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MEASUREMENT APPROACHES FOR EFFECTIVE COVERAGE ESTIMATION

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Measurement Approaches for Effective Coverage Estimation

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PREFACE

The Demographic and Health Surveys (DHS) Program is one of the principal sources of international data on fertility, family planning, maternal and child health, nutrition, mortality, environmental health, HIV/AIDS, malaria, and provision of health services.

One of the objectives of The DHS Program is to continually assess and improve the methodology and procedures used to carry out national-level surveys as well as to offer additional tools for analysis. Improvements in methods used will enhance the accuracy and depth of information collected by The DHS Program and relied on by policymakers and program managers in low- and middle-income countries.

While data quality is a main topic of the DHS Methodological Reports series, the reports also examine issues of sampling, questionnaire comparability, survey procedures, and methodological approaches. The topics explored in this series are selected by The DHS Program in consultation with the U.S. Agency for International Development.

It is hoped that the DHS Methodological Reports will be useful to researchers, policymakers, and survey specialists, particularly those engaged in work in low- and middle-income countries, and will be used to enhance the quality and analysis of survey data.

Sunita Kishor
Director, The DHS Program

ABSTRACT

Effective coverage is increasingly being used to evaluate maternal and child health programs. Effective coverage can be described as crude coverage adjusted for the quality of care provided. However, there are many ways to calculate effective coverage – including using different datasets or different measures of quality – that may result in different conclusions about a program. This report compares three different approaches to calculating effective coverage in antenatal care and sick child care in five countries – Haiti, Malawi, Nepal, Senegal, and Tanzania. The first approach uses data from Demographic and Health Surveys (DHS) to estimate effective coverage. The second approach combines DHS data with basic measures of health facility readiness and process quality from Service Provision Assessment (SPA) data. The third approach combines DHS data with expanded measures of health facility readiness and process quality from SPA data.

Results show that estimates of effective antenatal care coverage were higher when only DHS data were used in the calculations. The sick child care effective coverage estimates were lower when only DHS data were used. Incorporating SPA data allowed for estimation of more steps along the effective coverage cascade. Comparisons of the basic measures of readiness and process quality used in Approach 2 and the expanded measures used in Approach 3 showed that the effect of these measures depended on the service area and country. With antenatal care, in three countries, the expanded measures resulted in lower quality-adjusted coverage, while in Malawi and Tanzania, the quality-adjusted coverage was higher. With sick child care, the expanded measures resulted in lower quality-adjusted measures in all countries, although the differences were very small in Nepal and Senegal.

This study explored different approaches to calculating effective coverage and provides insights into how to contextualize the measures with different approaches. When using only DHS data, the effective coverage estimates are likely to be an overestimate of antenatal care or sick child care effective coverage. Using data from health facility assessments such as the SPA can provide better estimates of effective coverage, while using a basic or expanded measure of readiness and process quality of care results in similar estimates of quality-adjusted coverage.

Key words: antenatal care, sick child care, effective coverage, quality of care, measurement, SPA, DHS, Haiti, Malawi, Nepal, Senegal, Tanzania

ACRONYMS AND ABBREVIATIONS

ANC	antenatal care
ARI	acute respiratory illness
CI	confidence interval
DHS	Demographic and Health Surveys
EC	effective coverage
HIV	human immunodeficiency virus
IMCI	integrated management of childhood illness
MMR	maternal mortality ratio
ORS	oral rehydration solution
QOCI	quality of care index
SARA	Service Availability and Readiness Assessment
SPA	Service Provision Assessment
U5MR	under-5 mortality rate
USAID	United States Agency for International Development
WHO	World Health Organization

1 INTRODUCTION

Maternal and child mortality has improved greatly over the past decades. The global maternal mortality rate (MMR) was estimated at 211 maternal deaths per 100,000 live births in 2017, which is a 38% reduction since 2000, when it was estimated at 342 (WHO 2019). The global under-5 mortality rate (U5MR) dropped from 93 deaths per 1,000 live births in 1990 to 39 in 2017 (United Nations Inter-agency Group for Child Mortality Estimation 2017). At the same time that maternal mortality has been decreasing, rates of antenatal care (ANC) and facility deliveries have been increasing (Benova et al. 2018; Diamond-Smith and Sudhinaraset 2015). However, MMRs are not decreasing at the rates expected given the simultaneous increase in health care utilization. This has led some to question the quality of maternal health care provided at health facilities (Graham, McCaw-Binns, and Munjanja 2013; Hodgins and D'Agostino 2014; Nguhiu, Barasa, and Chuma 2017).

For children under age 5, the overall trend of decreasing mortality rates has been attributed largely to expanded vaccination programs, greater use of oral rehydration therapy, improvement in the health and nutritional status of mothers and children, and decreases in the number of high-risk births (Ahmad, Lopez, and Inoue 2000). Care-seeking for sick children has not shown the same pattern as maternal health care utilization. Trends in care-seeking for the most common causes of sick child care – acute respiratory infection (ARI), diarrhea, and fever – have varied over time by region and country (Assaf and Pullum 2016; Bennett et al. 2015). A recent analysis of care-seeking in 24 United States Agency for International Development (USAID) priority countries showed that while over half (68.2%) of caregivers sought treatment outside of the home when their child experienced one of these symptoms, the percentage ranges from 38.8% in Ethiopia to 88.9% in Indonesia (Bradley, Rosapep, and Shiras 2020). The vast majority of under-5 deaths are due to causes amenable to health care and prevention – preterm birth complications, pneumonia, intrapartum-related complications, diarrhea, and malaria (Liu et al. 2016).

For both mother and child, increases in the coverage of interventions will not be sufficient to reduce mortality to desired levels. The quality of the care provided must be high for health systems to deliver optimum health gains (Kruk, Larson, and Twum-Danso 2016; Leslie et al. 2017). The concept of effective coverage has emerged as a way to account for quality when measuring coverage.

Tanahashi first conceptualized a framework that considered five elements that are necessary to achieve effective coverage: availability of health services, physical accessibility to services within reasonable distances, acceptability by those in need in terms of cost and religious or ethnic values, and contact, or actual use of the service (Tanahashi 1978). Shengelia and colleagues further simplified the concept of effective coverage into one defined by need, use, and quality (Shengelia et al. 2005). A recent paper from an initiative on effective coverage led by UNICEF and the World Health Organization (WHO) describes seven steps in the effective coverage cascade, with adjustment for the expected health outcome as the final step (Marsh et al. 2020). More simply, effective coverage of population health needs by a health system is assessed based on the actual health outcomes among those in need of health services. However, in many cases, data on the expected health outcome are not available. In these cases, quality-adjusted coverage may serve as a proxy for effective coverage (Marsh et al. 2020), and effective coverage measures would be based on the quality of health services received by those in need of such health services.

Despite most conceptualizations of effective coverage that describe a multi-step cascade, many recent studies of effective coverage include only one measure of coverage and one measure of quality (Amouzou et al. 2019; Koulidiati et al. 2018; Larson et al. 2017; Wang et al. 2018; Yakob et al. 2019). This may be due to most facility assessments only capturing the readiness aspect of quality (Nickerson et al. 2014). Some studies combine components of readiness and process quality into a global quality measure to use in the calculation of effective coverage (Larson et al. 2017).

The Service Provision Assessment (SPA) and the Service Availability and Readiness Assessment (SARA) are the most commonly used, standardized health facility assessment tools (Sheffel, Karp, and Creanga 2018). However, the SPA is the only tool with both readiness and process quality of care measures for ANC, family planning, and sick child care. Unfortunately, most countries that have conducted a Demographic and Health Survey (DHS) have not conducted an SPA. The SPA has only been implemented in 18 countries as of mid-2020. Therefore, many countries are struggling with how to measure effective coverage with only DHS data, or perhaps considering if they should implement a health facility survey to capture readiness and process quality of care data. When a health facility survey is being considered, what items should be included in the readiness and process quality of care measures? Does a more limited set of tracer items adequately capture readiness and process quality of care, or should expanded measures with more items be used? There are no clear-cut answers to these questions because there are many health facility assessment tools available (Nickerson et al. 2014), and there are no universally defined measures of ANC, sick child care readiness, or process quality. Although previous studies have compared methodologies for assessing readiness and process quality of care as standalone measures (Sheffel et al. 2019), this same comparison has not been applied to the effective coverage cascade.

This study contributes to the research on effective coverage in health facilities by comparing three methods for calculating effective coverage estimates in five countries with high prevalence of maternal and child mortality (see Table 1). In Approach 1, we use only DHS data to estimate effective coverage of ANC and sick child care. In Approach 2, we combine data from the DHS surveys with data on health facility readiness and provision of care from the SPA, using a limited set of tracer items to measure readiness and process quality of care. In Approach 3, we use a wider range of items to provide a broader assessment of the readiness and process quality of care provided at facilities. Findings from this study will provide a better understanding of these different measurement approaches, and will allow stakeholders interested in effective coverage measures to decide whether to conduct and what to include in a health facility survey, as well as how to interpret effective coverage measures that use only data from household surveys.

Table 1 Under-5 mortality rate (U5MR), pregnancy-related mortality ratio, and maternal mortality ratio (MMR) for the countries selected for the analysis

Country	Survey	U5MR	Pregnancy-related mortality ratio	MMR
Haiti	2016-17 DHS	81 (CI: 71 – 92)	646 (CI: 480 – 812)	529 (CI: 375 – 684)
Malawi	2015-16 DHS	64 (CI: 59 – 69)	497 (CI: 400 – 593)	439 (CI: 348 – 531)
Nepal	2016 DHS	39 (CI: 33 – 45)	259 (CI: 151 – 366)	239 (CI: 134 – 345)
Senegal	2018 DHS	51 (CI: 43 – 58)	NA	315 (CI: 214 – 468)[a]
Tanzania	2015-16 DHS	67 (CI: 60 – 74)	530 (CI: 405 – 655)	398 (CI: 281 – 570)[a]

Source: All estimates are from STATcompiler (https://www.statcompiler.com/en/) except for [a] those which were not available in STATcompiler and are estimated by WHO (2015b) with an 80% uncertainty interval. NA – Not available.

2 DATA AND METHODS

2.1 Data

The analysis is based on data from the DHS and SPA surveys in five countries – Haiti, Malawi, Nepal, Senegal, and Tanzania. These countries were selected because they had a recent DHS survey and a recent SPA survey completed within 2 years of each other. The Haiti and Malawi SPA surveys were census surveys that included all formal facilities in the country. The remaining SPA surveys were based on a sample of facilities in the country. The list of surveys and the year they were conducted are provided in Table 2. For more detail on the SPA and DHS sampling procedure for each survey, please check the final reports available on The DHS Program website.

Table 2 Surveys used in the analysis

Country	DHS survey	SPA survey
Haiti	2016-17	2017-18
Malawi	2015-16	2013-14
Nepal	2016	2015
Senegal	2018	2018
Tanzania	2015-16	2014-15

2.2 Defining the Components of Effective Coverage

As described in the introduction, effective coverage is the level of coverage of a service adjusted for its quality. The simplest approach to calculating effective coverage involves multiplying the percent of the population covered by a service by a measure of quality. However, Marsh and colleagues (2020) specified additional service delivery measures that are required to calculate effective coverage: service contact (service contact coverage), service readiness (input-adjusted coverage), receipt of the complete intervention (intervention coverage), and process quality (quality-adjusted coverage). Each component requires a specific measure, which are described here. More detail on the calculation of the effective coverage cascade will be described in the next section.

This study uses three approaches to estimate each aspect of service delivery. These different approaches are detailed below, and the measures are defined in detail in Table 3.

Approach 1 uses only DHS data. Many countries do not have data from an SPA or similar health facility survey. For each step of the effective coverage cascade, measures were developed to represent each construct. Service contact coverage is calculated as the percent of women with a birth in the last 5 years who have had at least one ANC visit with a skilled provider for the most recent birth and the percent of children under age 5 with diarrhea or ARI symptoms who sought care at a health facility (sick child). Since no facility data are available in the DHS data, the service readiness measure is not possible to calculate in Approach 1. “Complete” intervention is defined as having four ANC visits and children with diarrhea or ARI symptoms who sought care at a facility having received treatment. These measures are available in the DHS data. For quality of care, since no sick child quality measures are available in the DHS data, the quality of care measure is not included in Approach 1 for sick child care. Women are asked in the DHS to report the essential ANC interventions they received during their last pregnancy, and ANC process quality of care is then measured with a composite index that combines if a woman received iron supplementation, had blood pressure and urine sample taken, and received at least two tetanus injections during pregnancy for the most recent birth. The DHS indicators used to calculate measures in this approach are described in Appendix 1 and were coded according to the standard code available on The DHS Program code share library site hosted on GitHub.[1]

Approach 2 combines DHS data with SPA data to allow for a more complete assessment of the cascade. Including the SPA data provides direct information on the quality of the care and the readiness of the facilities visited for care. The same DHS-based measures of service contact coverage from Approach 1 were used with Approach 2. In addition, the DHS-based ANC complete intervention coverage measure was also used. However, the sick child complete intervention coverage measure is improved by using SPA data, since it is calculated with a denominator of children diagnosed with pneumonia or diarrhea and not just the children with symptoms of pneumonia or diarrhea in the last 2 weeks. Therefore, an SPA-based measure was used with the percent of children receiving appropriate treatment of those diagnosed with diarrhea or pneumonia at a facility that provides sick child care.[1] Short measures of facility readiness and quality of care were created for ANC and sick child care using the SPA data. Items included in each measure were selected based on previous research to identify a quality of care index (QOCI) (Mallick et al. 2020), except for ANC readiness, which did not have any items represented in the QOCI. Items for ANC readiness were selected based on the frequency of inclusion in the antenatal structural quality of care measures identified in previous literature using the SPA ANC data (Bintabara et al. 2019; Gage et al. 2018; Kruk et al. 2017; Lee, Madhavan, and Bauhoff 2016; Macarayan et al. 2018; Owili et al. 2019; Sharma et al. 2017; Wang et al. 2014; Yakob et al. 2019). Measures were calculated with a simple average approach, where the sum of the items available (for readiness) or the sum of the items observed to have been performed (process quality of care) is divided by the total number of items (Mallick, Wang, and Temsah 2017). Readiness and process quality were calculated only among the facilities at which the service is provided, such as ANC readiness and process quality at facilities that provide ANC services, and sick child readiness and process quality at facilities that provide sick child curative services.

