to food security and care significantly lowers the probability of stunting, the magnitude of this effect differs across children based on their location, wealth, and gender (see Table 5). For instance, the 2010 data show that the effect was slightly larger for children from urban areas and boys, while the reverse is observed in the 2014 data. Rural children with adequate access to food security and care were 22.1 percent less likely to be stunted than children without adequate access to any nutrition driver—an improvement from 9.5 percent in 2010. Similarly, the probability of being stunted associated with having adequate access to food security and care was 26.4 percent for children from households in the bottom 40 percent of the wealth distribution in 2014 (from 11.9 percent in 2010) and 22.2 percent for girls in 2014 (from 7.7 percent in 2010). Given that between 2010 and 2014, stunting rates increased in rural areas (see Figure 2) and among the poorest households (see Figure 3), these results provide useful insights for policy response. Improving access to adequate food security and care for children in rural areas and those from the poorest households will significantly contribute to lowering stunting rates in Sudan.

Box 1: Comparing Sudan with Other Countries in Sub-Saharan Africa

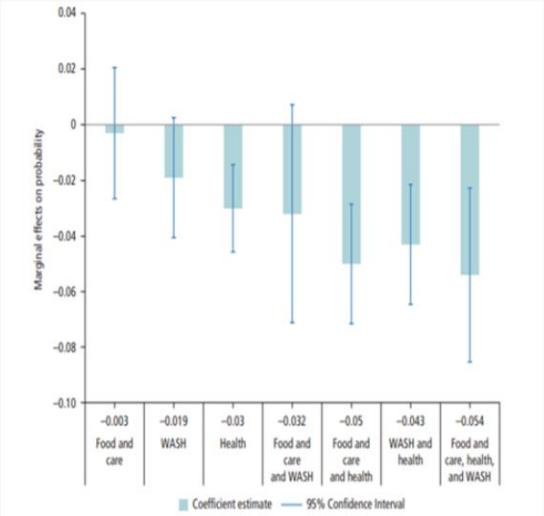
In the graphs below, we compare results from the 2010 and 2014 MICS data from Sudan and results from 2010 or later DHS data from 33 other countries in Sub-Saharan presented in the All Hands on Deck report (Skoufias, Vinha, and Sato 2019). Although as documented in the report, there exist significant heterogeneity across the 33 Sub-Saharan African countries which is likely to mask the effects of access to nutrition drivers on stunting, the results provide useful insights on the state of stunting in the sub-region and hence an important benchmark for comparison. A striking difference in the comparison is the larger effect of adequate access to food security and care on stunting in Sudan relative to other countries in Sub-Saharan Africa. In both 2010 and 2014, the marginal effect of adequate access to food security and care on the probability of being stunted was significantly larger in Sudan. For instance, under budgetary constraints, it appears the greatest "bang for the buck" in reducing stunting in other Sub-Saharan African countries is through expanded access to health care (see Panel b) below). In Sudan, using the latest round of the MICS data collected in 2014, ensuring adequate access to food security and care appears to yield the largest gains for reducing stunting (see Panel a) below). The increased prominence of food security and care in reducing stunting in Sudan may be sensitive to recent macroeconomic events- particularly rising prices; which have characterized the country following the independence of the South.

However, in the case of simultaneous access to the underlying drives of nutrition, data from both Sudan and other countries in sub-region illustrate large gains from joint access to food security and care; and health care. Synergies of interventions by nutrition and health sectors may contribute to significantly lowering stunting among 0-23 month old children in Sudan as well as in other countries in the Sub-region. While the implementation of multisectoral strategies to tackle stunting is likely to vary across countries due to budgetary constraints, effectiveness of coordination systems and incentive mechanisms among other factors, certain similarities exist. By combining insights from country-specific studies on stunting and drawing lessons from other countries which are effectively implementing multisectoral approaches to tackle stunting, significant gains can be registered.

