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Malnutrition Gap as a New Measure of Child Malnutrition

A Global Application

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Abstract

"Leaving no one behind" is an overarching principle of the Sustainable Development Goals. Many countries are prioritizing resources for those who are furthest behind. Existing malnutrition indicators—underweight, stunting, wasting, overweight, and severe wasting—are headcount ratios. They do not capture how far behind malnourished children are relative to the World Health Organization growth standards. To understand the severity of malnutrition, this study develops a new malnutrition measurement, using the method originally developed for estimating poverty. This study estimates the prevalence, gap, and gap squared for stunting, wasting, overweight, and underweight, using data from 94 developing countries over 20 years. The results show that although in most cases the headcount measures and gap measures are moving in the same direction, in many other cases, they are moving in opposite directions. Moreover, employing the new measures, the study can identify countries that have low levels of headcount for a malnutrition measure but comparatively high severity of malnutrition according to the gap measures, and vice versa. This suggests that these new malnutrition measures provide additional information on the severity of malnutrition that is not possible to be known from headcount measures. These new measures of the severity of malnutrition can therefore improve the monitoring of child malnutrition across countries, and consequently help countries to achieve their Sustainable Development Goals.

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Malnutrition Gap as a New Measure of Child Malnutrition: A Global Application

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Keywords: new measurement; malnutrition; gap; severity; global dataset

Disclaimer: The views expressed in this paper are those of the authors and do not necessarily reflect the official views of the Food and Agriculture Organization of the United Nations or the World Bank.

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1. Introduction

A renewed aspiration from the Millennium Development Goals (MDGs), the second Sustainable Development Goal (SDG) calls for achieving, by 2025, the internationally agreed targets for reduction of stunting and wasting in children under 5 years of age.[1] "Leaving no one behind" is an overarching principle of the newly adopted SDGs. The UN 2016 SDGs Report states,

> *"In committing to the realization of the 2030 Agenda for Sustainable Development, Member States recognized that the dignity of the individual is fundamental and that the Agenda's Goals and targets should be met for all nations and people and for all segments of society. Furthermore, they endeavored to reach first those who are furthest behind." (UNSD 2016, p. 48)*

The World Health Organization (WHO) defines child malnutrition as growth measures more than 2 standard deviations (SD) below the median WHO growth standards. In addition, the WHO defines severe acute child malnutrition as weight for height below -3SD from the median WHO growth standards (WHO and UNICEF 2009). Existing child malnutrition indicators include prevalence of underweight (weight for age below -2SD), stunting (height for age below -2SD), wasting (weight for height below -2SD), overweight (weight for height above 2SD), and severe wasting (weight for height below -3SD).

These prevalence indicators are headcount measures and do not vary with the distance between individual Z-scores (number of SD) and the WHO reference lines. And thus, such headcount measures fail to identify malnourished children furthest away from the reference line, i.e. the inequality in malnutrition present among the malnourished population. As the SDGs require

[1] United Nations. Sustainable Development Goals. (http://www.un.org/sustainabledevelopment/sustainable-development-goals).

more granular data to monitor progress, it has motivated us to develop new indictors to provide supplemental, yet critical, evidence to the conventional indicators.

There have only been a limited number of studies that attempt to develop a measure of severity of child malnutrition. McDonald et al. (2014) proposes a measure of malnutrition based on the notion of multiple anthropometric deficits. For example, a child is considered to be severely malnourished if she/he is both stunted and underweight. However, this measure is still a headcount measure, and it compounds the information when people want to know how stunted and how underweight a child is separately.

In contrast, studies by Shekar et al. (2015) and Jolliffe (2004 & 2004) adopt the techniques used for measuring poverty to measure nutrition outcomes. Specifically, they put the Foster, Greer and Thorbecke (1984, hereafter referred to as FGT) class of poverty indicators in the context of malnutrition. Shekar et al. (2015) estimated FGT(0) as the stunting prevalence (similar to the poverty headcount measure) and FGT(1) as the stunting gap (similar to the poverty gap) in Mali from 2001 to 2013. Similarly, Jolliffe (2004 & 2004) uses FGT to calculate the overweight gap and gap-squared to understand the overweight problem in the U.S. They demonstrated that the stunting gap and overweight gap, analogous to the poverty gap, can provide further information in addition to the stunting prevalence in nutrition diagnostics and policy recommendations.

This paper aims to provide supplementary, but critical, information to the conventional headcount measures of malnutrition. Specifically, following Shekar et al. (2015), this paper will adopt the techniques used for measuring the depth and severity of poverty to measure the severity of malnutrition. More specifically, we develop the following eight measures of malnutrition in this study: (i) stunting gap, (ii) stunting gap squared, (iii) wasting gap, (iv) wasting gap squared, (v)

overweight gap, (vi) overweight gap squared, (vii) underweight gap, and (viii) underweight gap squared.

This study makes two important contributions to the research literature. First, while the stunting gap measure has been developed by Shekar et al. (2015), the other seven measures of malnutrition are developed for the first time in this study. Hence, in addition to the conventional headcount indicators, these proposed indicators can provide useful information about a country's malnutrition status, especially on the depth and severity of malnutrition, which can consequently improve evidence-based decision-making. Second, we employ over 20 years of malnutrition data from 94 developing countries to calculate the new measures. Employing the new measures, we are able to identify countries that have low levels of headcount for a malnutrition measure, but comparatively high severity of malnutrition according to the gap and gap-squared measures, and vice versa. This allows us to identify cases where headcount measures may be providing an incomplete description of a certain country's malnutrition status.

From a policy perspective, it is important to distinguish between malnutrition measures based on the headcount and measures of depth and severity in malnutrition. As countries are in particular committed to reach first those who are furthest behind in order to realize the SDGs 2030 agenda, high-quality data are needed for monitoring the progress of these individuals and providing evidence for effective policy making.

We proceed as follows. Section 2 discusses the methodology for the new measures. Section 3 describes the data used in the empirical application. Section 4 presents the results. Section 5 concludes.

2. Methodology

While we adopt the method of Shekar et al. (2015), it is not the only application of the FGT poverty indicators in non-monetary indicators. Nguyen and Wodon (2012, 2015) applied the same approach to the estimation of child marriage. Apart from estimating the incidence of child marriage (the share of girls marrying before age 18), they also estimated the "child marriage gap," which accounts for how early a girl marries.

We intend to generalize the method for all of the aforementioned existing malnutrition indicators and produce the gap estimate for every country with data, using a standardized data set of growth Z-scores calculated from Demographic and Health Surveys (DHS) and Multiple Indicator Cluster Surveys (MICS). We will also extend the calculation to the squared malnutrition gap, i.e., FGT(2). Foster, Greer, and Thorbecke (1984) showed that the FGT class of poverty indicators have a number of attractive axiomatic properties such as additive decomposability and subgroup consistency.

Analog to the poverty gap, the malnutrition gap is defined as the average shortfall of children's Z-scores of an anthropometric measure from the reference line (counting zero shortfall for non-malnourished children) as a proportion of the reference line. It measures how far off a child is from the WHO growth standards. Taking stunting as an example, the national average stunting gap (*Gap*) can be expressed as

$$Gap = \frac{1}{N}\sum_{i=1}^{M}\frac{z_i-(-2)}{-2} \qquad (1)$$

where N denotes the total number of children under 5 years of age in a given population, M denotes the number of stunted children, and z_i denotes individual Z-scores of stunting and $z_i < -2$ in this equation. Implicitly in this equation, the shortfall for non-stunted children is zero when $z_i \geq -2$.