Approach 3 again combines DHS data with SPA data for a more complete assessment of the effective coverage cascade. However, with this approach, the measures of facility readiness and quality of care include more items, while the other measures remain the same as in Approach 2. This more extensive list of items encompasses both clinical and interpersonal aspects of quality of care. Items were identified for inclusion through a literature review of the global ANC care and Integrated Management of Childhood Illness (IMCI) standards (WHO 2014, 2015a, 2016), as well as previous research into antenatal quality of care using the SPA data (Bintabara et al. 2019; Gage et al. 2018; Kruk et al. 2017; Lee, Madhavan, and Bauhoff 2016; Macarayan et al. 2018; Owili et al. 2019; Sharma et al. 2017; Wang et al. 2014; Yakob et al. 2019) and sick child data (Getachew et al. 2020; Kruk et al. 2017; Lama et al. 2019; Larson, Leslie, and Kruk 2017; Liu et al. 2019; Macarayan et al. 2018; Wang et al. 2014). Items in the global standards that were also frequently used to assess antenatal and sick child readiness and quality of care were included in our more robust measures. As shown in Appendix Table 2, for sick child care, there are two items in the basic list of readiness indicators used for Approach 2, and 31 items in the expanded list (Approach 3). For ANC, there are 3 items for the basic and 33 items for the expanded list of readiness indicators. For the sick child care quality of care measures, there are 6 items for the basic list used in Approach 2 and 32 items for

[1] https://github.com/DHSProgram

the expanded list in Approach 3. For ANC quality of care, there are 2 items in the basic list and 18 items in the expanded list. A simple average approach was again used to calculate the score for readiness and process quality of care. Again, readiness and process quality were calculated only among the facilities at which the service is provided.

Since we prioritized using standard measures that would be applicable across all five countries, any items with large proportions of missing data or items that were not available in all the countries were not included. For example, in sick child care, asking about the mother's human immunodeficiency virus (HIV) status was recommended for inclusion as part of a comprehensive clinical assessment of a sick child. However, in Nepal, assessment of maternal HIV status is not done due to the low HIV prevalence. Therefore, it was removed from the measure included in this study.

For all measures calculated with DHS data, sampling weights are used to produce the estimates. For SPA readiness measures, facility-level weights are applied, and for quality measures, client-level weights were used. Table 3 explains each of the variables, as well as the source of data used for this analysis. Appendix Table 2 provides the list of items found in SPA data that were used for the basic (Approach 2) and expanded (Approach 3) measures. Appendix Table 3 provides the estimates of the readiness indicators used in the composite service readiness measures, by country, and Appendix Table 4 provides the estimates for the process indicators used in the composite process quality measures. The code used to produce these estimates is found on the DHS Analysis repository on GitHub.[2]

[2] https://github.com/DHSProgram/DHS-Analysis-Code

Table 3 Description of measures used to construct the effective coverage cascade

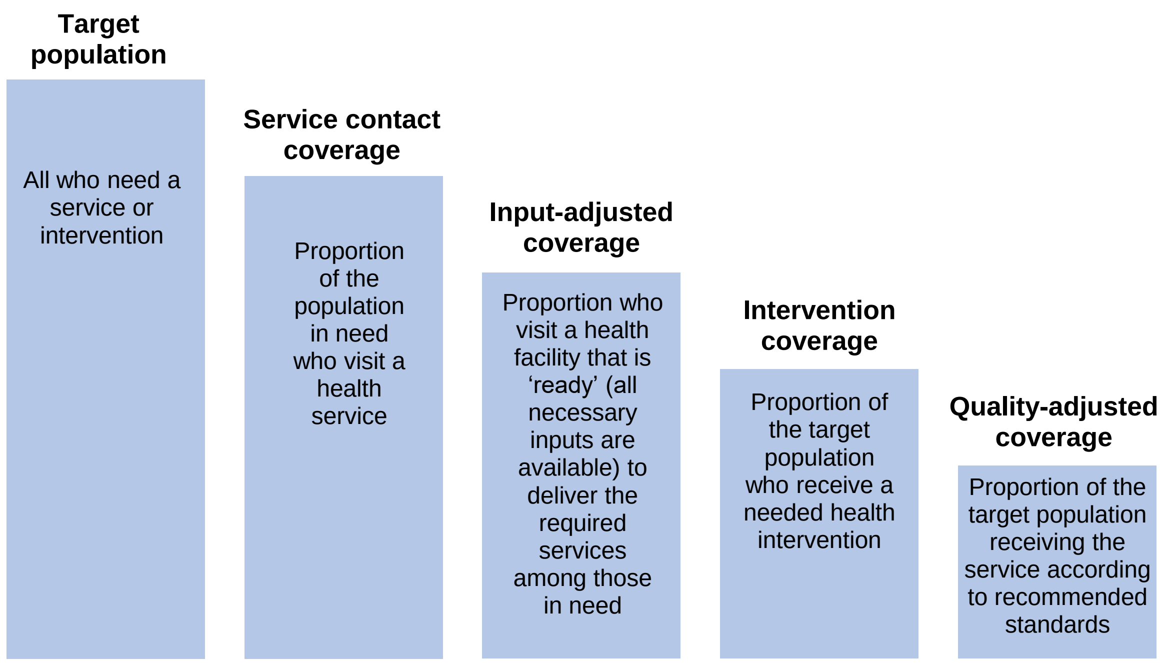
Approach	Coverage	Readiness	Receipt of complete intervention	Process quality
1: Only DHS data	ANC: Women with at least one ANC visit with a skilled provider for the most recent birth among women who gave birth at least once in the last 5 years. A skilled provider was defined as a doctor, nurse, midwife, or other health worker.[1]	ANC: Not available in DHS data	ANC: Women with a birth in the last 5 years who attended at least four ANC visits for the most recent birth.	ANC: A composite index that combines received iron supplementation, blood pressure taken, urine sample taken, and received at least two tetanus injections during pregnancy for the most recent birth.
	Sick child care: Children who sought care at a health facility among children under age 5 who had diarrhea or ARI symptoms in the last 2 weeks.	Sick child care: Not available in DHS data	Sick child care: Children under age 5 who received treatment (ORS or antibiotics) among children under age 5 who sought care at a facility for diarrhea or ARI symptoms.	Sick child care: Not available in DHS data
2: DHS and SPA using basic readiness and process variables from SPA	ANC: Women with at least one ANC visit with a skilled provider for the most recent birth among women who gave birth at least once in the last 5 years. A skilled provider was defined as a doctor, nurse, midwife, or other health worker.[1]	ANC: A composite index of basic readiness for ANC (3 items).[2]	ANC: Women with a birth in the last 5 years who attended at least four ANC visits for the most recent birth.	ANC: A composite index of basic process quality for ANC (3 items).[2]
	Sick child care: Children who sought care at a health facility among children under age 5 who had diarrhea or ARI symptoms in the last 2 weeks.	Sick child care: A composite index of basic readiness for sick child care (4 items).[2]	Sick child care: Children under age 5 who received appropriate treatment among children under age 5 who were diagnosed with diarrhea or pneumonia at a facility.[3]	Sick child care: A composite index of basic process quality for sick child care (6 items).[2]
3: DHS and SPA using expanded readiness and process variables from SPA	ANC: Women with at least one ANC visit with a skilled provider for the most recent birth among women who gave birth at least once in the last 5 years. A skilled provider was defined as a doctor, nurse, midwife, or other health worker.[1]	ANC: A composite index of expanded readiness for ANC (33 items).[2]	ANC: Women with a birth in the last 5 years who attended at least four ANC visits for the most recent birth.	ANC: A composite index of expanded process quality for ANC (18 items).[2]
	Sick child care: Children who sought care at a health facility among children under age 5 who had diarrhea or ARI symptoms in the last 2 weeks.	Sick child care: A composite index of expanded readiness for sick child care (31 items).[2]	Sick child care: Children under age 5 who received appropriate treatment among children under age 5 who were diagnosed with diarrhea or pneumonia at a facility.[3]	Sick child care: A composite index of expanded process quality for sick child care (34 items).[2]

Note: 1. Source of ANC is not asked – women who receive ANC from a skilled provider will be assumed to have received care in a health facility; 2. See Appendix 2 for list of items in SPA used for Approach 2 (basic) and Approach 3 (expanded); and 3. Sick child complete intervention coverage measured with SPA data in Approaches 2 and 3.

2.3 Calculating the Effective Coverage Cascade

With the measures described in Table 3, we then calculated the effective coverage cascade, shown in Figure 1. The cascade begins with the target population, and at each step, adjusts for an additional aspect of service delivery.

Figure 1 Effective coverage cascade



Note: Adapted from Amouzou et al. (2019).

To obtain the estimates for the cascade, each measure described in the table (except for the first) is multiplied by the previous measure. The target population for ANC is all women who have been pregnant at least once in the last 5 years and for sick child care, all children under age 5 who have had ARI symptoms or diarrhea in the last 2 weeks. Children under age 5 are defined as sick if they had symptoms of ARI or diarrhea in the 2 weeks before the survey. Symptoms of ARI were defined as short, rapid breaths and a problem in the chest. Illustrative examples of the calculation of each step in the effective coverage cascade are shown in Table 4 for ANC, and Table 5 for sick child care.

Table 4 Calculation example of antenatal care effective coverage cascade in Approach 2

	Measures						
Steps in effective coverage cascade	**Coverage**		**Readiness**		**Receipt of complete intervention**		**Process quality**
Service contact	Women with at least one ANC visit with a skilled provider for the most recent birth among women who gave birth at least once in the previous 5 years						
Input-adjusted	Women with at least one ANC visit with a skilled provider for the most recent birth among women who gave birth at least once in the last 5 years	**X**	Average readiness across ANC facilities using the *basic* facility readiness				
Intervention	Women with at least one ANC visit with a skilled provider for the most recent birth among women who gave birth at least once in the last 5 years	**X**	Average readiness across ANC facilities using the *basic* facility readiness	**X**	Women with 4+ ANC visits at a health facility among women who gave birth at least once in the last 5 years		
Quality-adjusted	Women with at least one ANC visit with a skilled provider for the most recent birth among women who gave birth at least once in the last 5 years	**X**	Average readiness across ANC facilities using the *basic* facility readiness	**X**	Women with 4+ ANC visits at a health facility among women who gave birth at least once in the last 5 years	**X**	Average process quality across ANC facilities using the *basic* process quality index

Note: The same calculation is used for Approach 3, but with the *expanded* measures instead of the *basic* measures. Each coverage measure is the product of the previous measures except for the service contact coverage.

Table 5 Calculation example of sick child care effective coverage cascade in Approach 2

	Measures						
Steps in effective coverage cascade	**Coverage**		**Readiness**		**Receipt of complete intervention**		**Process quality**
Service contact	Children who sought care at a health facility among children under age 5 who had diarrhea or ARI symptoms in the last 2 weeks						
Input-adjusted	Children who sought care at a health facility among children under age 5 who had diarrhea or ARI symptoms in the last 2 weeks	**X**	Average readiness across sick child care facilities using the *basic* facility readiness				
Intervention	Children who sought care at a health facility among children under age 5 who had diarrhea or ARI symptoms in the last 2 weeks	**X**	Average readiness across sick child care facilities using the *basic* facility readiness	**X**	Children under age 5 who received appropriate treatment among children under age 5 who were diagnosed with diarrhea or pneumonia at a facility		
Quality-adjusted	Children who sought care at a health facility among children under age 5 who had diarrhea or ARI symptoms in the last 2 weeks	**X**	Average readiness across sick child care facilities using the *basic* facility readiness	**X**	Children under age 5 who received appropriate treatment among children under age 5 who were diagnosed with diarrhea or pneumonia at a facility	**X**	Average process quality across sick child care facilities using the basic process quality index

Note: the same calculation is used for Approach 3, but with the *expanded* measures instead of the *basic* measures. Each coverage measure is the product of the previous measures except for the service contact coverage.

For Approaches 2 and 3, we linked the DHS and SPA data with ecological linkage at the national level. In this approach, the coverage and intervention measures are aggregated for all women who had a birth within the last 5 years and all children with pneumonia or diarrhea symptoms in the entire country. The mean readiness and mean process quality received by women at those facilities are aggregated across all facilities in the country. The levels of effective coverage can then be interpreted as the mean or expected effectiveness for a randomly selected pregnant woman or child in the population who showed symptoms of illness. More complex approaches to calculating effective coverage take into account regional variation in coverage, readiness, and quality, as well as population distribution or variation in readiness and quality across health facility type and the distribution of those facility types (Munos et al. 2018). However, since our focus is different methods of measurement of the effective coverage cascade, we present the simplest calculation in this analysis.

2.4 Estimating the Confidence Intervals in the Cascade

As described earlier, the cascaded effective coverage estimates are constructed as products of measures that come from different data files, either the DHS or SPA data. Standard methods can be used to calculate a confidence interval for each measure separately. However, a confidence interval for the product of two or more terms lies outside the usual statistical framework. In earlier DHS reports, the confidence interval for the product was estimated with the "delta" method (Wang et al. 2018). When this approach was compared with alternatives by Sauer et al. (2020), the delta method was found to be successful at generating confidence intervals of appropriate width based on simulation studies. The extension to cascades requires confidence intervals for products of three or four means, and potentially more. It is desirable to find an alternative procedure, with a more automated framework, to calculate the estimates in the cascade and confidence intervals.

The procedure in this report can be described as the "stacking" of constructed variables and the use of a Stata command *nlcom*. In Stata, *nlcom* is a post-estimation command that provides the values, standard errors, and confidence intervals for nonlinear combinations of coefficients. The method Stata uses to estimate the standard errors is a very general, automated application of the delta method. A 95% confidence interval is calculated by adding +/-1.96 * the standard error to the point estimate.