(a) Sudan



(b) Sub-Saharan Africa



Source: Panel a)Authors' calculation using MICS 2010 and 2014 data., Panel b) Skoufias, Vinha, and Sato 2019, p13.

On joint access to nutrition drivers, significant heterogeneity exists across space, wealth, and gender: for boys, children from poor households, and those from urban areas, joint access to food security and care and WASH has larger effects in lowering the probability of stunting; for girls, joint access to food security and care and health care has a larger effect; and for children in rural areas, joint access to WASH and health care yields larger gains toward lowering stunting. As highlighted earlier, gains from joint access to food security and care and health care are particularly large in Sudan. In 2010, the effect of simultaneous access to food security and care and health care on stunting was particularly large for children in rural areas—boys and girls. However, data from 2014 show that the effect is still large and statistically significant—but for girls. In 2014, girls with adequate access to both food security and care and health care were 22.8 percent less likely to be stunted than girls with inadequate access to any of the three nutrition drivers.

On the other hand, the effect of joint access to food security and care and WASH on the probability of being stunted is larger for boys (than girls), children in urban areas (than those in rural areas) and children from the poorest households (than those from the richest households). The probability of being stunted associated with having simultaneous access to food security and care and WASH was 13.1 percent and 13.7 percent less for boys in 2010 and 2014, respectively; 10.1 percent and 14.7 percent less for children in urban areas in 2010 and 2014, respectively; and 12.3 percent and 22.7 percent less for children from households in the bottom 40 percent of the wealth distribution in 2010 and 2014, respectively. In each of these cases, the reference group is children without adequate access to any of the three nutrition drivers. In rural areas, although joint access to food security and care and health care has a large effect in lowering stunting, the effect of having joint access to WASH and health care is larger. Rural children with joint access to WASH and health care were 28.7 percent and 15.3 percent less likely to be stunted in 2010 and 2014, respectively. These results provide further and more specific insights to inform responses to tackle stunting. These results also highlight the importance of access to adequate food security and care in improving nutrition outcomes of Sudanese children. Additional insights for complementing access to food security and care for children across space, wealth, and gender are also provided. These additional insights are particularly useful for effectively identifying priorities and targeting most affected children

Table 5: Marginal Effects: The Heterogeneity of Joint Access to Underlying Determinants of Nutrition

Variables	2010						2014					
	Rural	Urban	Bottom 40	Top 20	Boys	Girls	Rural	Urban	Bottom 40	Top 20	Boys	Girls
Adequate food security/care only	−0.0949*** (0.0206)	−0.114*** (0.0370)	−0.119*** (0.0266)	0.0283 (0.113)	−0.122*** (0.0250)	−0.0773*** (0.0261)	−0.221*** (0.0370)	−0.150** (0.0766)	−0.264*** (0.0387)	1.543*** (0.241)	−0.184*** (0.0467)	−0.222*** (0.0425)
Adequate WASH only	−0.00521 (0.0322)	−0.0512 (0.0415)	0.0171 (0.0428)	−0.0480 (0.0713)	−0.0211 (0.0365)	−0.0231 (0.0327)	−0.0327 (0.0302)	−0.00957 (0.0532)	−0.0127 (0.0376)	1.654*** (0.229)	−0.0196 (0.0330)	−0.0243 (0.0335)
Adequate health care only	−0.120 (0.0947)	−0.0901 (0.130)	−0.122 (0.148)	−0.0028 (0.143)	−0.0816 (0.111)	−0.155 (0.109)	0.162** (0.0677)		0.129 (0.0828)		0.0330 (0.102)	0.166** (0.0741)
Adequate food/care and WASH only	−0.0934** (0.0412)	−0.101** (0.0414)	−0.123* (0.0693)	−0.0218 (0.0784)	−0.131*** (0.0413)	−0.0529 (0.0400)	−0.123** (0.0481)	−0.147*** (0.0517)	−0.227*** (0.0742)	1.618*** (0.212)	−0.137*** (0.0437)	−0.124*** (0.0430)
Adequate food/care and health only	−0.251** (0.100)	−0.154 (0.121)	−0.272 (0.168)	0.155 (0.109)	−0.232* (0.121)	−0.221** (0.0890)	−0.165 (0.101)	—	−0.116 (0.142)	—	−0.206 (0.132)	−0.228** (0.115)
Adequate WASH and health care only	−0.287* (0.164)	−0.111 (0.0834)	—	−0.178* (0.0947)	−0.219** (0.106)	−0.129 (0.110)	−0.153* (0.0810)	0.00716 (0.0713)	−0.184 (0.153)	1.658*** (0.226)	−0.00291 (0.0891)	−0.101 (0.0672)
Adequate all 3 determinants	−0.296** (0.149)	−0.255** (0.102)	—	−0.122 (0.0912)	−0.286** (0.133)	−0.274*** (0.104)	−0.134 (0.101)	−0.173* (0.0885)	−0.370** (0.178)	1.586*** (0.242)	−0.0795 (0.0950)	−0.278*** (0.0968)
State fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,446	1,323	2,057	601	2,407	2,362	3,082	1,191	1,942	548	2,177	2,096