Subsequently, the national average squared stunting gap (*SqGap*) can be expressed as

$$SqGap = \frac{1}{N}\sum_{i=1}^{M}\left(\frac{z_i-(-2)}{-2}\right)^2. \qquad (2)$$

The squared malnutrition gap takes into account not only the distance between the malnourished children and the reference line (the malnutrition gap), but also the inequality among the malnourished children. That is, a higher weight is placed on those who are further away from the reference line.

3. Data

We reanalyzed all DHS and MICS, phases 3 onwards, and calculated individual Z-scores for all children with available anthropometric data according to the WHO standard approach. As of today, we obtained estimates for 168 DHS from 1993 to 2014 and 70 MICS from 2005 to 2014. These surveys combined cover 94 countries. Annex 1 lists all the surveys included in this data set.

The recalculation of Z-scores was based on the WHO child growth standards and prevalence estimates were generated following standard analysis as per available Stata macro (http://www.who.int/childgrowth/software/en/). The recalculated Z-scores may generate slightly different prevalence estimates from those published by DHS and MICS reports, mainly due to the use of the WHO standard approach, which (i) uses all valid Z-scores for each child, and (ii) imputes the missing day of birth as 15.

Each of our surveys is representative for the data collection areas, and most are nationally representative for the country. Therefore, we use survey weights in our analysis to ensure that we have a representative estimation for the country or the areas where data were collected.

4. Results

4.1 Comparison of Changes in Malnutrition Headcount and Malnutrition Gap

We applied the class of FGT measures to each of the malnutrition indicators and produced results for all eight measures mentioned in section 1. Given the space limitation, we limit our discussions on the results to the primary malnutrition indicator – stunting. For interested audiences, the whole data set is available upon request.

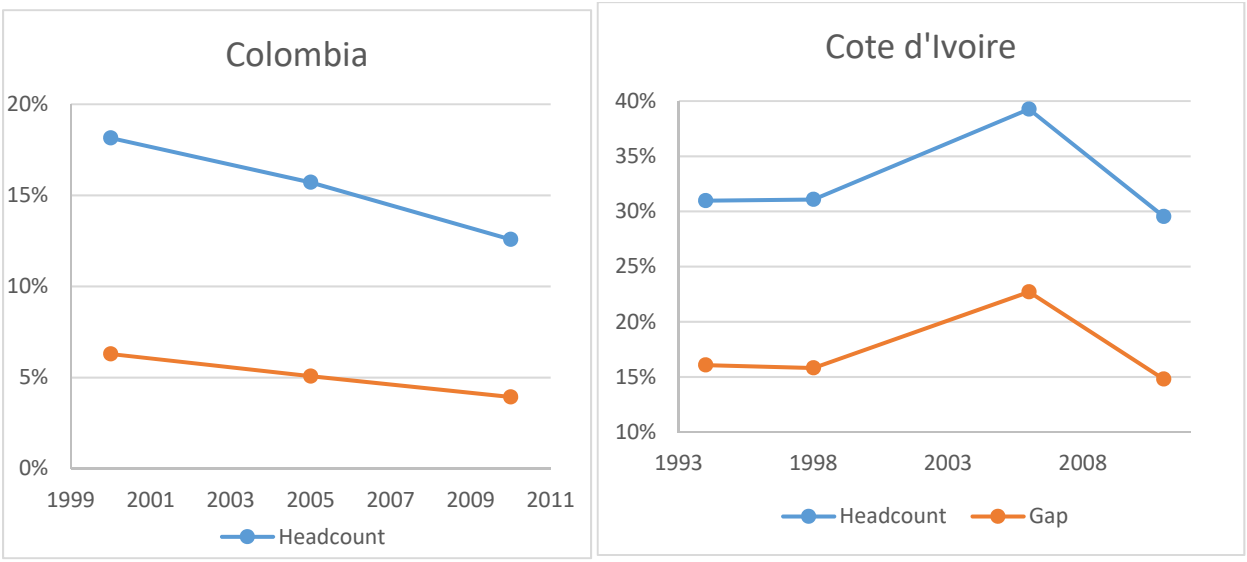
One of the motivations to develop these new measures is to obtain insight that is not offered by the headcount measures. For example, if the malnutrition gap of a country increases significantly over time, but the malnutrition headcount does not, it would indicate that malnutrition severity in a country is increasing over time, a fact that is not captured by the headcount measure. This is why we examine whether the headcount measure and gap measure change in a similar manner over time for each country.

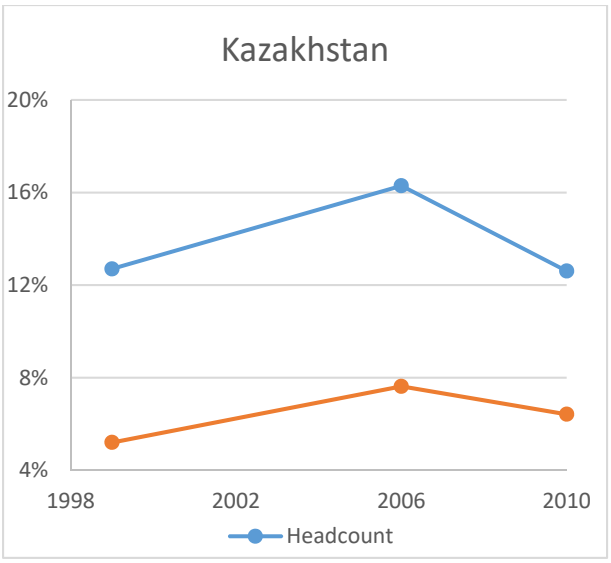
To understand these changes, we measure the change in malnutrition headcount and the change in malnutrition gap over each consecutive survey rounds for each country. We identify whether the headcount measure and gap measure increase significantly, decrease significantly, or face no significant change over time. If there is a significant change in one measure (headcount or gap), but no significant change or a significant change in the opposite direction for the other measure, then we categorize those two differing changes as "headcount and gap moving in different directions." In contrast, if both the headcount and gap remain statistically unchanged, or increase or decrease statistically significantly, then we categorize them as "headcount and gap moving in the same direction."

Figure 1 presents four examples of countries where the headcount and gap are moving in the same direction and four examples of countries where the headcount and gap are moving in different directions. For the cases of the headcount and gap moving in the same direction, we can observe

that the headcount and gap track each other closely for all four countries: Colombia, Côte d'Ivoire, Kazakhstan and Niger. In contrast, for countries where the headcount and gap are moving in different directions, we can observe the opposite movements in each measure. For example, the stunting headcount remained the same for Chad from 1996 to 2004 (44%). However, in that same period, the stunting gap in Chad increased from 29% to 32%. Similarly for Mozambique, the stunting headcount increased by 2 percentage points between 1997 and 2003 and decreased by 1 percentage point between 2008 and 2011. In contrast, the stunting gap moved in the opposite direction: it decreased by 3 percentage points between 1997 and 2003 and increased by 2 percentage points between 2008 and 2011.