In the final step, the confidence interval estimates are shifted slightly to account for the need to be entirely between 0 and 1. This is done by treating the effective coverage estimate as if it were a probability whose logit has a normal sampling distribution. This calculation is done on the logit scale to maintain the confidence intervals within the bounds of a proportion and transformed to the original scale. As with quantities like odds ratios, confidence intervals may be asymmetrical as a result.

We have confirmed that the calculations of effective coverage that arise from the stacked constructed variables and *nlcom* agree exactly with the simpler strategy of calculating means in the two (DHS and SPA) datasets and multiplying them together. Further details on the statistical approach to calculating the confidence intervals can be found in Appendix 5.

2.5 Anticipated Differences in Effective Coverage Measurement Approaches

Based solely on the characteristics of the data sources used for the effective coverage components, we can anticipate differences in the ultimate effective coverage estimates.

Anticipated differences in effective coverage measurement approaches

- Approach 1 quality-adjusted coverage estimates will be higher than Approaches 2 or 3 for ANC.
- Approach 1 intervention-adjusted coverage estimates will be the same or lower than Approaches 2 or 3 for sick child care.
- Approach 3 input-adjusted coverage and quality-adjusted coverage estimates will be the same or lower than Approach 2 for both ANC and sick child care.
- Sick child care quality-adjusted coverage will be lower than ANC quality adjusted coverage.

2.5.1 DHS-only approach compared with both DHS and SPA approaches

In both services, Approach 1 differs from Approaches 2 and 3 on the source of content of care information. Approach 1 uses only self-reported data, while Approaches 2 and 3 incorporate data from direct observations.

For ANC, we anticipate that compared to Approaches 2 and 3, Approach 1 estimates of quality-adjusted effective coverage will be higher for ANC. Agreement between direct observation quality of care measures and self-reported quality of care measures differ depending on the recall period, as well as the type of care provided. Prior research has shown that while self-reported quality of care data for ANC upon client exit from ANC is generally accurate (McCarthy et al. 2020), self-reported quality of care data for ANC received within the last 5 years, as it is asked in the DHS, may result in overestimates of quality, especially for components of routine ANC (Blanc et al. 2016; Liu et al. 2013). In addition, the ANC quality of care questions that women answer in the DHS ask if the routine components of ANC were done at least once. Therefore, a woman who attends more than one ANC visit has a greater chance of actually receiving any component of ANC. In contrast, since direct observation is for one visit, there is only one opportunity for the provider to demonstrate that they are providing each component of high-quality care.

For sick child, we anticipate that estimates of intervention-adjusted effective coverage will be the same or lower for sick child care. Sick child intervention coverage in Approach 1 differs in two ways. First, it is based on maternal report of treatment of symptoms, which means that both maternal recall and the denominator, based on symptoms and not diagnosis, may be subject to error. However, there is no evidence of systematic error in maternal recall of pneumonia treatment for sick children in the last 2 weeks (Hazir et al. 2013). The denominator will be inflated due to the measurement approach and will therefore likely result in a lower proportion of complete intervention coverage compared to Approaches 2 and 3. Second, there is no quality of care measure for sick child care in Approach 1. While the differences in the intervention coverage measure may lead to underestimates, with no readiness or quality of care measure in Approach 1, the value of intervention-adjusted coverage may not ultimately be lower than the final quality-adjusted estimate in the other two approaches.

2.5.2 Basic SPA measures compared with expanded SPA measures

The basic SPA measures used in Approach 2 are limited to the essential items and actions necessary for ANC or sick child care, while Approach 3 includes a longer list of essential and recommended items. Therefore, results from Approaches 2 and 3 will differ based on the similarities or differences in estimates of the basic vs. expanded measures of readiness and process quality. Previous research has shown that readiness and quality of care in ANC and sick child care is poor (Kruk et al. 2017; Lama et al. 2019; Lee, Madhavan, and Bauhoff 2016; Leslie et al. 2017). However, ANC quality measures of different lengths were found to have good agreement in three of our five countries (Sheffel et al. 2019). Taken together, this context leads us to expect that measuring more aspects of ANC and sick child care will result in similar or lower estimates of input-adjusted and quality-adjusted coverage.

2.5.3 Antenatal care compared with sick child care

As described in earlier sections, the first step in the effective coverage cascade is the proportion of the population in need who visit a health service. From previous research, we know that the proportion of pregnant women who attend at least one ANC visit is much higher than the proportion of children under age 5 who had symptoms of ARI or diarrhea in the last 2 weeks who visited a health facility (Bradley, Rosapep, and Shiras 2020; Leslie et al. 2017). Therefore, at this first step, sick child care effective coverage will likely already be much lower than ANC effective coverage. Given the way the effective coverage cascade is calculated, each subsequent step will further separate the ANC and sick child effective coverage estimates, unless readiness, intervention coverage, or process quality of care is markedly higher in sick child care than in ANC.

3 RESULTS

The results below summarize the effective coverage cascades with each approach and for each level of coverage. This is organized by country, and for ANC and sick child care.

Table 6 shows the estimates for each measure used in the cascade calculations, for ANC and sick child care, by country. These are the estimates used to calculate the cascade values, as described in Tables 4 and 5 in the previous section.

Table 6 Values of each component of each effective coverage measurement approach

	Coverage	Readiness	Receipt of complete intervention	Process quality
Haiti				
ANC				
Approach 1	0.91 [0.90, 0.93]	NA	0.67 [0.64, 0.69]	0.84 [0.83, 0.85]
Approach 2	0.91 [0.90, 0.93]	0.70 [0.70, 0.70]	0.67 [0.64, 0.69]	0.59 [0.57, 0.60]
Approach 3	0.91 [0.90, 0.93]	0.58 [0.58, 0.58]	0.67 [0.64, 0.69]	0.55 [0.53, 0.56]
Sick child				
Approach 1	0.26 [0.23, 0.29]	NA	0.20 [0.17, 0.23]	NA
Approach 2	0.26 [0.23, 0.29]	0.73 [0.73, 0.73]	0.45 [0.40, 0.50]	0.46 [0.43, 0.49]
Approach 3	0.26 [0.23, 0.29]	0.59 [0.59, 0.59]	0.45 [0.40, 0.50]	0.37 [0.36, 0.39]
Malawi				
ANC				
Approach 1	0.98 [0.98, 0.99]	NA	0.51 [0.49, 0.52]	0.70 [0.69, 0.71]
Approach 2	0.98 [0.98, 0.99]	0.50 [0.50, 0.50]	0.51 [0.49, 0.52]	0.49 [0.47, 0.51]
Approach 3	0.98 [0.98, 0.99]	0.62 [0.62, 0.62]	0.51 [0.49, 0.52]	0.57 [0.55, 0.58]
Sick child				
Approach 1	0.53 [0.50, 0.55]	NA	0.42 [0.40, 0.44]	NA
Approach 2	0.53 [0.50, 0.55]	0.85 [0.85, 0.85]	0.92 [0.89, 0.94]	0.29 [0.27, 0.32]
Approach 3	0.53 [0.50, 0.55]	0.64 [0.64, 0.64]	0.92 [0.89, 0.94]	0.33 [0.31, 0.35]
Nepal				
ANC				
Approach 1	0.94 [0.93, 0.95]	NA	0.69 [0.67, 0.72]	0.83 [0.81, 0.84]
Approach 2	0.94 [0.93, 0.95]	0.61 [0.58, 0.63]	0.69 [0.67, 0.72]	0.51 [0.48, 0.54]
Approach 3	0.94 [0.93, 0.95]	0.53 [0.52, 0.54]	0.69 [0.67, 0.72]	0.51 [0.49, 0.53]
Sick child				
Approach 1	0.47 [0.40, 0.55]	NA	0.25 [0.20, 0.31]	NA
Approach 2	0.47 [0.40, 0.55]	0.61 [0.59, 0.63]	0.78 [0.72, 0.82]	0.35 [0.30, 0.40]
Approach 3	0.47 [0.40, 0.55]	0.58 [0.57, 0.59]	0.78 [0.72, 0.82]	0.35 [0.32, 0.37]

(Continued…)

Table 6—*Continued*

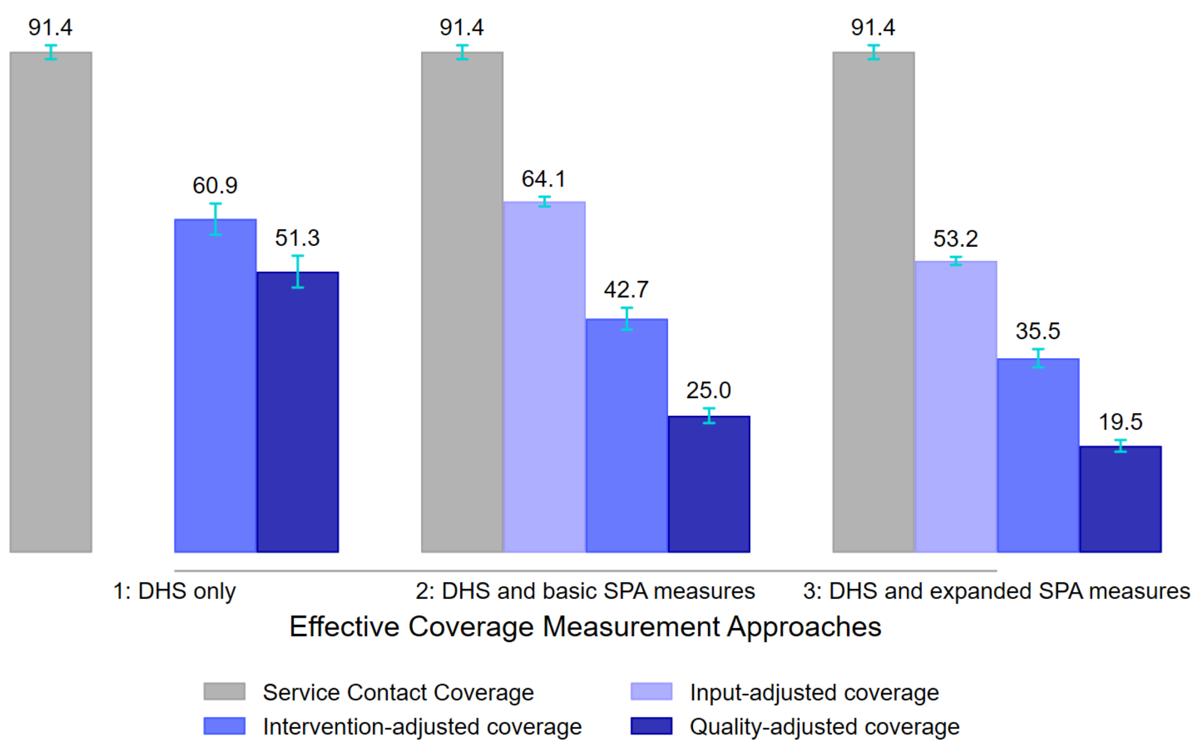
	Coverage	Readiness	Receipt of complete intervention	Process quality
Senegal				
ANC				
Approach 1	0.98 [0.97, 0.98]	NA	0.59 [0.56, 0.61]	0.85 [0.84, 0.85]
Approach 2	0.98 [0.97, 0.98]	0.88 [0.84, 0.91]	0.59 [0.56, 0.61]	0.64 [0.61, 0.67]
Approach 3	0.98 [0.97, 0.98]	0.77 [0.75, 0.78]	0.59 [0.56, 0.61]	0.68 [0.65, 0.70]
Sick child				
Approach 1	0.36 [0.32, 0.41]	NA	0.29 [0.26, 0.33]	NA
Approach 2	0.36 [0.32, 0.41]	0.76 [0.65, 0.84]	0.84 [0.67, 0.93]	0.59 [0.55, 0.64]
Approach 3	0.36 [0.32, 0.41]	0.76 [0.74, 0.77]	0.84 [0.67, 0.93]	0.37 [0.35, 0.39]
Tanzania				
ANC				
Approach 1	0.98 [0.97, 0.98]	NA	0.51 [0.49, 0.53]	0.66 [0.65, 0.68]
Approach 2	0.98 [0.97, 0.98]	0.55 [0.53, 0.58]	0.51 [0.49, 0.53]	0.56 [0.53, 0.58]
Approach 3	0.98 [0.97, 0.98]	0.59 [0.58, 0.60]	0.51 [0.49, 0.53]	0.61 [0.60, 0.62]
Sick child				
Approach 1	0.68 [0.65, 0.72]	NA	0.45 [0.42, 0.49]	NA
Approach 2	0.68 [0.65, 0.72]	0.77 [0.75, 0.80]	0.77 [0.74, 0.80]	0.31 [0.29, 0.34]
Approach 3	0.68 [0.65, 0.72]	0.60 [0.59, 0.61]	0.77 [0.74, 0.80]	0.36 [0.34, 0.38]

3.1 Haiti

3.1.1 ANC

Figure 2 summarizes the estimates of the ANC effective coverage cascade in Haiti for each measurement approach. Service-contact coverage is high: 91% of women with her last pregnancy in the last 5 years attended at least one ANC visit. Large drop-offs are seen when the readiness of facilities to provide ANC is considered. Input-adjusted coverage, only possible in Approaches 2 and 3, ranges from 64% with a basic readiness measure in Approach 2 to 53% when using an expanded readiness measure in Approach 3. When adjusted for attendance of 4+ ANC visits, there are additional drop-offs, although the level of intervention-adjusted coverage varies with the different measurement approaches. Intervention-adjusted effective coverage is highest (61%) in Approach 1 and lower in Approaches 2 (43%) and 3 (36%). The final step in this effective coverage cascade considers the process quality of care provided when women attend ANC. Quality-adjusted effective coverage ranges from 51% when using a woman's recall of the quality of her most recent ANC in Approach 1, to 20% in Approach 3 when expanded quality measures are collected by using client-provider observation of ANC visits.