Note: Robust standard errors clustered in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Among food security and care indicators, food security yields the largest gains on children's nutritional outcomes. Controlling for child, mother, and household characteristics as well as state fixed effects, children who are food secured (that is, have adequate access to quality diets) were 10.6 percent less likely to be stunted than those without adequate access to any of the nutrition drivers in 2014. The effect using the 2010 data was significant but only when geographic location fixed effects are accounted for (see Table 6). Among the care indicators, age-appropriate breastfeeding has a large effect on children's probability of being stunted. Controlling for state fixed effects, children who are age-appropriately breastfed were 4 percent less likely to be stunted than those without adequate access to any of the nutrition drivers. However, the effect is statistically insignificant when child, mother, and household characteristics are controlled for in the 2010 and 2014 data. In both years, the probability of being stunted associated with early initiation of breastfeeding is statistically insignificant.

Among the WASH indicators, access to improved sanitation facilities has the largest effect on children's probability of being stunted. Children with access to improved sanitation (such as flush toilet, ventilated or slabbed pit latrine, or a composting toilet) are on average less likely to be stunted. In 2010, the effect of having access to improved sanitation on stunting is larger than the effect of access to the other WASH indicators. Children with improved sanitation were 4 percent less likely to be stunted in 2010 than those without adequate access to any of the nutrition drivers. A similar effect is observed in 2014, but only when state fixed effects and child, mother, and household characteristics are not controlled for.

Among the health care access indicators, immunization yields the largest reductions in the probability of being stunted. Controlling for child, mother, and household characteristics and state fixed effects, children who are in compliance with their immunization requirements were 13.7 percent and 11.1 percent less likely to be stunted in 2010 and 2014, respectively. Nutritional gains from immunization compliance among Sudanese children are larger than gains from access to any of the individual indicators of the three nutrition drivers considered in this report. Other indicators of access to health care which also reduce the probability of being stunted include health facility-assisted delivery. The probability of being stunted for children who were delivered by health professionals decreased by 4.8 percent in 2010 when state fixed effects were included. However, when child, mother, and household characteristics are added, the effect (although still negative) turns statistically insignificant.