Figure 1a Examples of countries with gap and headcount moving in same direction





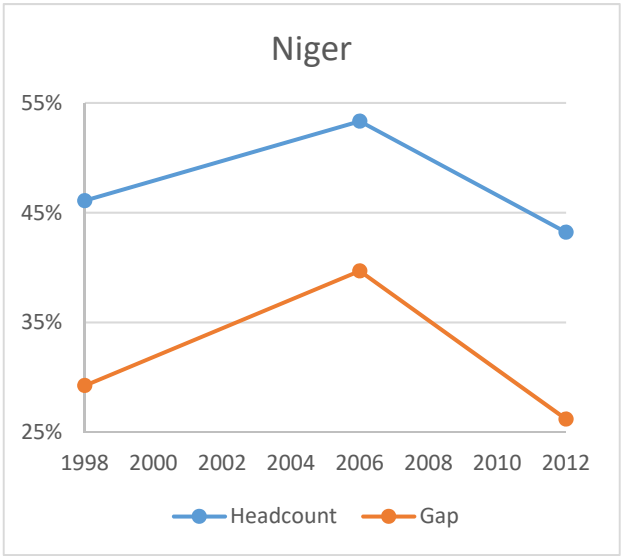
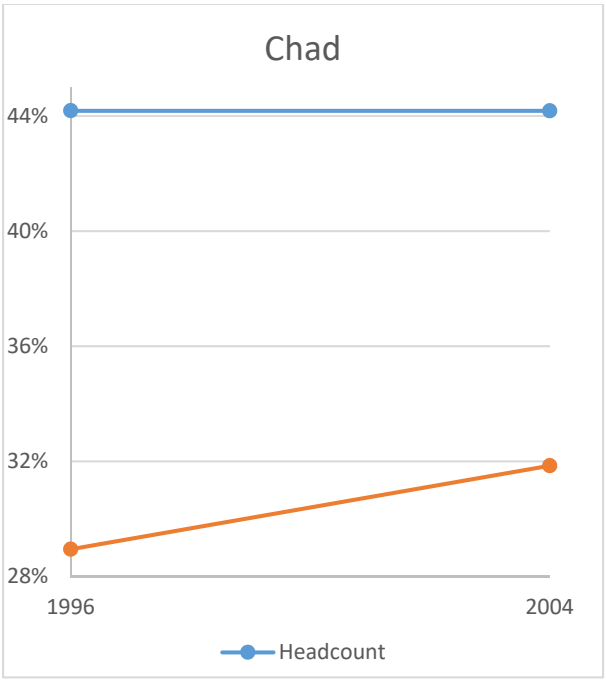
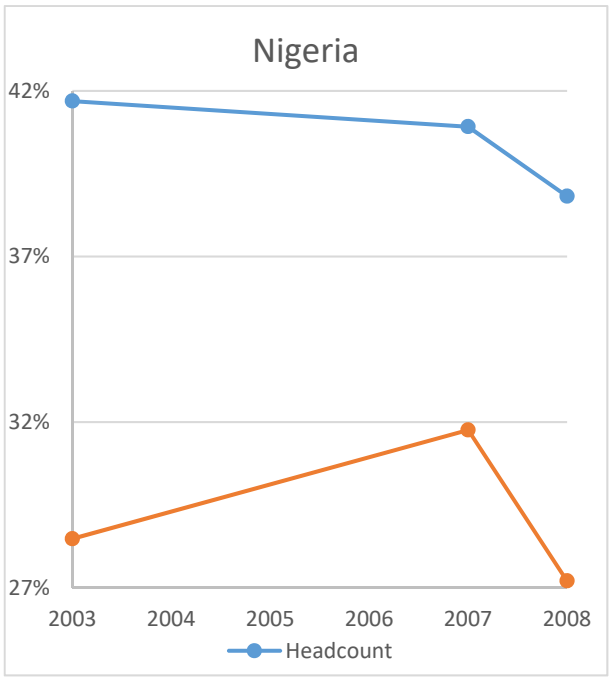
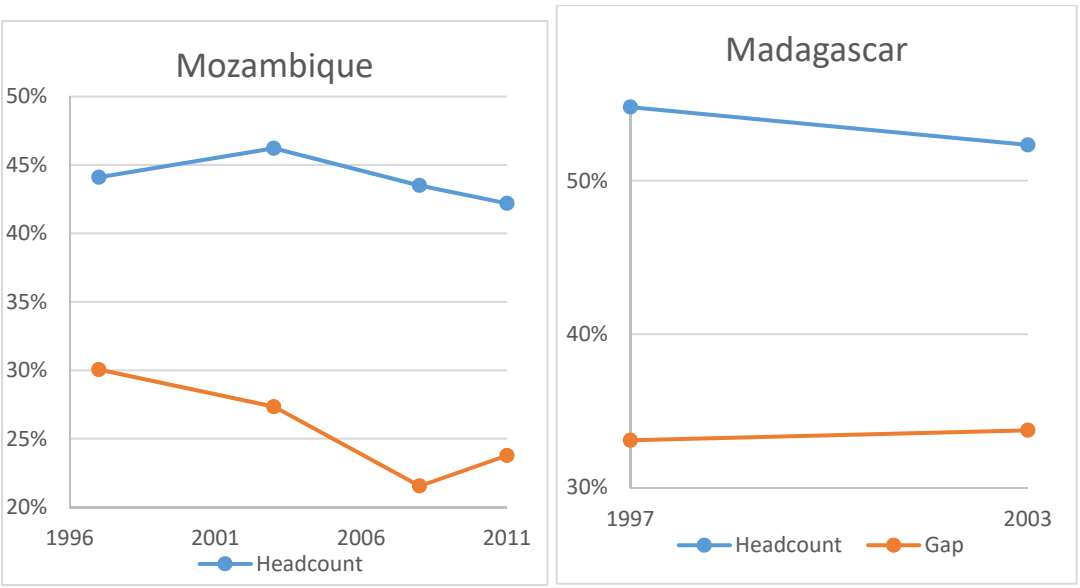


Figure 1b Examples of countries with gap and headcount moving in different directions







Source: Authors' calculations using DHS and MICS.

These results may imply the effects of different policy interventions. Overall, the fact that in most cases the headcount and gap are moving in the same direction (and improving) is supportive of the fact that the policies in place have been effective for all the children below the reference line, not just those closest to it. For example, countries like Colombia that have lowered both the stunting headcount and stunting gap may have targeted their interventions to all children and brought them above, or closer to, the reference line (Figure 1a). Likewise, a country for which the gap is improving but not the headcount may have targeted its interventions to the most malnourished, and the effects of this targeting are not showing up yet on the headcount (Figure 1b). By contrast, if a country wants to prioritize its efforts and investments towards those children who are the closest to the reference line, this would be consistent with an improving headcount without necessarily seeing improvements in the gap measures (Figure 1b).

Figure 1 only provides a handful of examples. To have a comprehensive understanding of the differences in trends in the headcount and gap measures across all developing countries, it is

important to understand the proportion of countries that have headcount and gap measures moving in different directions. In Table 1, we present the results of our analysis where we summarize the number and percentage of countries that had the headcount and gap either (i) moving in the same direction, or (ii) moving in different directions.

Given there is a strong long-term decreasing trend in malnutrition across most countries, to understand whether the gap measure is changing differently than headcount measures, it is important to measure changes in malnutrition over relatively short periods of time. For a fair comparison of changes in malnutrition over time across countries, we want to compare all countries over the same time period. Therefore, we chose the following three overlapping time ranges: years 1993 to 2005, 2000 to 2009, and 2005 to 2014. We chose overlapping time ranges to ensure that we have sufficient number of countries with consecutive survey rounds in each of the three time ranges; otherwise, we would be unable to measure changes over time for certain periods. As repeat surveys occur within 5 years of a prior round for most countries, we have an overlap of 5 years between the three time ranges to ensure that we cover the greatest number of consecutive survey rounds.