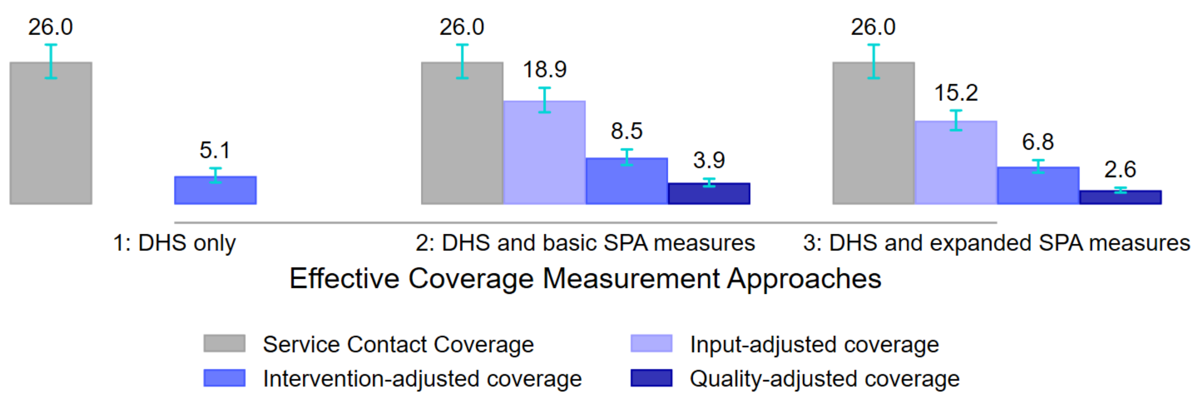
Figure 2 ANC effective coverage cascade in Haiti for each measurement approach



3.1.2 Sick child

Figure 3 summarizes the estimates of the sick child effective coverage cascade in Haiti for each measurement approach. Across all approaches, service-contact coverage, the proportion of children with diarrhea or ARI symptoms in the last 2 weeks who sought care at a health facility is low (26%). Drop-offs are seen when the readiness of facilities to provide sick child care is considered. Input-adjusted coverage ranges from 19% when using a basic readiness measure in Approach 2 to 15% when using an expanded readiness measure in Approach 3. When adjusted for receipt of oral rehydration solution (ORS) for diarrhea or antibiotics for ARI, there are additional drop-offs. The level of intervention-adjusted coverage varies between the different measurement approaches. Intervention-adjusted effective coverage is highest in Approaches 2 (9%) and 3 (7%), and lowest (5%) in Approach 1. The final step in this effective coverage cascade considers the process quality of care for sick children when seen at health facilities. Quality-adjusted effective coverage ranges from 4% in Approach 2 with a basic process quality measure, to 3% in Approach 3 when expanded process quality measures are collected with client-provider observation of sick child visits.

Figure 3 Sick child effective coverage cascade (among children with ARI/diarrhea symptoms in last 2 weeks) in Haiti for each measurement approach

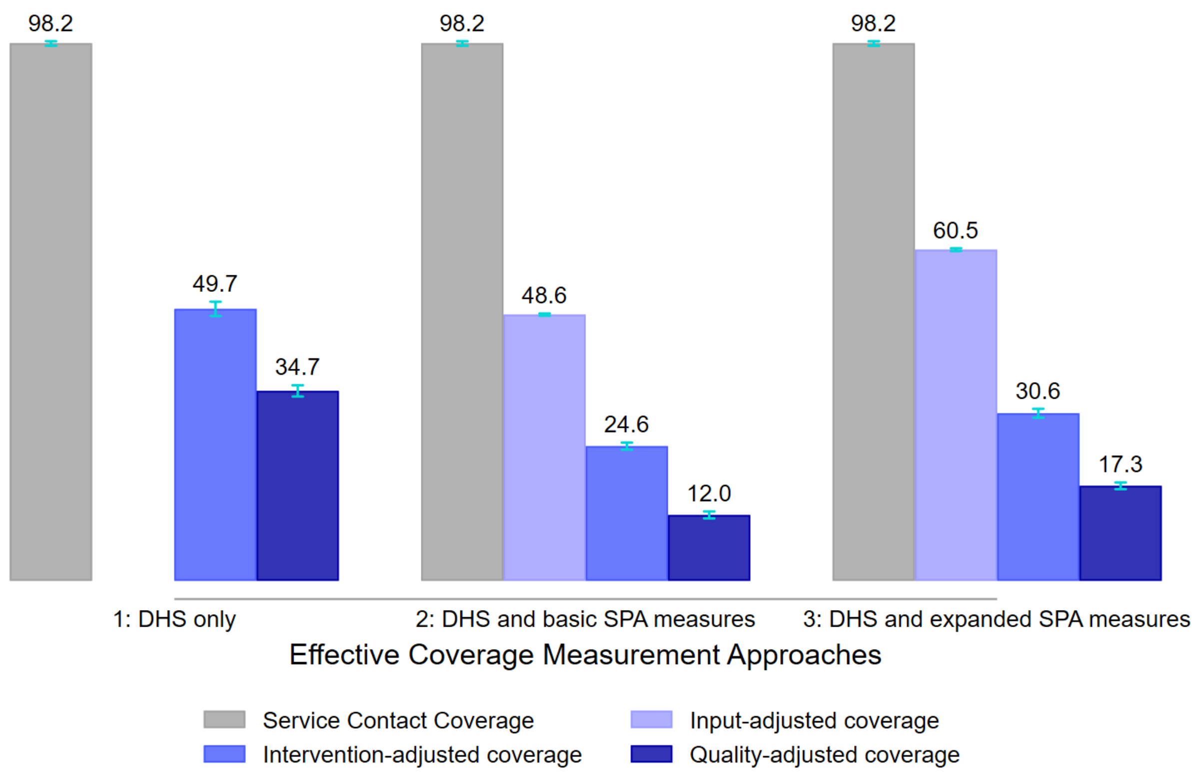


3.2 Malawi

3.2.1 ANC

Figure 4 summarizes the ANC effective coverage cascade in Malawi. We see almost universal service contact coverage in every approach with 98% of women in Malawi with a birth in the last 5 years who have had at least one ANC visit. However, this drops to less than 50% when we consider the facility readiness to provide ANC services. Input-adjusted coverage was estimated to be 49% with the basic readiness measure in Approach 2 and 61% with the expanded readiness measure in Approach 3. After accounting for attendance of 4+ ANC visits for the intervention-adjusted coverage estimates, we see further drop-offs for Approaches 2 and 3 to 25% and 31%, respectively. In Approach 1, which uses only DHS data, intervention-adjusted coverage of 4+ ANC visits was 50%. For the final step in the cascade, we consider the quality of care either reported by women in the DHS survey or observed in the SPA survey for a quality-adjusted effective coverage measure. Just over one-third (35%) of women received the recommended ANC service based on women's recall in Approach 1. However, when we use the observations of ANC quality in SPA data, this was only 12% based on basic quality of care measures and 17% for the expanded quality of care measures.

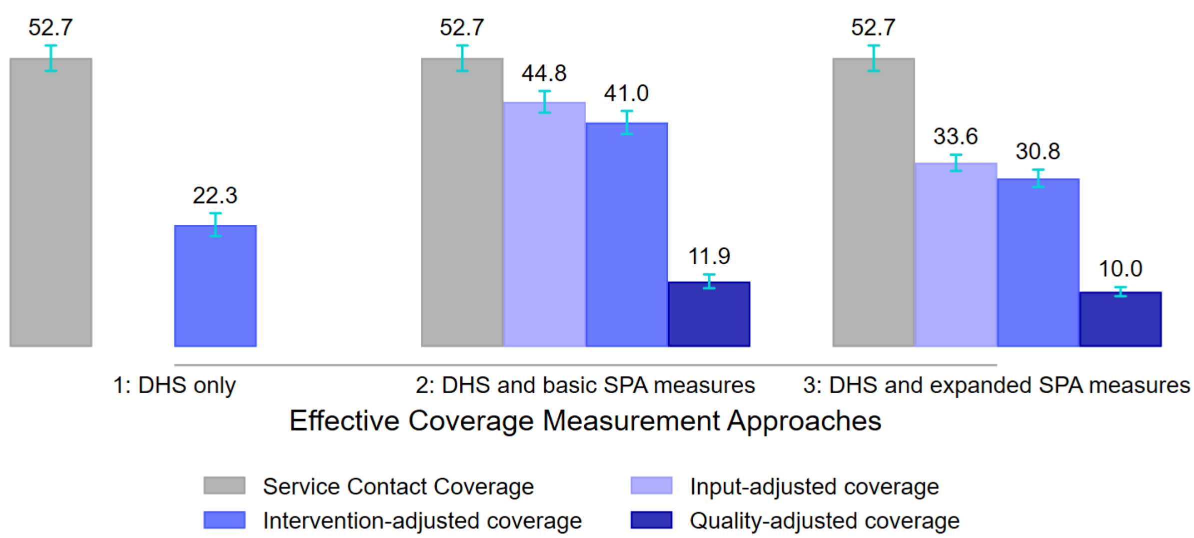
Figure 4 ANC effective coverage cascade in Malawi for each measurement approach



3.2.2 Sick child

Figure 5 summarizes the sick child effective coverage cascade estimates for Malawi. Over half (53%) of children with diarrhea or ARI symptoms in the last 2 weeks sought care at a health facility. This decreases to 45% when we account for sick children attending a facility with basic sick child readiness and 33% with the expanded readiness measure. Approximately 22% of sick children received ORS for diarrhea or antibiotics for ARI symptoms as shown in the intervention-adjusted coverage for Approach 1. However, when we account for facility readiness as well as intervention coverage and use an SPA measure of complete intervention coverage, intervention-adjusted coverage drops to 41% when a basic readiness measure is used (Approach 2) and 31% when an expanded readiness measure is used (Approach 3). In the final step of the cascade, which adjusts for quality of sick child services, there is a large drop-off, with a 12% level of quality-adjusted coverage when using a basic measure of process quality of care and 10% with the expanded measure.

Figure 5 Sick child effective coverage cascade (among children with ARI/diarrhea symptoms in last 2 weeks) in Malawi for each measurement approach

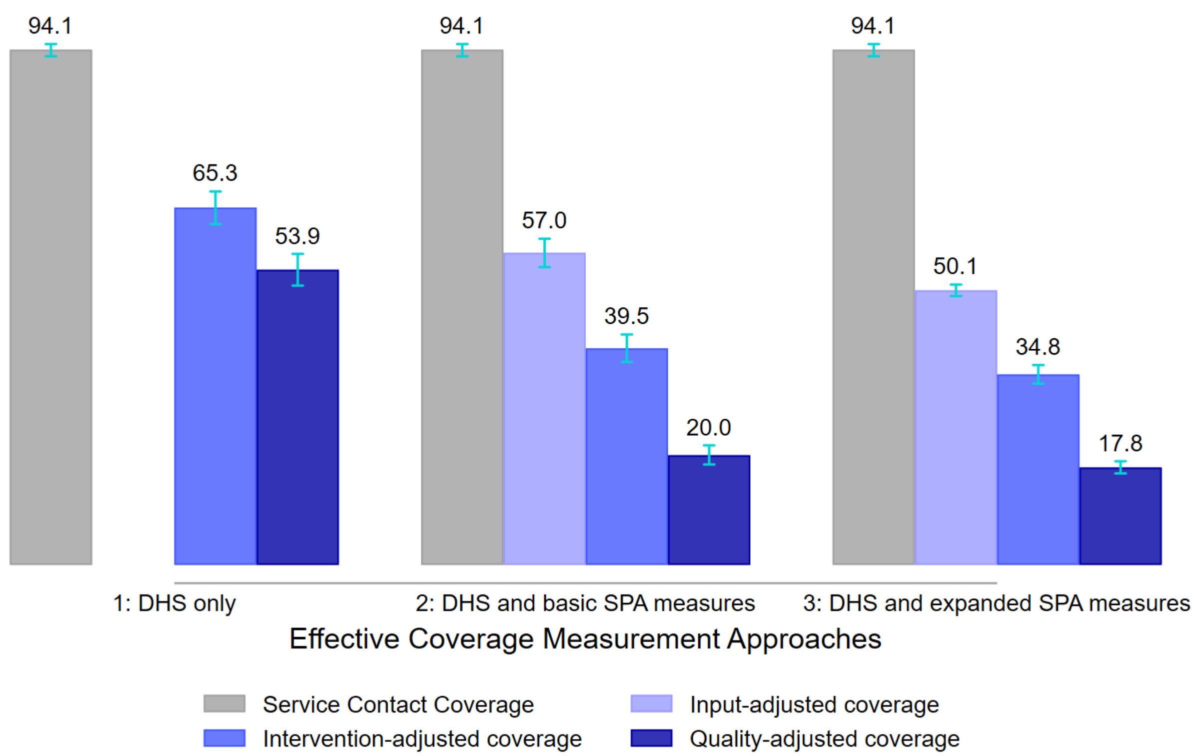


3.3 Nepal

3.3.1 ANC

Figure 6 shows the ANC effective coverage cascade for Nepal. Approximately 94% of women had at least one ANC visit with a skilled provider in Nepal. However, this decreases to 57% when we account for women attending a facility with basic readiness components and 50% with an expanded readiness measure. Approximately 65% of women in Nepal who attended at least one ANC visit with a skilled provider had 4+ ANC visits, as shown in the intervention-adjusted coverage in Approach 1. This drops to 40% when we account for attending 4+ ANC visits in a facility with basic readiness and 35% for a facility with the expanded measure of readiness. When we examine quality of care, 54% of women reported receiving the required quality of care during their most recent ANC visit. However, based on the observational data, this is only 20% for the basic quality of care measure and 18% for the expanded measure.