Table 6: Marginal Effects: Components of Underlying Determinants of Nutrition

Variables	2010			2014		
	(1)	(2)	(3)	(1)	(2)	(3)
Food security and care indicators						
Minimum acceptable diet	**−0.0330***	**−0.0365***	**−0.0291**	**−0.110*****	**−0.116*****	**−0.106*****
	(0.0191)	(0.0190)	(0.0191)	(0.0233)	(0.0233)	(0.0280)
Early initiation of breastfeeding	0.0364	0.0330	0.0278	−0.00497	−0.00736	−0.0261
	(0.0244)	(0.0236)	(0.0235)	(0.0249)	(0.0244)	(0.0257)
Age appropriate breastfeeding	−0.0384*	−0.0401**	−0.0312	−0.0225	−0.0185	−0.0273
	(0.0202)	(0.0198)	(0.0200)	(0.0236)	(0.0238)	(0.0253)
WASH indicators						
Safe water	−0.0263	−0.00710	0.00131	−0.0275	−0.0297	−0.0151
	(0.0176)	(0.0176)	(0.0176)	(0.0214)	(0.0217)	(0.0228)
Improved sanitation	−0.0824***	−0.0750***	−0.0426*	−0.0488**	−0.0264	0.00626
	(0.0194)	(0.0207)	(0.0223)	(0.0224)	(0.0241)	(0.0233)
Community sanitation	−0.0264	−0.0353*	−0.0196	0.0243	0.0418*	0.0577**
	(0.0210)	(0.0208)	(0.0220)	(0.0242)	(0.0240)	(0.0239)
Handwashing facilities	—	—	—	−0.0246	−0.0163	−0.0167
				(0.0234)	(0.0244)	(0.0243)
Feces disposal	0.00305	0.00908	0.0222	−0.0245	−0.0319	−0.0348
	(0.0186)	(0.0194)	(0.0192)	(0.0232)	(0.0241)	(0.0218)
Health care indicators						
Use of prenatal services	−0.0214	−0.0258*	−0.0137	−0.0235	−0.0181	−0.00332
	(0.0161)	(0.0156)	(0.0151)	(0.0181)	(0.0193)	(0.0208)
Health facility assisted delivery	−0.0586***	−0.0484**	−0.0358	−0.0306	−0.0112	0.00757
	(0.0212)	(0.0237)	(0.0245)	(0.0235)	(0.0251)	(0.0256)
Immunization compliance	**−0.151*****	**−0.147*****	**−0.137*****	**−0.0990*****	**−0.0967*****	**−0.111*****
	(0.0178)	(0.0178)	(0.0192)	(0.0202)	(0.0205)	(0.0238)
State fixed effects	—	**Yes**	**Yes**	—	**Yes**	**Yes**
Additional controls	—	—	**Yes**	—	—	**Yes**
Observations	4,846	4,846	4,769	4,580	4,580	4,273

Note: Robust standard errors clustered in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Nutritional gains from food security are larger for children from urban areas, poorest households, and girls. Although food security has the largest effect on the probability of being stunted among the other indicators of food security and care, the effect is quite heterogenous across space, wealth, and gender, as shown in Table 7. Between rural and urban areas, nutritional gains from food security are larger for children from urban areas. In 2014, the probability of being stunted associated with having food security for children in urban areas was 12.3 percent in 2014 compared to 9.97 percent for children in rural areas. However, children from rural areas gained more from early initiation of breastfeeding. Across the wealth distribution, children from the poorest households gain more from food security; access to quality diets for these children lowers their probability of being stunted by 21.1 percent based on data from 2014. Children from the richest households gained more from early initiation of breastfeeding; the probability of being stunted associated with early breastfeeding for these children decreased by 10.1 percent in 2014. Between girls and boys, although the effects of food security on

stunting were larger for boys in 2010, the reverse was observed in 2014. The probability of being stunted associated with having food security decreased by 12.5 percent in 2014 for girls compared to 9.1 percent for boys. These differences in the effect of food security on stunting highlight the heterogeneity which masks the large gains from access to quality diets and provide insights for policy response.