As shown in Table 1, we find that between 1993 and 2005, 29 percent of cases represented the stunting headcount and gap moving in different directions than each other. Similarly, for the periods 2000-2009 and 2005-2014, we find that for 17 percent of cases, the stunting headcount and gap are moving in different directions. We observe similar percentages, 21 percent, 17 percent and 17 percent respectively, over the three periods for the underweight measures. In contrast, we observe lower percentages, 6 percent, 11 percent, and 5 percent respectively, for the overweight measures. However, overall, these results suggest that the stunting gap provides additional

important information on the severity of malnutrition that is not always represented by headcount measures.

Table 1 Changes in headcount and gap for child stunting, underweight and overweight

	Changes from 1993 to 2005		Changes from 2000-2009		Changes from 2005 to 2014	
	Number of countries	% of countries	Number of countries	% of countries	Number of countries	% of countries
Stunting						
Headcount and gap moving in same direction	24	71%	29	83%	49	83%
Headcount and gap moving in different direction	10	29%	6	17%	10	17%
Underweight						
Headcount and gap moving in same direction	27	79%	29	83%	49	83%
Headcount and gap moving in different direction	7	21%	6	17%	10	17%
Overweight						
Headcount and gap moving in same direction	32	91%	31	89%	56	95%
Headcount and gap moving in different direction	2	6%	4	11%	3	5%

Source: Authors' calculations using DHS and MICS.

4.2: Comparison of Severity for Countries with Similar Headcounts

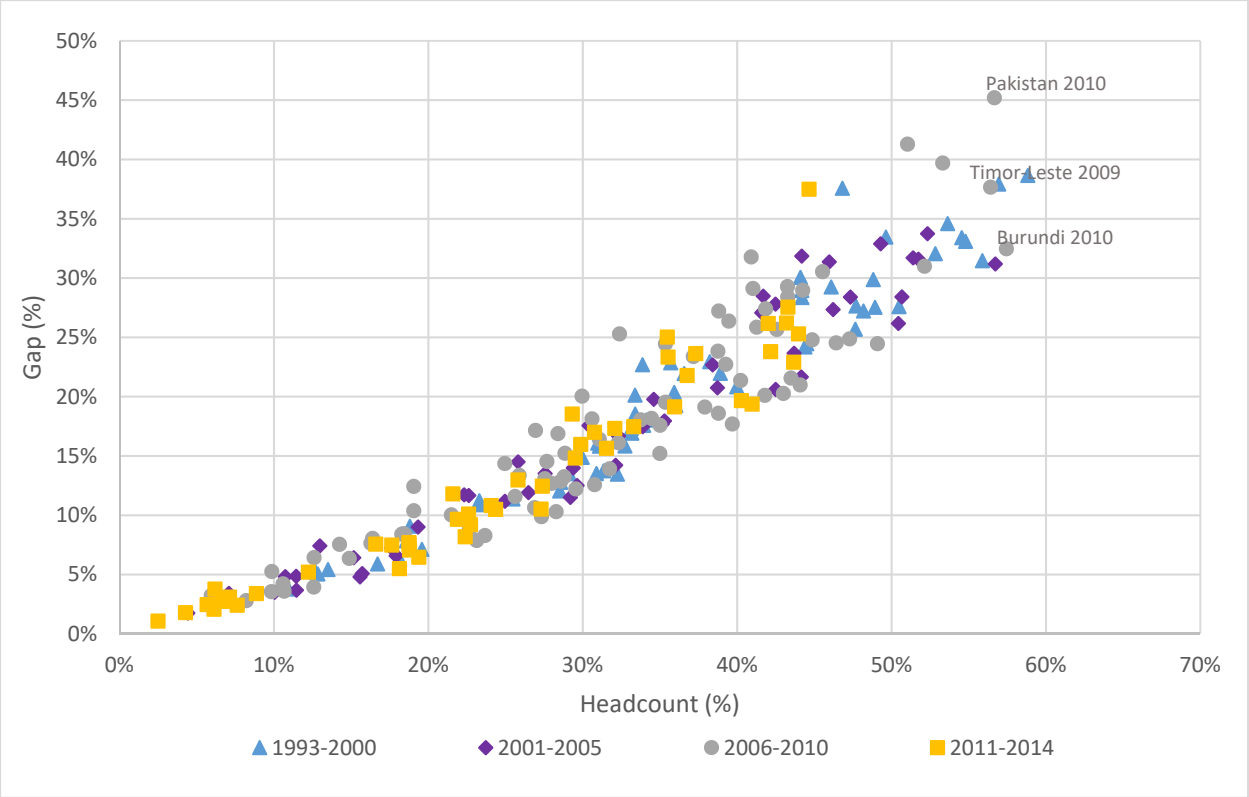
In addition to understanding changes in malnutrition over time, it would also be useful to examine how the malnutrition gap and gap-squared vary for countries with similar headcount rates. If the malnutrition gap and gap-squared measures are substantially different for countries that have similar headcount rates, it would indicate that the gap measures are capturing information regarding severity that is not captured in the headcount measures. This is why we compare the gap and gap-squared measures for countries that have similar headcount rates, i.e. headcount rates within one percentage point of another country.

Ideally, we would want to compare the malnutrition status across countries for each year. However, as we do not have malnutrition data for enough countries for each year, we instead create four time periods: 1993-2000, 2001-2005, 2006-2010, and 2011-2014. Both Figure 2 and Table 2 illustrate how diverse the stunting gaps can be for countries with similar stunting prevalence. In Figure 2, for example, Pakistan, Timor-Leste and Burundi have a similar headcount ratio (57.7%, 56.4% and 57.4% respectively) in 2009-2010, but their gaps are various (45.2%, 37.6% and 32.5% respectively).

In Table 2, we provide examples of countries whose stunting headcount is within 1 percentage point of another country, but their gap and gap-squared measures are statistically significantly different from the other (tested using a t-test). Each group of countries is shaded or unshaded for ease of visualization in the table. For example, the first two countries in the list are Ethiopia and Nepal. Ethiopia has a stunting headcount rate of 57 percent and Nepal has 56 percent. However, their stunting gap and stunting gap-squared are substantially different, which is expressed in the t-test results in the last column, which examines whether the difference in the gap between the countries is statistically significant. The stunting gap and gap-squared for Ethiopia are both 38 percent, but for Nepal they are 31 and 28 percent, respectively. Similarly, the next set of countries, India, Bangladesh, and Tanzania, have similar stunting headcount rates: 50, 50, and 49 percent, respectively. However, India's gap and gap squared measures are substantially different from the other two countries. India's stunting gap rate is 33 percent compared to 28 percent for Bangladesh and Tanzania. And the stunting gap squared in India is 35 percent, which is substantially higher than 24 percent for Bangladesh and Tanzania. This shows that India has more severe malnutrition even though a similar fraction of its population suffers from stunting as in Bangladesh and Tanzania. The rest of Table 2 provides similar differences between the headcount

and gap measures, which suggests that the gap measures are capturing important differences in malnutrition status that the headcount measure does not, which points to the importance of these new measures.

Figure 2 Comparison of stunting head count ratios and stunting gaps



Source: Authors' calculations using DHS and MICS.