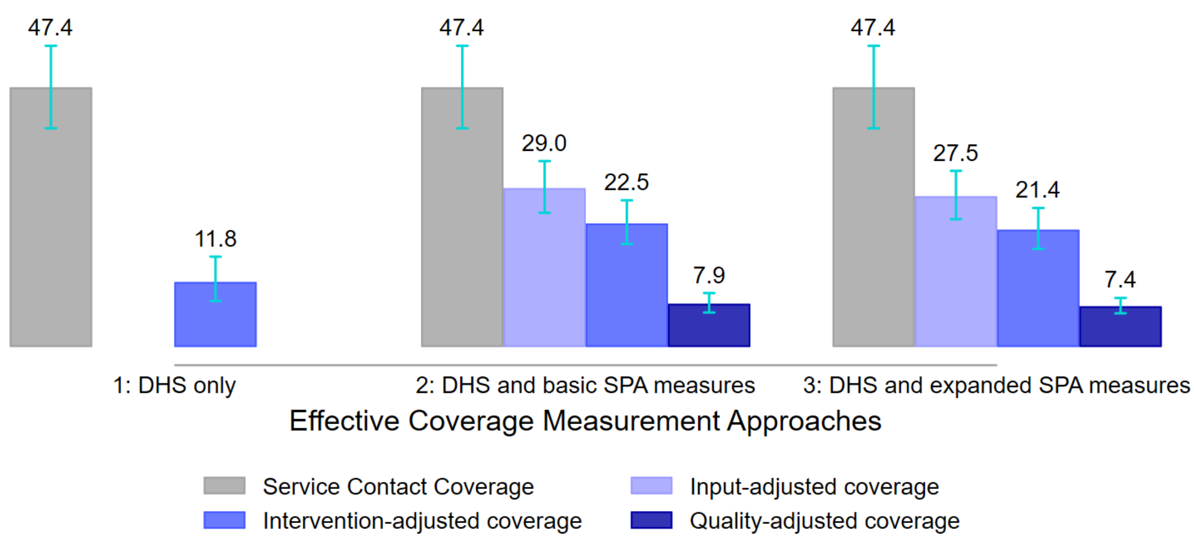
Figure 6 ANC effective coverage cascade in Nepal for each measurement approach



3.3.2 Sick child

Figure 7 summarizes the sick child effective coverage cascade in Nepal. Nearly half (47%) of children with diarrhea or ARI symptoms in the last 2 weeks sought care at a health facility. However, this drops to lower than 30% when we consider the facility readiness to provide sick child services. This input-adjusted coverage was estimated to be 29% with the basic readiness measure in Approach 2 and 28% with the expanded readiness measure in Approach 3. After accounting for receipt of ORS for diarrhea or antibiotics for ARI in the intervention-adjusted coverage estimates, we see further drop-offs for Approaches 2 and 3 to 23% and 21%, respectively. In Approach 1, which uses only DHS data, the intervention-adjusted coverage measure was 12%. For the final step in the cascade, we consider the quality of care observed in the SPA survey for a quality-adjusted effective coverage measure. Adjusting for these process quality measures, this was 8% with the basic and 7% with the expanded quality of care measures. Nepal had no difference in process quality when comparing Approach 2 and 3, in either ANC or sick child care (See Table 6.).

Figure 7 Sick child effective coverage cascade (among children with ARI/diarrhea symptoms) in Nepal for each measurement approach

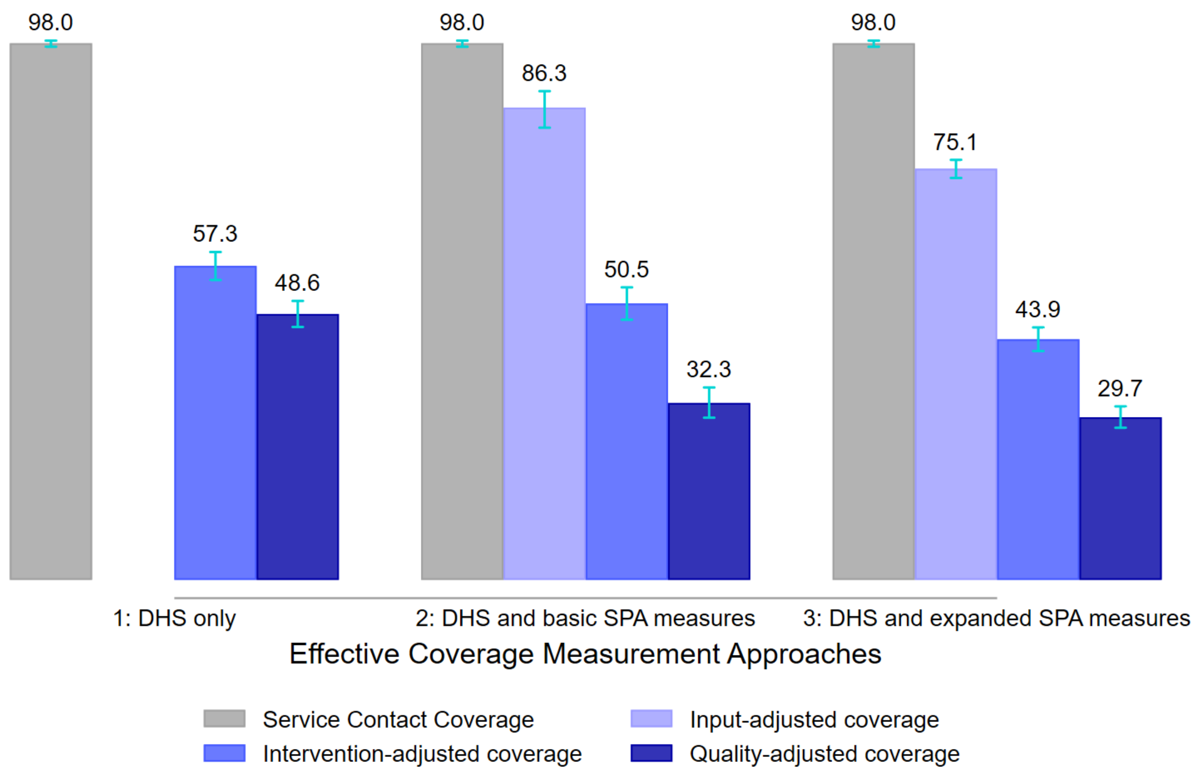


3.4 Senegal

3.4.1 ANC

Figure 8 summarizes the ANC effective coverage cascade estimates for Senegal. Almost all women (98%) with a birth in the last 5 years have had at least one ANC visit across all approaches according to the service contact coverage measure. This decreases to 86% when we account for women attending a facility with basic ANC readiness and 75% with the expanded readiness measure. Approximately 57% of women had 4+ ANC visits as shown in the intervention-adjusted coverage for Approach 1. However, when we account for SPA data, this drops to 51% for women who had these visits in a facility with basic readiness and 44% for facilities with expanded readiness. In the final step of the cascade, which adjusts for quality of ANC services, we observe that almost half (49%) of women reported receiving the required ANC services for their most recent visit. When we use observational data, this drops to 32% for basic quality of care and 30% for the expanded quality of care list.

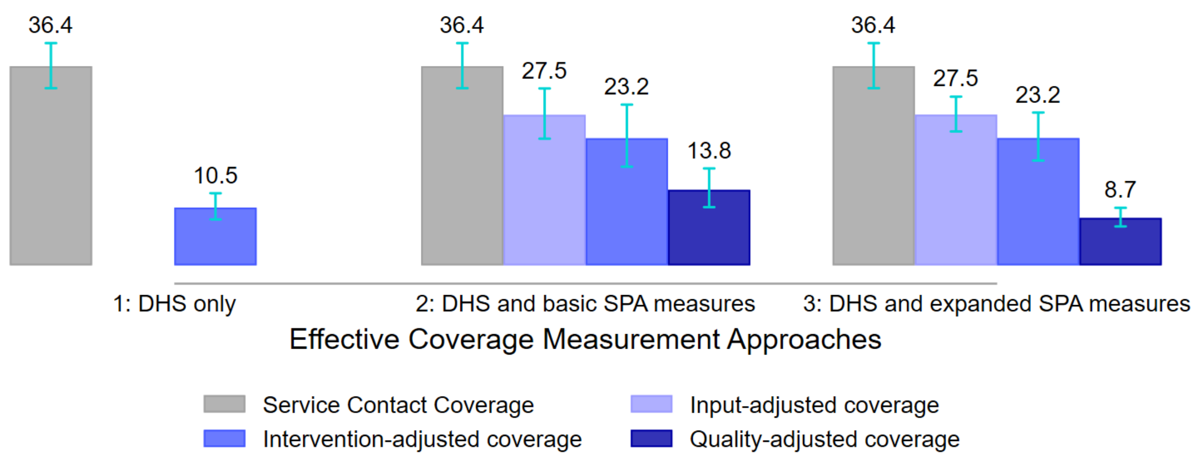
Figure 8 ANC effective coverage cascade in Senegal for each measurement approach



3.4.1 Sick child

Figure 9 shows the sick child effective coverage cascade for Senegal. Just over one-third (36%) of children with diarrhea or ARI symptoms in the last 2 weeks sought care at a health facility. However, this decreases to 28% when we consider whether children visited a facility with basic readiness components or when we use an expanded readiness measure. When reported by mothers of sick children, 11% of sick children received ORS for diarrhea or antibiotics for ARI, as shown in the intervention-adjusted coverage in Approach 1. This increases to 23% if we account for children having been diagnosed with diarrhea or pneumonia and receiving ORS or antibiotics at a facility with basic readiness or an expanded measure of readiness. When we examine process quality of care with observational data, we find that quality-adjusted coverage is 14% when a basic quality of care measure is used and 9% with the expanded measure. Compared to other countries, Senegal had the largest difference (22%) in sick child process quality when comparing Approaches 2 and 3 (see Table 6).

Figure 9 Sick child effective coverage cascade (among children with ARI/diarrhea symptoms) in Senegal for each measurement approach

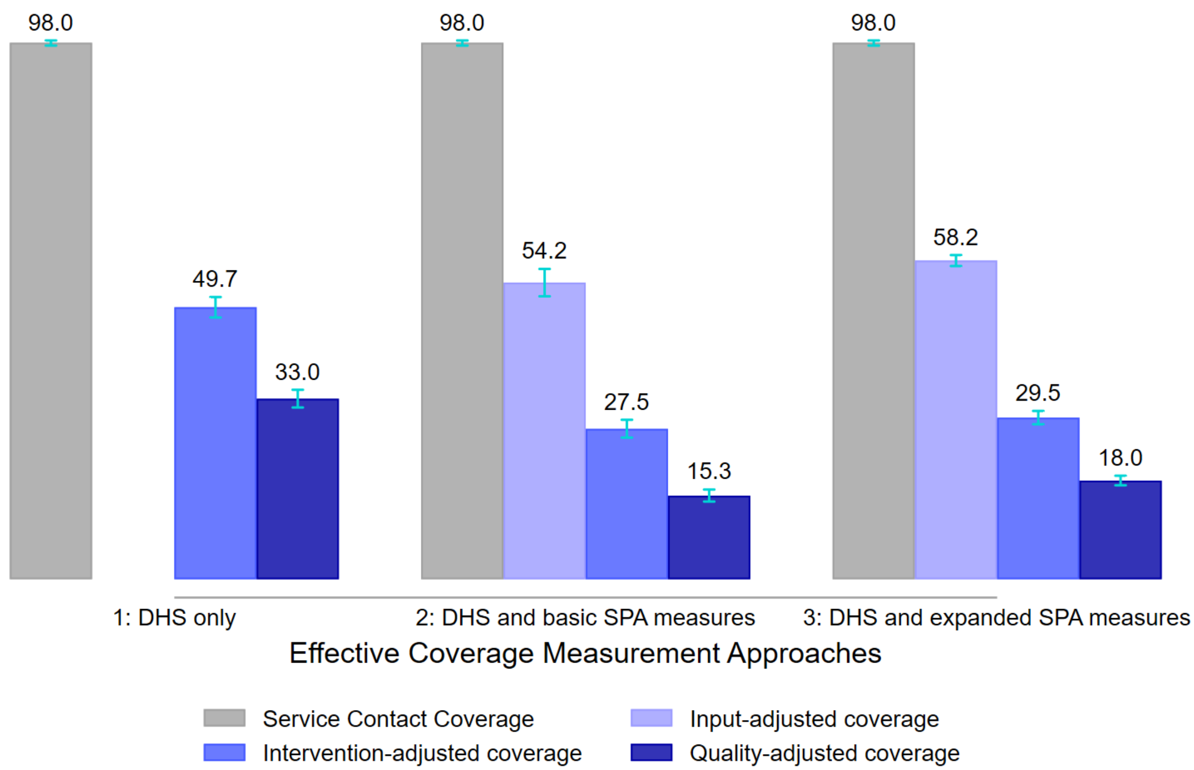


3.5 Tanzania

3.5.1 ANC

Figure 10 shows the ANC effective coverage cascade for Tanzania. Almost all women in Tanzania (98%) with a birth in the last 5 years had at least one ANC visit with a skilled provider. However, this decreases to 54% when we consider if women attended a facility with basic readiness components and 58% if visiting a facility with the expanded readiness components. Almost half of women in Tanzania who attended at least one ANC visit with a skilled provider had 4+ ANC visits (50%). This drops to 28% with facilities having basic readiness and 30% with facilities that have expanded readiness to provide ANC. When we add in quality of care, there is a 33% level of quality-adjusted coverage based on women's self-reported quality of care during their most recent ANC visit. However, when we use observational data, quality-adjusted coverage is only 15% for the basic quality of care measure and 18% for the expanded measure.