In terms of access to health care, gains from immunization compliance are particularly large for children from rural areas, the poorest households, and girls. Similar to food security, gains from immunization compliance are heterogenous across Sudanese children. Across space, immunization compliance yields larger gains in lowering stunting than other indicators of health care. These gains are larger for children from rural areas than for those from urban areas. The probability of being stunted associated with immunization compliance decreased by 15.3 and 12.5 percent for children from rural areas in 2010 and 2014, respectively, compared to 8.4 and 7.7 percent for children from urban areas in 2010 and 2014, respectively. Across the wealth distribution, gains from immunization compliance are larger and statistically significant for children from the poorest households but not for children from the richest households. Children from households in the bottom 40 percent of the wealth distribution were 16.4 and 7.3 percent less likely to be stunted in 2010 and 2014, respectively. Similarly, although immunization compliance lowers the probability of being stunted for both boys and girls, the magnitude of the gains for boys is larger. Boys who complied with their immunization schedule were 14.9 and 12.5 percent less likely to be stunted in 2010 and 2014, respectively, compared to 12.5 and 8.9 percent for girls in 2010 and 2014, respectively. These results reinforce the fact that while gains from immunization compliance are statistically significant and larger than the effects of other health care indicators, and highlight the extent of the heterogeneity across children, ensuring that rural children and children from poor households are immunized can significantly contribute toward lowering stunting rates in Sudan.

Table 7: Marginal Effects: The Heterogeneity of the Effects of Components of Underlying Determinants of Nutrition

Variables	2010						2014					
	Rural	Urban	Bottom 40	Top 20	Boys	Girls	Rural	Urban	Bottom 40	Top 20	Boys	Girls
Food security and care indicators												
Minimum acceptable diet	**−0.0164** (0.0226)	**−0.0599*** (0.0346)	**−0.0418** (0.0308)	**0.0441** (0.0401)	**−0.0465*** (0.0266)	**−0.0119** (0.0266)	**−0.0997***** (0.0376)	**−0.123***** (0.0278)	**−0.211***** (0.0398)	**−0.0183** (0.0347)	**−0.0907***** (0.0336)	**−0.125***** (0.0370)
Early initiation of breastfeeding	0.00631 (0.0278)	0.0949** (0.0421)	−0.0109 (0.0372)	−0.0774 (0.0694)	0.0174 (0.0332)	0.0255 (0.0331)	−0.0516* (0.0304)	0.0227 (0.0450)	−0.0552 (0.0409)	−0.101* (0.0590)	−0.0318 (0.0359)	−0.0166 (0.0338)
Age appropriate breastfeeding	−0.0392 (0.0240)	−0.0235 (0.0341)	−0.0104 (0.0304)	0.0421 (0.0470)	−0.0340 (0.0306)	−0.0277 (0.0264)	−0.0317 (0.0315)	−0.0359 (0.0397)	0.00943 (0.0382)	−0.0639 (0.0497)	−0.0197 (0.0332)	−0.0228 (0.0340)
WASH indicators												
Safe water	0.0152 (0.0193)	−0.0326 (0.0398)	0.00198 (0.0244)	−0.0795 (0.0777)	0.00594 (0.0240)	−0.00157 (0.0226)	−0.0132 (0.0258)	0.0643 (0.0619)	0.00601 (0.0318)	0.0866 (0.0976)	−0.0198 (0.0313)	−0.00667 (0.0298)
Improved sanitation	−0.0272 (0.0268)	−0.0535 (0.0354)	0.00609 (0.0410)	−0.0146 (0.0441)	−0.0650** (0.0317)	−0.0248 (0.0279)	0.0162 (0.0290)	−0.0225 (0.0359)	−0.0167 (0.0497)	0.0505 (0.0595)	−0.00329 (0.0323)	0.0156 (0.0280)
Community sanitation	−0.0184 (0.0228)	−0.0600 (0.0639)	−0.0227 (0.0357)	−0.0138 (0.0646)	0.00371 (0.0294)	−0.0486* (0.0282)	0.0535** (0.0272)	0.102* (0.0537)	0.0297 (0.0360)	0.0649 (0.0973)	0.0911*** (0.0314)	0.0263 (0.0306)
Handwashing facilities							−0.0129 (0.0314)	−0.0261 (0.0353)	0.000727 (0.0466)	0.0196 (0.0377)	−0.0565* (0.0315)	0.0215 (0.0314)
Feces disposal	0.0195 (0.0203)	0.0301 (0.0409)	0.0325 (0.0307)	−0.0591 (0.0449)	0.0146 (0.0274)	0.0315 (0.0252)	−0.0419 (0.0272)	−0.0138 (0.0413)	−0.0432 (0.0314)	0.0418 (0.0597)	−0.0480* (0.0283)	−0.0270 (0.0312)
Health care indicators												
Use of Prenatal services	−0.0183 (0.0180)	−0.0143 (0.0279)	0.00656 (0.0248)	0.00277 (0.0393)	−0.0227 (0.0219)	−0.00294 (0.0204)	−0.00853 (0.0267)	0.0138 (0.0271)	0.00129 (0.0299)	0.101** (0.0415)	0.00918 (0.0262)	−0.0153 (0.0247)
Health facility assisted delivery	−0.0487 (0.0317)	−0.0134 (0.0371)	−0.0106 (0.0432)	−0.0181 (0.0398)	−0.0242 (0.0318)	−0.0646* (0.0344)	−0.00608 (0.0334)	0.0327 (0.0349)	0.0169 (0.0439)	0.0431 (0.0391)	0.00843 (0.0358)	0.000267 (0.0291)
Immunization compliance	**−0.153***** (0.0231)	**−0.0835***** (0.0316)	**−0.164***** (0.0317)	**−0.0709** (0.0474)	**−0.149***** (0.0260)	**−0.125***** (0.0272)	**−0.125***** (0.0290)	**−0.0774**** (0.0329)	**−0.0730***** (0.0281)	**−0.0498** (0.0382)	**−0.125***** (0.0333)	**−0.0890***** (0.0254)