Table 2: List of countries/surveys with similar headcount rates but different gap measures

Country	Year	Source	Stunting headcount	Stunting gap	Stunting gap squared	t-stat for gap
Years: 1993-2000						
Ethiopia	2000	DHS	57%	38%	38%	
Nepal	1996	DHS	56%	31%	28%	7.8
India	1998	DHS	50%	33%	35%	
Bangladesh	1999	DHS	50%	28%	24%	9.4
Tanzania	1996	DHS	49%	28%	24%	9.3
Nigeria	1999	DHS	47%	38%	43%	
Rwanda	2000	DHS	48%	28%	25%	7.0
Tanzania	1999	DHS	48%	26%	21%	7.9
Niger	1998	DHS	46%	29%	29%	5.6
Uganda	2000	DHS	44%	24%	21%	
Burkina Faso	1998	DHS	44%	28%	28%	5.2
Chad	1996	DHS	44%	29%	29%	6.3
Mozambique	1997	DHS	44%	30%	31%	6.5
Uzbekistan	1996	DHS	34%	23%	24%	
Bolivia	1994	DHS	34%	18%	16%	3.5
Zimbabwe	1999	DHS	33%	17%	15%	4.0
Egypt, Arab Rep.	1995	DHS	33%	20%	20%	
Bolivia	1998	DHS	33%	16%	13%	7.4
Kyrgyzstan	1997	DHS	32%	13%	10%	6.9
Years: 2001-2005						
Malawi	2004	DHS	51%	32%	30%	
Bangladesh	2004	DHS	50%	26%	21%	8.1
Mozambique	2003	DHS	46%	27%	26%	
Sierra Leone	2005	MICS	46%	31%	33%	5.0
Chad	2004	DHS	44%	32%	34%	
Tanzania	2004	DHS	44%	22%	17%	12.8
Lesotho	2004	DHS	44%	24%	21%	7.0
Cambodia	2005	DHS	42%	21%	17%	
Nigeria	2003	DHS	42%	28%	30%	8.6
Mali	2001	DHS	42%	27%	27%	8.4
Congo (Brazzaville)	2005	DHS	30%	18%	16%	
Honduras	2005	DHS	30%	13%	9%	8.3

Country	Year	Source	Stunting headcount	Stunting gap	Stunting gap squared	t-stat for gap
Years: 2006-2010						
Pakistan (Balochistan)	2010	MICS	57%	45%	51%	
Burundi	2010	DHS	57%	32%	28%	12.3
Timor Leste	2009	DHS	56%	38%	38%	8.0
Guinea-Bissau	2006	MICS	46%	31%	32%	
Malawi	2010	DHS	46%	25%	21%	6.8
Zambia	2007	DHS	45%	25%	22%	6.7
Congo, Democratic Republic	2007	DHS	44%	29%	31%	
Rwanda	2010	DHS	44%	21%	17%	8.6
Bangladesh	2007	DHS	43%	20%	16%	
Sierra Leone	2010	MICS	43%	28%	29%	11.7
Central African Republic	2006	MICS	43%	29%	30%	13.1
Tanzania	2010	DHS	42%	20%	16%	
Benin	2006	DHS	42%	27%	29%	13.2
Congo, Democratic Republic	2010	MICS	43%	26%	24%	9.7
Nigeria	2007	MICS	41%	32%	37%	
Tanzania	2010	DHS	42%	20%	16%	19.8
Central African Republic	2010	MICS	40%	21%	18%	18.4
Cambodia	2010	DHS	40%	18%	14%	15.3
Tanzania	2010	DHS	42%	20%	16%	19.8
Somalia	2006	MICS	41%	29%	31%	12.3
Cambodia	2010	DHS	40%	18%	14%	
Chad	2010	MICS	39%	26%	27%	13.4
Côte D'Ivoire	2006	MICS	39%	23%	21%	7.3
Nigeria	2008	DHS	39%	27%	29%	15.3
Nigeria	2008	DHS	39%	27%	29%	
Lesotho	2009	DHS	39%	19%	15%	10.6
Uganda	2006	DHS	38%	19%	16%	10.6
Sierra Leone	2008	DHS	35%	24%	26%	10.3
Kenya	2008	DHS	35%	18%	15%	7.3
Zimbabwe	2009	MICS	35%	15%	12%	10.3
Burkina Faso	2010	DHS	34%	18%	16%	6.9
Djibouti	2006	MICS	32%	25%	30%	
Zimbabwe	2010	DHS	32%	14%	10%	9.1
South Sudan	2010	MICS	30%	20%	21%	
Eswatini	2010	MICS	31%	13%	9%	9.9
Togo	2010	MICS	30%	12%	9%	11.3
São Tomé and Príncipe	2008	DHS	29%	15%	14%	
Peru	2007	DHS	28%	10%	6%	5.0
Egypt, Arab Rep.	2008	DHS	28%	17%	16%	
Peru	2007	DHS	28%	10%	6%	10.7

Country	Year	Source	Stunting headcount	Stunting gap	Stunting gap squared	t-stat for gap
Peru	2008	DHS	27%	10%	6%	
Syrian Arab Republic	2006	MICS	27%	17%	18%	14.6
Years: 2011-2013						
Benin	2011	DHS	45%	37%	45%	
Ethiopia	2011	DHS	44%	25%	23%	17.9
Lao PDR	2011	MICS	44%	23%	20%	21.6
Congo, Democratic Republic	2013	DHS	42%	26%	25%	
Bangladesh	2011	DHS	41%	19%	16%	11.3

Source: Authors' calculations using DHS and MICS.

4.3: Regional Analysis

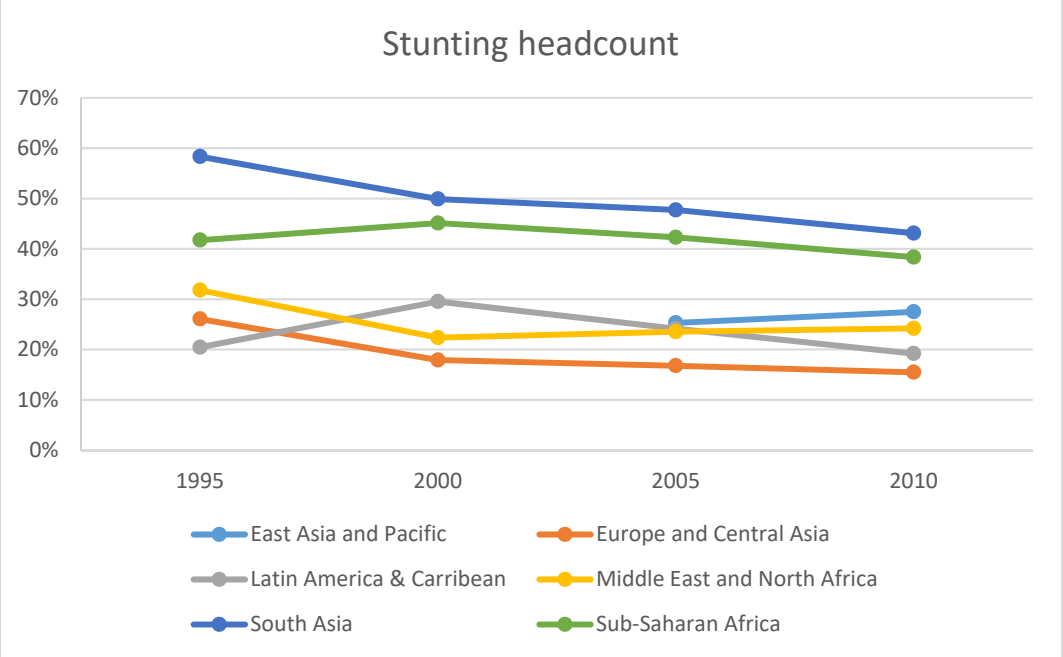
Until now we have focused on headcount and gap measures only at the country level. Extending this analysis to the regional level may provide further insight on malnutrition across the world. Therefore, we examine the regional averages of malnutrition. As survey data are not available every year for most countries, only a few countries in a particular region have a survey in a given year, with some regions having no survey conducted in certain years.