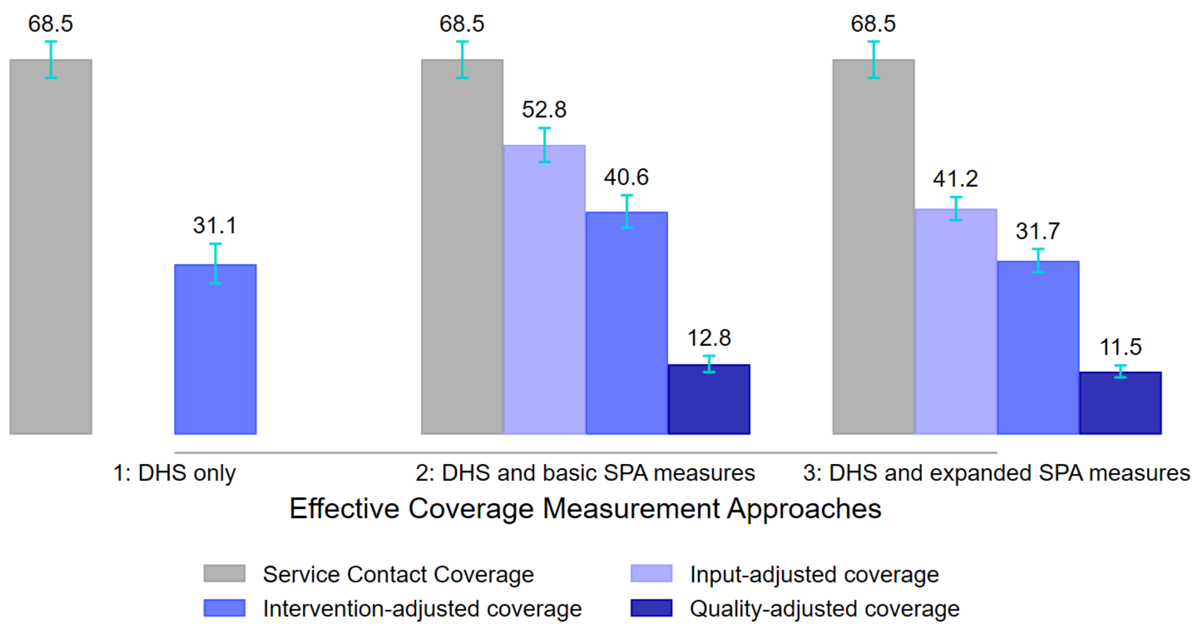
Figure 10 ANC effective coverage cascade in Tanzania for each measurement approach



3.5.2 Sick child

Figure 11 summarizes the estimates of the sick child effective coverage cascade in Tanzania for each measurement approach. Across all approaches, service-contact coverage, the proportion of children with diarrhea or ARI symptoms in the last 2 weeks who sought care at a health facility, is the highest of all five countries (69%). Drop-offs are seen when the readiness of facilities to provide sick child care is considered. Input-adjusted coverage ranges from 53% with a basic readiness measure in Approach 2 to 41% with an expanded readiness measure in Approach 3. When adjusted for receipt of ORS for diarrhea or antibiotics for ARI, there are slight drop-offs. The level of intervention-adjusted coverage varies between the different measurement approaches. Intervention-adjusted effective coverage is highest (31%) when reported by mothers in Approach 1 and lower when reported with client-provider observation in Approaches 2 (41%) and 3 (32%). When adjusted for process quality of care for sick children seen at health facilities, effective coverage ranges from 13% in Approach 2 with a basic process quality measure, to 12% in Approach 3 with expanded process quality measures.

Figure 11 Sick child effective coverage cascade (among children with ARI/diarrhea symptoms) in Tanzania for each measurement approach



4 DISCUSSION AND CONCLUSION

The concept of effective coverage is being applied more broadly to better understand weaknesses in programs and to provide more specific and actionable measures of coverage. However, the interpretation of the effective coverage measure may differ depending on how countries and programs define the measures in the calculations of effective coverage. The goal of this report has been to provide a comparison of different approaches to measuring the components of the effective coverage cascade and their effects on the ultimate values of effective coverage for antenatal and sick child care.

The results show that coverage of ANC was almost universal, with over 90% of women in all countries having at least one ANC visit in a facility. Coverage of sick child care seeking for diarrhea or ARI was much lower with ranges from 25–70% in the countries in the analysis. However, for women and children to receive sufficient and quality care, it is not sufficient to have contact with the service environment. The service women and children receive should include the necessary components of quality care. When we account for these factors, including service readiness, receipt of the required interventions, and process quality for a complete effective coverage measure, we see large decreases in the quality of care that are below 33% for ANC and below 13% for sick child care in all countries. This measure reached a low of 12% for ANC in Malawi and 3% for sick child care in Haiti. This implies that few women and children are receiving the high-quality services they need.

When we compare the approaches, we find our hypothesis that Approach 1 quality-adjusted coverage estimates would be higher than Approaches 2 and 3 for ANC services was shown in the data. The estimates of effective coverage using DHS data alone in Approach 1 have consistently provided larger estimates compared to using both DHS and SPA data. This shows that using DHS data alone, which rely on the women's recall of her ANC visits, will not provide the full picture of quality. In contrast, direct observation, as used in the SPA, may result in an overestimate of quality due to provider tendency to over-perform while observed (Hawthorne effect) (Leonard and Masatu 2006). However, given the large number of observations and repeated observations of each provider, the effect of this bias is likely to be minimal.

The hypothesis that Approach 1 intervention-adjusted coverage estimates would be the same or lower than Approaches 2 or 3 for sick child care was also confirmed. For sick child care, intervention-adjusted coverage was lower in all countries when using DHS data alone in Approach 1, compared to using DHS and SPA data in Approaches 2 and 3. This difference is likely due to the difference in the receipt of complete intervention measure, which identifies the children with diarrhea or ARI in the last 2 weeks who received appropriate treatment. Using the DHS data, the actual diagnosis of the child is unknown, and any children with symptoms of diarrhea or ARI are included in the denominator. In addition, previous research has shown that approximately two-thirds of mothers correctly recall antibiotic treatment with a 2-week recall period (Hazir et al. 2013). As previous research has found, this inflation of the treatment rate denominator makes the treatment rate appear lower than it actually is (Campbell et al. 2013; Fischer Walker, Fontaine, and Black 2013). In the SPA, data collectors observe whether children brought in with symptoms of diarrhea or ARI were in fact diagnosed with these illnesses, and only those eligible for ORS for the prevention and treatment of dehydration and those diagnosed with pneumonia are included in the denominator. Sensitivity of providers to ARI has been shown to be low in some contexts (Salisbury et al. 2021; Uwemedimo et al. 2018).

We hypothesized that the expanded measures of readiness and process quality used in Approach 3 would result in lower estimates of effective coverage when compared with the basic measures used in Approach 2. However, we found inconsistent results. In some cases, specifically for ANC in Malawi and Tanzania, Approach 3 resulted in higher estimates. Overall, the results have shown that using a basic measure of readiness or process compared to a more expanded measure of readiness or process produced similar estimates (see Table 6.). The average difference in readiness between Approach 2 and Approach 3 was similar for ANC (0.09) and sick child (0.11), while the average difference in process quality in ANC (0.04) was half of the comparable in sick child care (0.08). The average difference in quality-adjusted coverage was greater in ANC (4.6%) compared to sick child care (2.0%). The maximum difference in Approaches 2 and 3 ANC effective coverage was 5.5% and sick child care effective coverage was 5.1%. The smaller average and maximum differences in sick child care may be due to the service contact coverage already being low, which would limit the degree of change. If these methods are applied in settings or clinical areas with higher adjusted coverage to this point, the difference will be larger up to the maximum of the actual difference in the quality measures. This finding is promising, since it shows that collecting facility data with effective coverage calculations can potentially be very simple. For ANC, for example, the basic measures only require three items for either readiness or process compared to 33 items for readiness and 18 items for process. However, this does not imply that all the components listed in the expanded list are not required in the facility. These are, in fact, essential components in quality ANC and sick child services. The results here show that the basic measure can serve as a proxy for the expanded list when measuring effective coverage.

In the two cases where quality-adjusted coverage was higher in Approach 3 compared to Approach 2 – ANC in Malawi and Tanzania – these increases appear to be driven primarily by increases in the readiness measure from the basic to expanded approach, where all other countries saw decreases. This is illustrated by the larger difference between Approach 2 and 3 quality-adjusted coverage in Malawi, which saw a 0.12 increase in readiness between Approach 2 and 3, compared to Tanzania, which saw a 0.04 increase in readiness between Approach 2 and 3. Both countries had similar increases (0.08 for Malawi and 0.05 for Tanzania) in process quality between Approach 2 and 3.

The last hypothesis posited that sick child care quality-adjusted coverage will be lower than ANC quality-adjusted coverage, primarily due to the lower service-contact coverage. While this was generally the case, there were examples where quality-adjusted coverage in ANC and sick child care were separated by only a few tenths of a percent (Malawi) or a few percentage points (Tanzania). In Table 6, in these cases, sick child care had much higher readiness and intervention completion when compared to ANC in those cases, which allowed the effective coverage measures to become closer together.

This work has several limitations. There is a lack of universal quality of care measures for both ANC and sick child care. We addressed the different implications of this limitation in different ways. First, our selection of items for the readiness and process quality measures was based on global standards and previous research on quality, although some important items may have been excluded. Second, we assigned each item within a measure equal weight, as recommended by previous research on the quality of care measurement (Mallick, Wang, and Temsah 2017). Another approach would be to weigh items according to importance. However, we did not apply weights to different items, since we are using the components of care as a proxy for overall readiness and process quality of care. Finally, we included items related to the experience of care in the expanded quality measure. Recent work has highlighted how essential experience of care is to outcomes and to meeting the client's needs in both ANC and sick child care (Downe et al. 2016;

Larson, Leslie, and Kruk 2017). Unfortunately, the existing SPA tools do not include many important questions about the experience of care. Adding experience of care can be an additional step in the effective coverage cascade. This would be an important addition to this research, after data become available on the experience of care.

For ANC, the DHS data used for the measure of service contact coverage did not include the location of care. We assumed that women who reported receiving ANC from a skilled provider attended ANC at a health facility, although this may not always be the case if women are receiving community-based ANC. In addition, due to this lack of information, we were unable to categorize women's ANC attendance by health facility type. Previous research has shown that adjusting for health facility level and managing authority are recommended (Munos et al. 2018).

For sick child care, the effective coverage cascade only includes sick children who sought care at a health facility. In many settings, it is possible that pharmacies and community health workers are another source of care for common childhood illnesses. Since we do not have readiness or quality of care measures for care provided outside of facilities assessed by the SPA, this effective coverage cascade does not include these sites. Private pharmacies have been shown to be an important source of care for diarrhea and ARI symptoms in some countries (Chakraborty and Sprockett 2018). Although previous research has shown low levels of use of community health workers for sick child care (Geldsetzer et al. 2014; Hodgins, Pullum, and Dougherty 2013), more recent work has shown that exclusion of community health workers from the coverage measure of sick child care may underestimate coverage (Carter et al. 2018).

Linking clients and providers using exact match or ecological linking methods has been recommended when calculating effective coverage (Munos et al. 2018), particularly when effective coverage estimates will be used for programmatic improvement. If, for example, a larger proportion of pregnant women or sick children visit facilities with lower readiness score or a lower level of quality, not accounting for this distribution would lead to an overestimate of effective coverage. This analysis focused on differences in composition of the measures used for effective coverage calculations and, for simplicity, we calculated effective coverage estimates only at the national level without attempting to link women to facilities by region or subnational level. Future work could model how changes in the distribution of care over different types of facilities might influence effective coverage estimates.

Despite these limitations, this study provides valuable insights for stakeholders. As effective coverage gains popularity as a measure of health system performance, it is important that countries and programs understand the implications of the different sources of data that comprise their effective coverage measure. Our findings show that using a combination of household survey and health facility assessment data to calculate quality-adjusted coverage is recommended. Using household survey data alone will generally lead to an overestimate of quality-adjusted coverage for ANC and may lead to an underestimate of intervention-adjusted coverage for sick child care if the intervention measure is based on children with symptoms of rather than children diagnosed with pneumonia or diarrhea.

The findings of this study show that including more items in the composite measures of facility readiness and process quality does not dramatically change the estimates of quality-adjusted coverage. Therefore, countries and programs can consider focusing on a reduced set of tracer items rather than attempting to include all potential items necessary to represent readiness and process quality within the effective coverage calculations.

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APPENDICES

Appendix A **Details on items included in DHS and SPA measures**

Appendix B **Description of Effective Coverage and Confidence Interval (CI) Calculations**

Appendix A Details on items included in DHS and SPA measures

Appendix Table 1 **DHS indicators for ANC and sick child variables**

	Haiti % [95% C.I.]	Malawi % [95% C.I.]	Nepal % [95% C.I.]	Senegal % [95% C.I.]	Tanzania % [95% C.I.]
Approach 1 - ANC process quality					
Had 4+ ANC visits	66.6 [64.2,69.0]	50.6 [49.3,51.9]	69.4 [66.7,71.9]	58.5 [56.0,61.0]	50.7 [48.8,52.5]
ANC by skilled provider	90.6 [89.2,91.9]	94.8 [94.2,95.4]	83.6 [81.5,85.6]	97.7 [97.1,98.2]	86.8 [85.5,87.9]
Took iron	84.5 [82.7,86.2]	90.2 [89.4,91.0]	94.5 [93.2,95.6]	98.2 [97.7,98.6]	82.1 [80.6,83.6]
BP measured	96.5 [95.5,97.4]	83.1 [82.1,84.2]	91.3 [89.9,92.5]	99.3 [98.9,99.6]	70.8 [68.8,72.7]
Urine sample take	86.3 [84.2,88.2]	32.3 [30.9,33.8]	76.1 [73.8,78.3]	93.9 [92.7,94.9]	60.0 [57.6,62.4]
2+ tetanus toxoid injections	64.9 [62.7,66.9]	73.0 [71.9,74.1]	65.7 [63.5,67.9]	46.4 [44.0,48.9]	51.8 [49.9,53.7]
Approach 1 - sick child complete intervention coverage					
Had symptoms of ARI	10.0 [8.9,11.3]	5.4 [4.9,5.9]	2.4 [2.0,3.0]	5.0 [4.2,6.0]	3.7 [3.2,4.3]
Sought care at facility and received an antibiotic among those with symptoms of ARI	28.9 [24.0,34.4]	41.8 [37.3,46.4]	40.7 [30.4,51.9]	32.0 [25.8,38.9]	61.1 [55.1,66.8]
Had diarrhea	21.2 [19.7,22.8]	21.7 [20.7,22.6]	7.6 [6.4,9.0]	17.1 [15.4,19.0]	11.8 [10.9,12.8]
Sought care at facility and received ORS or zinc among those with diarrhea	88.4 [87.4,89.4]	93.6 [93.0,94.1]	95.9 [94.9,96.7]	90.2 [89.0,91.4]	94.3 [93.7,94.9]