Variables	2010						2014					
	Rural	Urban	Bottom 40	Top 20	Boys	Girls	Rural	Urban	Bottom 40	Top 20	Boys	Girls
State fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Additional controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,446	1,323	2,057	601	2,407	2,362	3,082	1,191	1,942	548	2,177	2,096

Note: Robust standard errors clustered in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

While the results above provide insights for multisectoral approaches to reducing stunting in Sudan, the implementation of such approaches is often quite complex. For instance, Sudan's current economic and sociopolitical conditions impose large constraints on its limited resources. As a result, implementing multisectoral approaches to reduce stunting maybe costly. Furthermore, the empirical evidence on the effectiveness of multisectoral approaches to reducing stunting is generally inconclusive. In particular, the lack of clarity and specificity of the roles of each sector under multisectoral approaches- particularly in environments where the coordination of resources, governance structures and other institutions is limited; is often cited as a major challenge to implementing such approaches (IEG 2009). These concerns and constraints may significantly affect the implementation of multisectoral approaches to reduce stunting in Sudan.

However, certain countries such as Senegal have registered some success in reducing undernutrition through multisectoral approaches (Skoufias, Vinha, and Sato 2019). Sudan can draw from these lessons- particularly the role of incentive structures and effective coordination of sectors; together with insights from the results presented in this paper to inform its design of multisectoral approaches to reduce stunting. Results from this report- particularly the differences in prevalence of stunting and gaps in access to nutrition drivers across states; as well as the large individual and joint effect of access to nutrition drivers such as food security and health on stunting; can inform certain aspects of multisectoral approaches such as the sequencing of interventions, geographic targeting and identification of missing sectors in Sudan.

In addition to this report, a recent study by the Health, Nutrition and Population (HNP) Group of the World Bank provide detail and sector-specific insights for health and nutrition approaches to reduce stunting in Sudan. In their report, the HNP team highlight five cost-effective and high impact nutrition-specific interventions (such as breastfeeding, complementary feeding, iron-folic acid and vitamin-A supplementation; and two additional nutrition-sensitive interventions which can be integrated within the health sector- such as family planning and hand-washing).