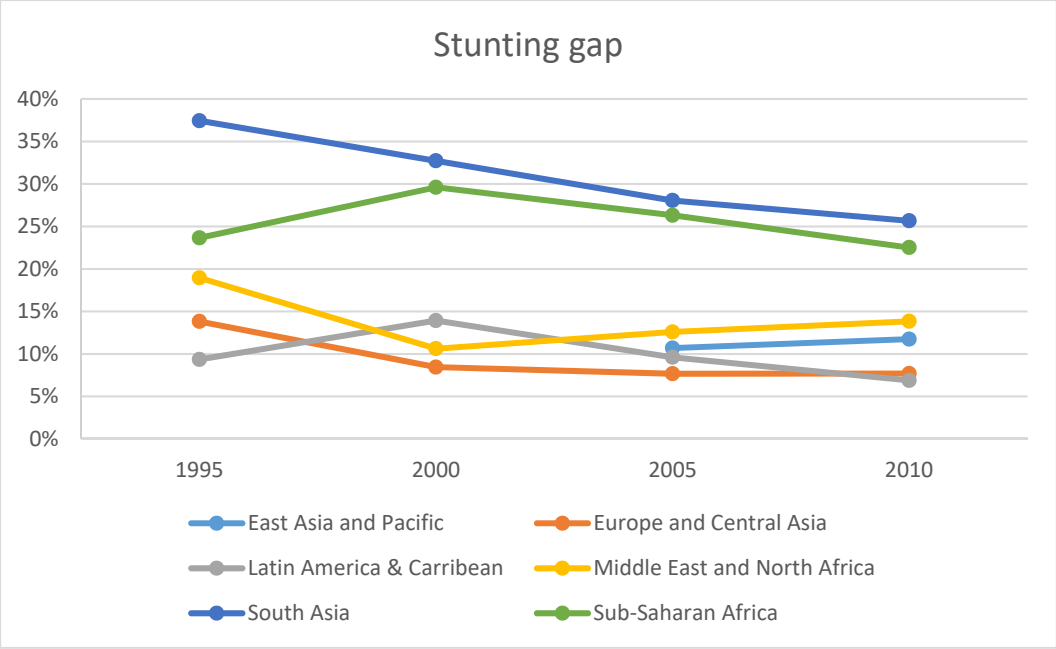
There are two common practices for calculating regional averages in such cases: (1) modeling methods and (2) aggregating over a range of years. An example of modeling methods closely related to this study is the UNICEF-WHO-World Bank joint child malnutrition estimates (JME) (UNICEF, WHO, and the World Bank 2018). The JME adopts linear mixed-effect models allowing for random effects at the country level and for heterogeneous covariance structures. One model is fitted for each region or country group for calculating its aggregated number. Such modeling methods are beyond the scope of this study. For simplicity, we chose to calculate regional averages for a range of years following the exercise in Nguyen and Wodon (2015). Thus, we create regional averages for five-year periods: 1993-1997, 1998-2002, 2003-2007, and 2008-2012. We use these five-year periods so that the middle years of these ranges,1995, 2000, 2005,

and 2010, coincide with the years in which under-five population data are compiled for each country in the sample.

We create regional averages of stunting measures weighted by the under-five population of each country of the middle of each reference period. Following the World Bank regional classification, we divide the countries in our sample into six regions: East Asia and Pacific (EAP), Europe and Central Asia (ECA), Latin America & Caribbean (LAC), Middle East & North Africa (MNA), South Asia (SAS), and Sub-Saharan Africa (SSA). These regional averages are presented in Figure 3 using two graphs that show (i) headcount rates for the different regions, and (ii) gap rates for the regions.

Figure 3: Regional trends of stunting headcount and stunting gap





Source: Authors' calculations using DHS and MICS. Results need to be interpreted with caution as the population coverage for some regions and years are below 50%.

A comparison of malnutrition across regions suggests that the stunting gap is telling a slightly different story from the stunting headcount for some regions. While the trends of the headcount and gap are the same for each particular region, the ranks of some regions differ depending on the type of measurement being used, i.e. headcount or gap rates. For example, according to the headcount measures in 2005 and 2010, EAP has a greater level of malnutrition than MNA. In contrast, according to the gap measures for the same period, MNA has a greater level of malnutrition than EAP.

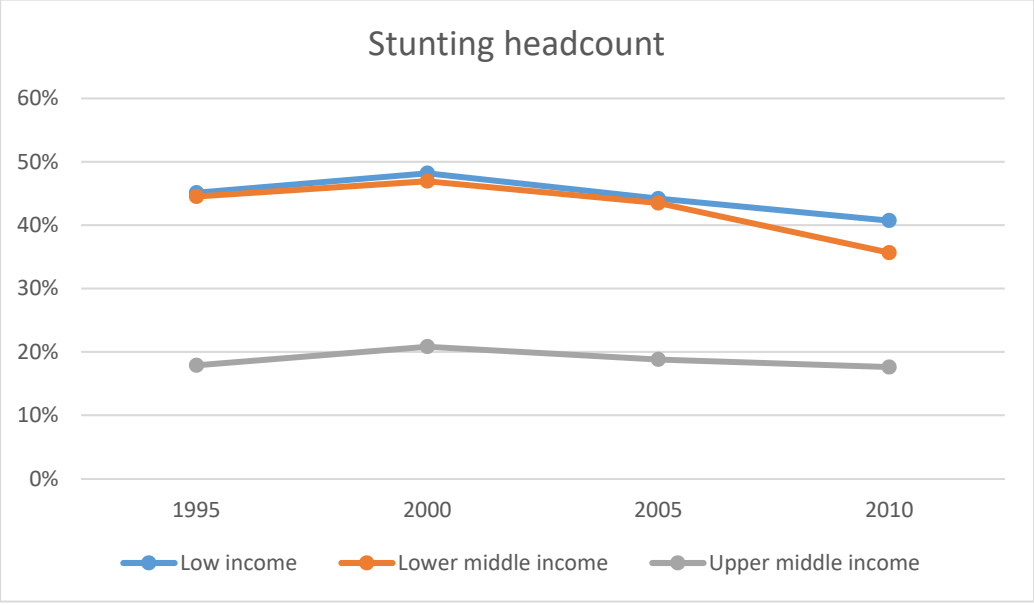
Similarly, according to the headcount measures, MNA and LAC have similar headcount rates in 2005, about 24% each, which is significantly higher than that of ECA (17%). However, in terms of the gap measure, MNA has a significantly higher gap rate (13%) than LAC (10%), and LAC is actually closer to ECA (8%). Similarly, for 2010, the headcount measure suggests a sizeable difference between LAC (19%) and ECA (15%). However, the gap measures suggest that both are