Appendix Table 2 **Items included in Approach 3 - composite readiness and quality of care measures. Items also included in Approach 2 indicated with (*).**

	Sick child care	Antenatal care
	(31 items)	**(33 items)**
Facility readiness	Medication availability: zinc/oral rehydration salts (ORS) for diarrhea*	Power (electricity or generator) *
	Medication availability: antibiotics for pneumonia (amoxicillin suspension or dispersible pediatric-dosed tablets) *	Soap and running water or alcohol-based hand rub*
	Power (electricity or generator)	Access to adequate sanitation facilities for clients*
	Improved water source	Improved water source
	Communication equipment	Communication equipment
	Emergency transportation	Emergency transportation
	Access to computer with email/internet access	Access to computer with email/internet access
	Safe final disposal of sharps	Safe final disposal of sharps
	Room with auditory and visual privacy for patient consultations	Disinfectant
	Access to adequate sanitation facilities for clients	Single use—standard disposable or auto-disable syringes
	Safe final disposal of infectious wastes	Latex gloves
	Monthly admin meetings	Room with auditory and visual privacy for patient consultations
	Quality assurance	Safe final disposal of infectious wastes
	System to collect client opinion	Appropriate storage of sharps waste
	Supervision visit in the last 6 months	Appropriate storage of infectious waste
	Health workers always available	Monthly admin meetings
	Equipment: child scale	Quality assurance
	Equipment: infant scale	System to collect client opinion
	Equipment: thermometer	Supervision visit in the last 6 months
	Equipment: stethoscope	Health workers always available
	Equipment: timer/watch or clock	Provide iron supplementation in ANC
	Medication availability: co-trimoxazole	Provide tetanus toxoid vaccination in ANC
	Medication availability: paracetamol	Provide folic acid supplementation in ANC
	Availability of IMCI guidelines	Availability of guidelines on ANC
	Appropriate storage of sharps waste	Blood pressure apparatus
	Appropriate storage of infectious waste	Urine dipstick - protein
	Disinfectant	Urine dipstick - glucose
	Single use—standard disposable or auto-disable syringes	Provide hemoglobin tests
	Soap and running water or alcohol-based hand rub	Fetoscope
	Latex gloves	Syphilis rapid test
	Staff trained in IMCI	Adult scale
		Stethoscope
		Staff trained in ANC

(Continued…)

Appendix Table 2—*Continued*

	Sick child care	Antenatal care
	(32 items)	**(18 items)**
Process quality of care	Provider counted respiration for 60 seconds*	Checked blood pressure*
	Checked skin turgor for dehydration (e.g., pinch abdominal skin) *	Daily oral iron and folic acid supplementation (counseled or prescribed) *
	Provider weighed client*	Hb test
	Provider checked palms / conjunctiva for pallor*	Urine test
	Provider plotted weight on growth chart*	Syphilis test
	Provider discussed weight/growth/growth chart*	Tetanus toxoid vaccination
	Provider asked / caretaker mentioned if child unable to drink or breastfeed	Client history
	Provider asked / caretaker mentioned cough or difficult breathing	Measured weight
	Provider asked / caretaker mentioned diarrhea	Physical examination/ vaginal exam
	Provider asked / caretaker mentioned fever	Checked edema
	Provider asked / caretaker mentioned convulsions	Checked fundal height
	Provider asked caretaker about vomiting	Checked client card
	Provider took temperature	Examined palms for anemia/ check pallor for anemia
	Provider checked for edema	Wrote on client card
	Provider asked / caretaker mentioned ear pain	Danger signs of current pregnancy
	Provide general information about feeding/breastfeeding	Counseling on health eating
	Felt the child for fever or body hotness	Encouraged questions
	Checked for neck stiffness	Informed the client about the progress of the pregnancy
	Looked in child's ear	*Counseled on breastfeeding (only included in Approach 2)*
	Felt behind child's ear	
	Checked vaccination status	
	Check mouth and throat	
	Provider asked about normal feeding/breastfeeding when not ill	
	Provider asked about feeding or breastfeeding during this illness	
	Advised extra fluids during this sickness	
	Advised continued feeding during sickness	
	Provider described more than 1 danger sign requiring return to facility	
	Provider stated diagnosis to caretaker	
	Provider explained dosing if medication prescribed	
	Provider asked caretaker to repeat the instructions for giving medicines at home (if medication prescribed)	
	Provider discussed follow-up visit	
	Provider used visual aids	
	Provider recorded on child's health card/booklet	

Appendix Table 3 Items included in Approach 3 - composite readiness and quality of care measures

	Haiti	Malawi	Nepal	Senegal	Tanzania
General readiness					
Regular electricity	75.1	59.4	48.9 [44.9,52.9]	55.5 [43.8,66.7]	67.0 [62.9,70.8]
Improved water source	76.8	94.2	81.0 [77.2,84.4]	97.5 [95.5,98.6]	68.2 [64.1,71.9]
Visual and auditory privacy	90.8	95.8	78.6 [74.5,82.3]	99.5 [98.2,99.9]	94.0 [91.7,95.6]
Client latrine	61.5	36.6	81.6 [77.7,85.0]	99.7 [99.0,99.9]	44.0 [40.4,47.8]
Communication equipment	64.1	75.5	20.2 [17.8,22.7]	74.9 [65.2,82.6]	50.9 [46.7,55.0]
Computer with internet	51.8	35.4	11.4 [10.3,12.5]	74.1 [64.4,81.8]	12.3 [10.2,14.8]
Emergency transport	27.8	76.5	59.4 [55.0,63.7]	75.2 [62.9,84.4]	57.6 [53.4,61.7]
Disposal of sharps	40.3	60.0	84.3 [80.8,87.3]	97.3 [95.6,98.4]	34.4 [30.6,38.4]
Disposal of medical waste	48.3	62.7	81.0 [77.3,84.3]	61.0 [49.6,71.3]	36.4 [32.5,40.5]
Monthly admin meetings	21.4	31.5	38.2 [34.0,42.6]	29.7 [23.3,37.1]	49.2 [45.0,53.3]
Quality assurance	6.7	13.6	20.5 [17.2,24.1]	32.4 [26.1,39.4]	14.5 [12.1,17.3]
System to collect client opinion	2.3	7.5	2.8 [1.9,4.2]	28.0 [22.4,34.5]	10.3 [8.1,13.0]
Supervision in last 6 months	73.3	80.0	63.1 [58.6,67.3]	52.9 [41.5,64.1]	90.6 [87.7,92.9]
Health workers always available	47.6	74.6	48.1 [44.3,51.8]	77.0 [61.5,87.5]	56.8 [52.6,60.9]
ANC readiness					
Facilities provide ANC	91.5	64.7	96.2 [94.7,97.3]	80.3 [65.0,89.9]	84.6 [81.7,87.1]
Staff trained in ANC	41.9	39.1	18.0 [14.9,21.6]	40.0 [30.2,50.7]	25.3 [21.8,29.1]
Provide iron supplementation in ANC	80.7	97.1	92.2 [89.7,94.2]	85.5 [72.3,93.0]	94.5 [92.4,96.0]
Provide folic acid supplementation in ANC	77.4	94.1	91.6 [88.9,93.7]	85.1 [72.0,92.7]	95.5 [93.6,96.9]
Provide tetanus toxoid vaccination in ANC	51.3	77.2	25.5 [22.2,29.0]	89.5 [74.4,96.1]	86.0 [82.5,89.0]
Availability of guidelines on ANC	32.7	59.2	25.0 [21.2,29.1]	78.7 [73.1,83.4]	55.7 [51.2,60.2]
Blood pressure apparatus	94.5	68.3	86.0 [82.3,89.0]	82.8 [77.9,86.7]	79.0 [75.1,82.5]
Provide hemoglobin tests	55.0	27.8	14.8 [13.3,16.5]	27.2 [17.0,40.6]	29.5 [26.0,33.2]
Urine dipstick - protein	44.2	20.0	15.6 [13.8,17.7]	99.0 [97.6,99.6]	33.2 [29.5,37.1]
Urine dipstick - glucose	46.1	18.0	13.7 [12.4,15.2]	99.0 [97.6,99.6]	28.5 [25.1,32.1]
Fetoscope	68.0	93.1	91.1 [88.2,93.3]	96.1 [92.9,97.9]	98.8 [97.3,99.5]
Adult scale	89.6	88.4	86.6 [83.0,89.5]	96.0 [93.1,97.7]	84.0 [80.2,87.1]
Syphilis rapid test	46.3	28.6	11.2 [10.1,12.4]	71.9 [59.0,82.0]	52.3 [47.9,56.8]
Stethoscope	96.7	74.6	88.9 [85.4,91.6]	70.9 [63.7,77.2]	83.4 [79.8,86.5]
Appropriate storage of sharps waste	79.4	87.4	85.2 [81.8,88.0]	98.6 [96.1,99.5]	96.0 [94.1,97.3]
Appropriate storage of infectious waste	27.1	43.1	6.7 [4.9,9.2]	79.7 [73.5,84.7]	53.5 [49.1,57.9]
Disinfectant	66.7	58.1	66.6 [62.2,70.8]	88.1 [83.7,91.4]	56.3 [51.8,60.7]
Syringes	70.8	81.6	88.7 [85.7,91.1]	42.1 [31.4,53.6]	85.9 [82.7,88.6]
Soap and running water or alcohol-based hand rub	73.9	53.1	51.4 [46.9,55.8]	99.1 [97.2,99.7]	64.6 [60.2,68.7]
Latex gloves	87.5	84.6	84.7 [81.1,87.7]	98.3 [96.2,99.2]	82.2 [78.6,85.4]

(Continued…)

Appendix Table 3—*Continued*

	Haiti	Malawi	Nepal	Senegal	Tanzania
Sick child readiness					
Facility provides sick child curative care	95.1	93.8	97.2 [96.7,97.7]	85.3 [67.7,94.1]	97.6 [96.1,98.6]
Staff trained in IMCI	26.8	26.1	22.1 [18.7,26.0]	53.1 [43.3,62.7]	19.5 [16.6,22.8]
Availability of IMCI guidelines	23.1	37.4	50.2 [45.7,54.7]	68.3 [55.2,79.0]	55.6 [51.4,59.7]
Equipment: child scale	69.6	73.6	45.5 [41.0,50.0]	94.2 [90.5,96.5]	82.6 [79.2,85.6]
Equipment: infant scale	59.0	56.3	63.7 [59.2,67.9]	95.7 [93.1,97.3]	52.2 [48.1,56.3]
Equipment: thermometer	95.6	89.0	95.0 [92.4,96.7]	100.0 [100,100]	85.4 [82.3,88.1]
Equipment: stethoscope	99.0	93.9	98.4 [96.3,99.3]	99.4 [98.1,99.8]	94.0 [91.7,95.7]
Equipment: timer/watch or clock	67.7	91.8	94.2 [91.6,96.0]	95.6 [92.0,97.6]	78.9 [75.1,82.2]
Medication availability: co-trimoxazole	68.5	31.4	49.1 [44.6,53.7]	33.7 [24.8,43.8]	73.1 [69.2,76.7]
Medication availability: antibiotics for pneumonia (amoxicillin suspension or dispersible pediatric-dosed tablets)	68.5	75.7	24.2 [20.6,28.1]	69.1 [58.8,77.9]	65.0 [60.9,68.9]
Medication availability: zinc/oral rehydration salts (ORS) for diarrhea	77.3	94.0	98.3 [97.5,98.8]	82.4 [70.8,90.0]	89.3 [86.5,91.7]
Medication availability: paracetamol	78.9	71.2	85.3 [81.8,88.3]	66.0 [55.8,74.9]	69.2 [65.3,72.9]
Appropriate storage of sharps waste	78.3	87.0	80.8 [77.5,83.7]	98.3 [96.4,99.2]	85.3 [82.1,88.1]
Appropriate storage of infectious waste	26.4	47.2	6.4 [4.6,8.9]	78.5 [72.3,83.6]	56.0 [51.8,60.0]
Disinfectant	68.1	56.7	61.2 [56.8,65.5]	86.1 [81.6,89.7]	54.8 [50.6,59.0]
Syringes	69.7	86.6	82.2 [79.0,85.0]	32.3 [21.8,44.9]	73.1 [69.3,76.6]
Soap and running water or alcohol-based hand rub	73.4	63.9	51.8 [47.3,56.2]	98.3 [96.2,99.2]	64.9 [60.9,68.7]
Latex gloves	86.3	88.7	79.1 [75.4,82.4]	97.4 [95.1,98.6]	79.5 [76.0,82.7]

Note: Haiti and Malawi do not have confidence intervals because the SPAs for these two countries were a census of all facilities.