5. Conclusion

This paper adopts a multisectoral approach to examine the effect of access to underlying determinants of nutrition on stunting among 0–23-month-old children in Sudan using data collected in 2010 and 2014. Using a framework developed by UNICEF, three categories of nutrition drivers are identified: food security and care, WASH, and health care. Components of food security and care include access to quality diets, early initiation of breastfeeding, and age-appropriate breastfeeding; components of WASH include access to safe drinking water, household and community sanitation, and access to handwashing facilities; and components of health care include access to prenatal services, health professional-assisted delivery, and immunization compliance. Adequate access to these components is determined based on international standards. We examine the extent to which adequate access to these components of nutrition drivers influences stunting among 0–23-month-old children in Sudan. We also examine the extent to which inequalities in access to nutrition drivers, particularly due to wealth, influence the prevalence of stunting across children. Results from these analyses contribute to existing literature by providing country-specific insights to inform policy response. With the increase in the prevalence of stunting in Sudan between 2010 and 2014, results from these analyses will be vital inputs for the ongoing interventions to improve nutritional outcomes of children, build human capital, and spur growth.

One of the key findings from this study is that the probability of a 0–23-month-old child being stunted decreases with improvements in adequate access to the underlying drivers of nutrition: food security and care, WASH, and health care. Children with adequate access to all three nutrition drivers are significantly less likely to be stunted than those without adequate access to any of the three nutrition drivers. However, although at a lesser magnitude, having adequate access to some nutrition drivers (one or two of the three) still influences nutritional outcomes by lowering the probability of being stunted. Estimates from the latest round of data used in this report show that holding child, household, and mother characteristics as well as state fixed effects constant, 0–23-month-old children with adequate access to all three nutrition drivers are 17.4 percent less likely to be stunted than those without adequate access to all three nutrition drivers. However, children with adequate access to two nutrition drivers and those with adequate access to one nutrition driver were, respectively, 13.4 percent and 7.5 percent less likely to be stunted than children without adequate access to any of the three nutrition drivers.

Although a multisectoral approach to tackling undernutrition may mask clarity and undermine specificity of sectors to prioritize, it can be a basis for designing evidenced-based and balanced multisectoral strategies to addressing stunting in Sudan. Results from this report together with lessons from countries which have successfully implemented such approaches can provide insights for sequencing of interventions and geographic targeting by highlighting both differences in prevalence of stunting and gaps in access to nutrition drivers. Given Sudan's current macroeconomic environment and the resulting constraints on its limited fiscal resources, such insights are useful for formulating appropriate interventions to tackle stunting. Our analysis indicates that ensuring food security (particularly in rural areas and among the poorest households) may contribute to significantly lowering stunting among 0–23-month-old Sudanese children. For children who already have adequate food security and care, ensuring adequate access to health care (particularly immunization compliance) may further improve their nutritional outcomes. The large nutritional gains from having adequate food security and care offer one possible explanation for the increase in the rate of stunting in Sudan between 2010 and 2014. Adequate access to food security and care decreased significantly in rural areas and among the poorest households, thereby resulting in large increases in stunting.

Implementing such multisectoral approaches in a country such as Sudan which already faces significant constraints and competing demands for its limited resources, requires geographic targeting of areas where stunting is most prevalent, identification of population groups most deprived of nutrition drivers and incentives for an effective coordination of all actors. Once these areas are identified, knowledge of available and missing sectors as well as gaps in access to nutrition drivers can inform the sequencing of interventions to tackle undernutrition in Sudan. Therefore states such as Blue Nile, North Darfur and Gezira which have experienced an increase in the prevalence of stunting between 2010 and 2014 (see Figure 2 – panel b)) by nearly 10 percent, require urgent attention. Identifying population groups within these states who are deprived from access to nutrition drivers is an essential first step. Similarly, in states such as Gadarif and North Kordufan where the percentage of children without access to any of the three nutrition drivers increased by 11 percent and 4 percent between 2010 and 2014 respectively (see Figure 4 – panel c)), prioritizing access to food security and care can contribute to lowering stunting. The effectiveness of these multisectoral approaches can be greatly enhanced by programs which aim to increase income levels and lower income variability. For households in the bottom 40 percent of the income distribution, interventions targeting income growth can significantly contribute towards lowering stunting.

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