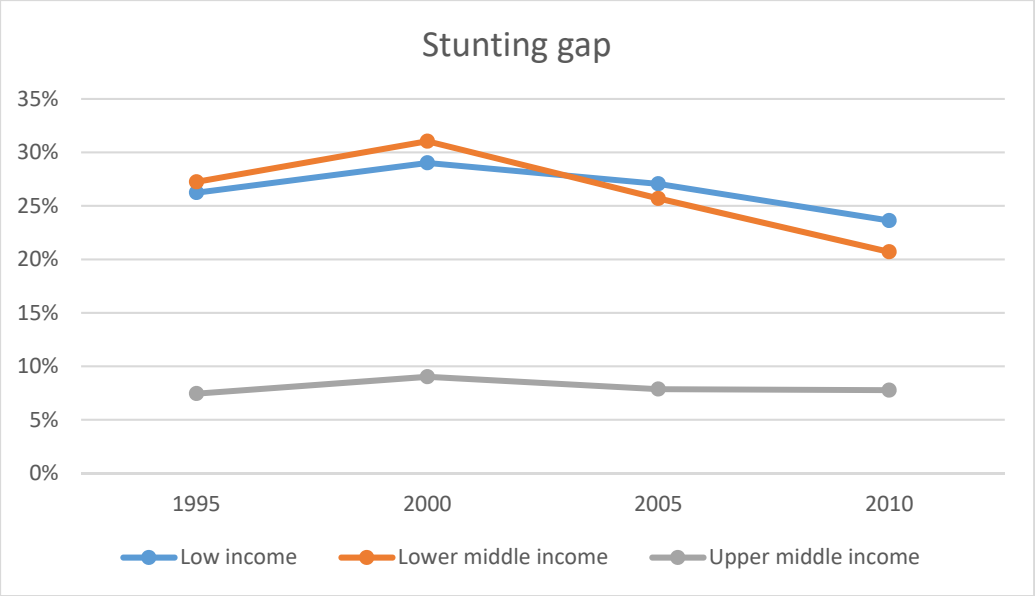
around 7 percent. This shows the importance of the gap measure, providing us further insight in addition to the headcount measures.

4.4 Income-group Analysis

Next we conduct our analysis by different income groups as defined by the World Bank: low income, lower-middle income, and upper-middle income. The results are presented in Figure 4. Similar to our regional analysis, we find that the trend of the stunting gap can reveal a different story than the trend of the stunting headcount. Specifically, the stunting headcount of lower-middle-income countries as a whole was slightly lower than that of low-income countries until sometime between 2000 and 2005. However, the trend of the stunting gap of lower-middle-income countries during this period of time was higher than that of low-income countries. In the reference year of 2000, the difference amounted to 2 percentage points.

Figure 4: Trends of stunting headcount and gap by income groups





Source: Authors' calculations using DHS and MICS. Results need to be interpreted with caution as the population coverage for some regions and years are below 50%.

4.5 Population Coverage

Next, we examine the population coverage in our analysis, i.e. the percentage of population in low- and middle-income countries that we cover through the nationally representative surveys in our analysis in each of the time ranges. We use data from WHO on the number of children below the age of 5 for all low- and middle-income countries in five-year intervals: 1995, 2000, 2005, and 2010. Thus, for each of survey year for a particular country, we use the closest population data available from WHO. Hence, we use population data from: 1995 for surveys conducted in years 1993-1997; 2000 for surveys in years 1998-2002; 2005 for surveys in years 2003-2007; and 2010 for surveys in years 2008-2012.

Table 3: Percentage of low and middle income country population covered in the malnutrition aggregations

Years	Percentage of population
1993-1997	18%

1998-2002	47%
2003-2007	57%
2008-2012	38%

Table 3 presents the population coverage for each five-year time period. We find that for the initial surveys from 1993 to 1997, the population coverage of low- and middle-income countries in our analysis was 18%. However, we see population coverage increase over the years to 47%, 57%, and 38% for the periods 1998-2002, 2003-2007, and 2008-2012, respectively. This shows that population coverage improved, likely because the number of surveys across countries increased over the years. While we may not have sufficient data for precise aggregation at this point, as more surveys are conducted in the future, we will have greater population coverage and greater precision in future analysis.

Table 4: Percentage of regional population covered in the malnutrition aggregations

Region:	1995	2000	2005	2010
East Asia and Pacific	0%	1%	5%	7%
Europe and Central Asia	40%	31%	57%	16%
Latin America & Caribbean	54%	22%	19%	20%
MENA	26%	26%	57%	43%
South Asia	12%	85%	85%	26%
Africa	32%	65%	86%	86%

Similarly, in Table 4 we present the population coverage for the regional aggregations in Figure 3. As we can see, while South Asia and Africa are well-represented in several of the time-windows, the coverage for the other regions are generally well below 50%. This demonstrates that the regional coverage estimates need to be interpreted with caution. However, it is important to note that the purpose of this exercise is not to create regional aggregates with sufficient coverage. It is instead to show how these new indicators and new estimates can be used for analysis.

5. Conclusions

This paper develops a new method of measuring malnutrition across the world. The current key measures of malnutrition, such as stunting and wasting, are based on headcount measures, i.e. the proportion of children who are suffering from malnutrition. However, a potential drawback of these headcount measures is that they do not inform us about the depth and severity of malnutrition. It is possible that a country with a low headcount rate for a particular malnutrition measure also has a high severity of malnutrition compared to countries with a similar headcount rate, and vice versa. Therefore, it is important to develop a measure of the severity of malnutrition.

To develop a measure of the severity of malnutrition, this study adopts a particular technique used in the development literature, specifically the Foster, Greer and Thorbecke (1984) class of poverty indicators, in the context of child malnutrition. Employing this new technique, we develop eight new measures of malnutrition in this study: (i) stunting gap, (ii) stunting gap squared, (iii) wasting gap, (iv) wasting gap squared, (v) overweight gap, (vi) overweight gap squared, (vii) underweight gap, and (viii) underweight gap squared. We employ over 20 years of malnutrition data from 95 developing countries to calculate these measures of severity.

Due to space limitations, this paper presents the results on stunting only, although all results have been calculated. It is of our interest to explore all our results in our future studies to understand if the additional information provided by the gap and gap squared measures is more useful for one malnutrition indicator than for another.

The malnutrition gap as a new measure enables us to monitor the development progress of those furthest away from the reference line, serving the principle of SDGs. Employing the new measures, we are also able to identify countries that have low levels of headcount for a malnutrition

measure, but have comparatively high severity of malnutrition according to the gap measures, and vice versa. This allows us to identify numerous cases where headcount measures may be providing a misleading description of a certain country's malnutrition status. Additionally, through regional and income-group analysis, we identify differences in the headcount and gap measurements. This study is extremely important from a policy perspective because comparing countries with similar headcount measures could hide important differences in the depth of malnutrition as reflected by differences in the malnutrition gap.

References

Foster, J. E., J. Greer, and E. Thorbecke. 1984. “A Class of Decomposable Poverty Indices.” *Econometrica*, vol. 52: 761-766.

Jolliffe, D. M. 2004a. “Continuous and Robust Measures of the Overweight Epidemic: 1971-2000.” *Demography*, vol. 41, no. 2: 303-314.

____. 2004b. “Extent of overweight among US children and adolescents from 1971 to 2000.” *International Journal of Obesity* 28: 4-9.

McDonald, C. M., I. Olofin, S. Flaxman, W. W. Fawzi, D. Spiegelman, L. E. Caulfield, R. E. Black, M. Ezzati and D. Goodarz. 2014. "The effect of multiple anthropometric deficits on child mortality: meta-analysis of individual data in 10 prospective studies from developing countries," *The American Journal of Clinical Nutrition*: 896-901.

Minh Cong Nguyen, and Quentin Wodon. 2012. “Measuring Child Marriage.” *Economics Bulletin* 32 (1): 398–411.

____. 2015. Global and Regional Trends in Child Marriage, *The Review of Faith & International Affairs*, vol. 13, no. 3: 6-11.

Shekar, M., M. Mattern, P. Eozenou, J.D. Eberwein, J.K. Akuoku, E. Di Gropello, R.W. Karamba,R. 2015. *Scaling up nutrition for a more resilient Mali: nutrition diagnostics and costed plan for scaling up*. Health, Nutrition and Population (HNP) Discussion Paper Series #95754. Washington, DC: World Bank.

UNICEF, WHO, and the World Bank. 2018. *UNICEF-WHO-The World Bank: Joint child malnutrition estimates - Levels and trends*. Available online: http://www.who.int/nutgrowthdb/estimates/en/.

United Nations Statistics Division (UNSD). 2016. *The Sustainable Development Goals Report*. New York, NY: United Nations.

World Health Organization and United Nations Children's Fund. 2009. *WHO child growth standards and the identification of severe acute malnutrition in infants and children: A Joint Statement*. New York, NY: WHO.

Annex 1
Surveys with anthropometric measurements for children under 5 years of age

COUNTRY	SURVEYS
Afghanistan	MICS 2010
Albania	MICS 2005 / DHS 2008
Armenia	DHS 2000 / DHS 2005 / DHS 2010
Azerbaijan	DHS 2006
Bangladesh	DHS 1996 / DHS 1999 / DHS 2004 / DHS 2007 / DHS 2011
Barbados	MICS 2012
Belarus	MICS 2005
Belize	MICS 2006 / MICS 2011
Benin	DHS 1996 / DHS 2001 / DHS 2006 / DHS 2011
Bhutan	MICS 2010
Bolivia	DHS 1994 / DHS 1998 / DHS 2003 / DHS 2008
Bosnia and Herzegovina	MICS 2006 / MICS 2011
Brazil	DHS 1996
Burkina Faso	DHS 1998 / DHS 2003 / MICS 2006 / DHS 2010
Burundi	DHS 2010
Central African Republic	DHS 1994 / MICS 2006 / MICS 2010
Cambodia	DHS 2000 / DHS 2005 / DHS 2010
Cameroon	DHS 1998 / DHS 2004 / MICS 2006 / DHS 2011
Chad	DHS 1996 / DHS 2004 / MICS 2010
Colombia	DHS 1995 / DHS 2000 / DHS 2005 / DHS 2010
Comoros	DHS 1996 / DHS 2012
Congo Brazzaville	DHS 2005 / DHS 2011
Congo Democratic Republic	DHS 2007 / MICS 2010 / DHS 2013
Côte d'Ivoire	DHS 1994 / DHS 1998 / MICS 2006 / DHS 2011
Djibouti	MICS 2006
Dominican Republic	DHS 1996 / DHS 2002 / DHS 2007 / DHS 2013
Egypt, Arab Rep.	DHS 1995 / DHS 2000 / DHS 2005 / DHS 2008
Ethiopia	DHS 2000 / DHS 2005 / DHS 2011
Gabon	DHS 2000 / DHS 2012
Gambia, The	MICS 2005 / DHS 2013
Georgia	MICS 2005

Ghana	DHS 1993 / DHS 1998 / DHS 2003 / MICS 2006 / DHS 2008 / MICS 2011
COUNTRY	**SURVEYS**
Guatemala	DHS 1995 / DHS 1998
Guinea	DHS 1999 / DHS 2005 / DHS 2012
Guinea Bissau	MICS 2006
Guyana	MICS 2006 / DHS 2009
Haiti	DHS 1994 / DHS 2000 / DHS 2005 / DHS 2012
Honduras	DHS 2005 / DHS 2011
India	DHS 1998 / DHS 2005
Iraq	MICS 2006 / MICS 2011
Jordan	DHS 1997 / DHS 2002 / DHS 2007 / DHS 2012
Kazakhstan	DHS 1995 / DHS 1999 / MICS 2006 / MICS 2010
Kenya	DHS 1993 / DHS 1998 / DHS 2003 / DHS 2008
Kyrgyzstan	DHS 1997 / MICS 2005 / DHS 2012
Lao PDR	MICS 2006 / MICS 2011
Lesotho	DHS 2004 / DHS 2009
Liberia	DHS 2007 / DHS 2013
Macedonia	MICS 2005 / MICS 2011
Madagascar	DHS 1997 / DHS 2003
Malawi	DHS 2000 / DHS 2004 / MICS 2006 / DHS 2010
Maldives	DHS 2009
Mali	DHS 1995 / DHS 2001 / DHS 2006 / DHS 2012
Mauritania	MICS 2007 / MICS 2011
Moldova	DHS 2005 / MICS 2012
Mongolia	MICS 2005 / MICS 2010
Montenegro	MICS 2005 / MICS 2013
Morocco	DHS 2003
Mozambique	DHS 1997 / DHS 2003 / MICS 2008 / DHS 2011
Namibia	DHS 2000 / DHS 2006 / DHS 2013
Nepal	DHS 1996 / DHS 2001 / DHS 2006 / DHS 2011
Nicaragua	DHS 1997 / DHS 2001
Niger	DHS 1998 / DHS 2006 / DHS 2012
Nigeria	DHS 1999 / DHS 2003 / MICS 2007 / DHS 2008 / MICS 2011 / DHS 2013
Pakistan	DHS 2012
Pakistan (Baluchistan)	MICS 2010*

Pakistan (Punjab)	MICS 2011*
Palestinians in Lebanon	MICS 2011*
COUNTRY	**SURVEYS**
Peru	DHS 1996 / DHS 2000 / DHS 2005 / DHS 2007 / DHS 2008 / DHS 2009 / DHS 2010 / DHS 2011 / DHS 2012
Rwanda	DHS 2000 / DHS 2005 / DHS 2010
São Tomé and Príncipe	DHS 2008
Senegal	DHS 2005 / DHS 2010 / DHS 2012 / DHS 2014
Serbia	MICS 2005 / MICS 2010 / MICS 2014
Sierra Leone	MICS 2005 / DHS 2008 / MICS 2010 / DHS 2013
Somalia	MICS 2006
St. Lucia	MICS 2012
West Bank and Gaza	MICS 2010
Sudan (North)	MICS 2010
Sudan (South)	MICS 2010
Suriname	MICS 2006 / MICS 2010
Eswatini	DHS 2006 / MICS 2010
Syrian Arab Republic	MICS 2006
Tajikistan	MICS 2005 / DHS 2012
Tanzania	DHS 1996 / DHS 1999 / DHS 2004 / DHS 2010
Thailand	MICS 2005
Timor-Leste	DHS 2009
Togo	DHS 1998 / MICS 2006 / MICS 2010 / DHS 2013
Tunisia	MICS 2011
Turkey	DHS 1993 / DHS 1998 / DHS 2003
Uganda	DHS 1995 / DHS 2000 / DHS 2006 / DHS 2011
Uzbekistan	DHS 1996 / MICS 2006
Vanuatu	MICS 2007
Vietnam	MICS 2010
Zambia	DHS 1996 / DHS 2001 / DHS 2007
Zimbabwe	DHS 1994 / DHS 1999 / DHS 2005 / MICS 2009 / DHS 2010 / MICS 2014

*Subnational sample