Appendix Table 4 **ANC process indicators among women attending their first visit and sick child intervention and process indicators**

	Haiti	Malawi	Nepal	Senegal	Tanzania
ANC process quality					
Client history	98.7 [97.6,99.3]	96.1 [94.4,97.3]	87.3 [81.2,91.6]	96.2 [92.2,98.2]	97.2 [95.9,98.2]
Urine test	66.0 [60.4,71.1]	4.3 [2.8,6.6]	38.9 [31.9,46.5]	68.0 [51.3,81.1]	41.4 [36.3,46.8]
Hb test	70.9 [65.4,75.9]	9.6 [7.4,12.5]	41.2 [34.1,48.6]	40.7 [29.8,52.7]	46.6 [41.2,52.1]
Syphilis test	64.0 [58.1,69.5]	12.6 [10.1,15.8]	22.8 [17.8,28.7]	64.6 [48.7,77.8]	41.9 [36.8,47.2]
Checked blood pressure	95.8 [92.9,97.5]	48.0 [44.2,51.8]	83.4 [76.7,88.5]	97.6 [93.9,99.1]	72.2 [66.6,77.2]
Measured weight	91.4 [87.6,94.1]	73.7 [70.0,77.0]	72.3 [63.9,79.5]	97.8 [93.8,99.2]	79.2 [73.4,83.9]
Checked fundal height	70.5 [65.1,75.3]	94.9 [93.2,96.2]	39.1 [32.9,45.7]	84.8 [61.1,95.2]	94.8 [92.7,96.2]
Physical examination/vaginal exam	10.4 [7.3,14.6]	3.5 [2.5,4.9]	2.8 [1.4,5.5]	74.8 [56.8,87.0]	10.3 [7.8,13.6]
Checked edema	18.6 [14.7,23.3]	64.8 [61.0,68.3]	26.2 [20.8,32.4]	78.5 [68.0,86.2]	58.6 [54.1,63.0]
Checked client card	43.9 [37.6,50.4]	99.9 [99.2,100.0]	90.2 [84.2,94.1]	86.4 [78.3,91.8]	94.1 [91.9,95.8]
Examined palms for anemia/check pallor for anemia	91.4 [87.6,94.1]	73.7 [70.0,77.0]	72.3 [63.9,79.5]	97.8 [93.8,99.2]	79.2 [73.4,83.9]
Daily oral iron and folic acid supplementation (counseled or prescribed)	80.6 [76.2,84.4]	90.7 [88.3,92.6]	77.7 [71.7,82.8]	97.6 [95.3,98.8]	86.5 [83.0,89.5]
Tetanus toxoid vaccination	29.7 [24.3,35.8]	45.2 [41.4,49.0]	31.3 [25.4,37.9]	66.3 [54.6,76.3]	52.1 [47.4,56.8]
Danger signs of current pregnancy	75.3 [70.5,79.5]	62.5 [58.6,66.3]	58.0 [50.2,65.5]	74.0 [55.9,86.4]	74.3 [69.0,78.9]
Counseling on healthy eating	49.2 [43.5,55.0]	44.5 [40.6,48.3]	52.9 [45.6,60.2]	61.2 [47.9,73.0]	34.7 [30.2,39.5]
Informed the client about the progress of the pregnancy	21.5 [17.6,26.0]	56.7 [52.9,60.4]	24.3 [18.5,31.1]	27.9 [19.6,38.0]	49.9 [45.2,54.7]
Counseled on breastfeeding	4.3 [2.4,7.5]	9.9 [7.5,12.9]	2.1 [1.0,4.6]	4.8 [2.4,9.5]	15.8 [13.0,19.1]
Wrote on client card	38.9 [32.7,45.4]	99.9 [99.2,100.0]	88.5 [82.5,92.7]	86.1 [78.0,91.6]	94.1 [91.9,95.7]
Encouraged questions	66.2 [60.1,71.9]	78.0 [74.6,81.1]	37.1 [30.2,44.4]	65.2 [49.6,78.2]	79.5 [74.9,83.4]
Sick child complete intervention coverage					
Child diagnosed with pneumonia	2.8 [2.1,3.8]	11.6 [10.3,13.1]	8.2 [6.5,10.2]	5.0 [3.0,8.1]	11.6 [10.2,13.1]
Child diagnosed with diarrhea	15.5 [13.7,17.5]	10.4 [9.2,11.7]	15.8 [13.8,18.0]	29.7 [14.0,52.2]	17.2 [15.5,19.0]
Child with pneumonia given any antibiotic	62.4 [48.4,74.5]	98.0 [95.9,99.1]	86.7 [79.1,91.8]	94.6 [80.5,98.7]	96.4 [94.0,97.8]
Child with diarrhea given ORS or zinc	41.7 [36.3,47.2]	85.9 [81.7,89.2]	74.4 [67.7,80.1]	82.1 [59.9,93.4]	64.9 [60.0,69.5]
Child with any of these 2 given treatment	44.9 [39.8,50.1]	91.6 [89.1,93.5]	77.8 [72.4,82.4]	84.4 [66.9,93.6]	76.9 [73.5,80.0]

Continued…

Appendix Table 4—*continued*

	Haiti	Malawi	Nepal	Senegal	Tanzania
Sick child process quality					
Provider counted respiration for 60 seconds	37.7 [32.9,42.7]	24.2 [22.0,26.5]	54.8 [49.1,60.3]	69.4 [54.3,81.2]	22.5 [19.4,26.0]
Provider weighed client	81.3 [77.7,84.5]	26.5 [24.3,28.7]	50.2 [45.5,54.9]	61.7 [38.6,80.4]	16.1 [13.7,18.8]
Provider plotted weight on growth chart	10.5 [8.4,13.1]	7.3 [6.0,8.7]	16.7 [13.6,20.3]	96.6 [94.1,98.0]	4.7 [3.3,6.5]
Provider checked palms/conjunctiva for pallor	49.4 [45.9,52.8]	43.6 [41.5,45.9]	14.5 [12.3,17.0]	17.3 [10.4,27.5]	41.7 [38.7,44.8]
Provider discussed weight/growth/growth chart	9.7 [7.9,11.8]	8.7 [7.6,9.8]	4.1 [3.0,5.6]	11.5 [6.8,18.6]	24.3 [21.8,27.0]
Checked skin turgor for dehydration	55.0 [49.0,60.8]	42.1 [37.8,46.4]	29.1 [23.5,35.5]	69.6 [43.6,87.1]	46.0 [41.5,50.6]
Provider took temperature	85.3 [82.3,87.8]	42.1 [39.9,44.2]	47.6 [43.6,51.7]	96.1 [92.9,97.9]	42.5 [38.8,46.2]
Provider checked for edema	5.8 [4.6,7.3]	8.0 [6.9,9.2]	1.6 [1.0,2.6]	8.0 [5.0,12.4]	6.0 [4.7,7.6]
Felt the child for fever or body hotness	16.1 [13.8,18.6]	42.3 [40.0,44.5]	29.0 [25.8,32.3]	5.5 [3.2,9.3]	33.9 [31.0,37.0]
Checked for neck stiffness	3.3 [2.4,4.4]	1.9 [1.5,2.6]	0.9 [.5,1.5]	0.6 [.2,1.5]	5.8 [4.6,7.4]
Looked in child's ear	16.1 [13.5,19.1]	4.0 [3.3,4.9]	10.1 [8.1,12.6]	10.8 [6.2,18.2]	12.7 [10.9,14.8]
Felt behind child's ear	11.3 [9.6,13.3]	4.4 [3.6,5.5]	5.8 [4.5,7.4]	9.4 [4.9,17.5]	9.0 [7.4,10.9]
Checked vaccination status	21.3 [18.9,23.9]	16.5 [15.1,18.0]	5.9 [4.8,7.4]	60.0 [44.4,73.9]	24.3 [21.8,26.9]
Check mouth and throat	19.2 [16.7,21.9]	9.6 [8.4,11.0]	11.4 [9.6,13.5]	23.0 [8.5,49.2]	17.1 [15.0,19.3]
Provider asked / caretaker mentioned if child unable to drink or breastfeed	19.5 [17.3,21.9]	27.8 [25.9,29.9]	21.6 [18.9,24.5]	2.4 [1.2,4.6]	27.8 [25.3,30.3]
Provider asked / caretaker mentioned cough or difficult breathing	64.5 [61.9,67.1]	73.8 [71.8,75.6]	55.9 [52.4,59.3]	59.8 [40.5,76.5]	75.4 [73.1,77.5]
Provider asked / caretaker mentioned diarrhea	32.0 [29.1,35.1]	39.0 [36.9,41.1]	41.2 [38.1,44.5]	42.8 [25.6,62.0]	59.4 [56.6,62.1]
Provider asked / caretaker mentioned fever	65.1 [62.2,68.0]	77.3 [75.2,79.2]	77.1 [73.9,80.0]	66.5 [45.4,82.6]	93.3 [92.1,94.3]
Provider asked / caretaker mentioned convulsions	3.7 [2.9,4.8]	9.3 [8.1,10.6]	4.5 [3.3,6.3]	0.8 [.4,2.0]	20.1 [17.7,22.7]
Provider asked caretaker about vomiting	24.7 [22.4,27.2]	34.8 [32.8,36.9]	20.4 [17.7,23.5]	16.7 [11.1,24.3]	48.7 [45.7,51.7]
Provider asked / caretaker mentioned ear pain	4.9 [3.9,6.0]	4.8 [3.9,5.8]	17.6 [14.8,20.8]	3.6 [1.6,8.0]	16.4 [14.1,19.0]
Provider asked about normal feeding/breastfeeding when not ill	39.9 [36.7,43.1]	14.2 [12.8,15.8]	17.7 [15.1,20.7]	26.7 [17.9,37.8]	27.9 [25.4,30.5]
Provider asked about feeding or breastfeeding during this illness	31.5 [28.9,34.1]	15.5 [14.0,17.1]	16.4 [14.0,19.2]	7.8 [4.7,12.7]	18.8 [16.8,21.0]
Provide general information about feeding/breastfeeding	27.9 [25.0,30.9]	8.7 [7.5,9.9]	11.1 [9.2,13.3]	25.4 [17.1,35.9]	14.4 [12.6,16.4]
Advise extra fluids during this sickness	16.8 [14.6,19.2]	7.5 [6.5,8.6]	17.5 [15.0,20.3]	6.8 [4.1,10.9]	11.9 [10.4,13.7]
Advise continued feeding during sickness	15.2 [13.2,17.5]	11.8 [10.5,13.1]	16.7 [14.4,19.3]	9.5 [6.1,14.7]	13.1 [11.4,14.9]
Provider described more than 1 danger sign requiring return to facility	5.8 [4.6,7.3]	11.3 [10.1,12.7]	7.1 [5.7,8.7]	6.3 [3.8,10.1]	16.6 [14.4,19.1]
Provider stated diagnosis to caretaker	15.2 [13.2,17.4]	40.5 [38.4,42.7]	34.9 [31.1,39.0]	12.1 [7.8,18.2]	48.8 [45.4,52.2]
Provider explained dosing if medication prescribed	73.0 [69.2,76.4]	51.1 [48.7,53.5]	56.2 [51.6,60.6]	66.8 [51.8,79.0]	50.5 [46.4,54.7]
Provider asked caretaker to repeat the instructions for giving medicines at home (if medication prescribed)	5.9 [4.6,7.6]	5.9 [5.0,7.0]	3.7 [2.4,5.5]	2.0 [1.1,3.8]	11.2 [9.0,13.9]
Provider discussed follow-up visit	35.3 [31.8,38.9]	20.7 [19.1,22.3]	25.9 [22.8,29.2]	60.3 [45.1,73.8]	22.8 [20.3,25.5]
Provider used visual aids	0.3 [0.1,0.9]	0.2 [0.1,0.4]	0.2 [0.1,0.7]	1.5 [0.6,3.2]	0.9 [0.4,1.8]
Provider recorded on child's health card/booklet	17.8 [14.8,21.1]	87.8 [86.1,89.4]	65.3 [60.3,70.1]	21.4 [7.2,48.9]	21.5 [18.5,24.8]

APPENDIX B DESCRIPTION OF EFFECTIVE COVERAGE AND CONFIDENCE INTERVAL (CI) CALCULATIONS

Effective coverage (EC) is calculated as a product of terms that represent the readiness or effectiveness of services and individual-level use of services. With a cascade approach, the interpretation of products must be tailored to the specific role of services and their use, although the calculations are a rather mechanical extension of the simplest situation. We will describe the reasoning and calculations for one example, the treatment for sick children. The data include a file of children age 0-59 months who had symptoms of illness in the 2 weeks before the interview, who may or may not have been taken to a facility for consultation and possible treatment, and a separate file of facilities to which children can be taken. The child file is restricted to the children with symptoms of illness.

We identify children with subscript i and facilities with subscript j. E_j is the effectiveness of facility j, on a scale from 0 to 1. The use of a facility for child i is indicated by C_i, which is 1 if a facility is used and 0 otherwise.

Coverage is calculated as the proportion of children for whom C_i=1, which is equivalent to the mean value of C, i.e. $\bar{C}$. Effectiveness is calculated as the mean of E, i.e. $\bar{E}$.

With complete data, each child taken to a facility could be matched with that specific facility in the facility file. If child i was taken to facility j, the "effective coverage" EC_i for the child would be the effectiveness of that facility, E_j; if the child was not taken to a facility, EC_i would be 0. Thus, for an individual child, EC_i is the product E_jC_i, except that the E_j term in this product is not defined if C_i=0. The summary (which we call EC without a subscript) would be the average of E_jC_i across all individuals.

Example. Consider an artificial sample of five children and three facilities. Children 1 and 2 are not taken to a facility and have C_i=0. Children 3, 4, and 5 were taken to a facility and have C_i=1. The mean of C is (0 + 0 + 1 + 1 + 1) / 5 = 0.6. The proportion of children with C=1 is the same, 3/5=0.6. Coverage is C=0.6.

Now suppose the service environment includes three facilities, with identifiers 1, 2, 3, respectively. These facilities have effectiveness scores 0.2, 0.4, and 0.6, respectively. The mean effectiveness, averaged across the three facilities, is (0.2 + 0.4 + 0.6)/3=0.4. Effectiveness is 0.4.

We now add the information that child 3 was taken to facility 1; child 2 to facility 2; and child 3 to facility 3. The effectiveness of treatment for children 3, 4, and 5 was 0.2, 0.4, and 0.6, respectively. The overall mean effective coverage, or EC, would then be (0 + 0 + 0.2 + 0.4 + 0.6) / 5 = 0.24.

In this example, EC could also be obtained as the product of the means of coverage and effectiveness: 0.6 * 04 = 0.24. With other hypothetical numbers, this might not be the case.

In this report, we calculate national-level EC. Here, coverage is pooled across all children with symptoms in the entire country. The mean effectiveness of facilities is also pooled, across all facilities in the country. EC is estimated at the national level with the product of the two means: $EC = \bar{E}\bar{C}$. EC can be interpreted as the mean or expected effectiveness for a randomly selected child in the population who shows symptoms of illness, where the effectiveness is zero for children not taken to a facility, and for children who were taken to a facility is the effectiveness of the facility.

B.1 Statistical Model

The cascaded estimates of EC are constructed as products of terms that come from different data files. Those files include two basic types: R files, derived from SPA data, and U files, derived from DHS data. Indicators of readiness and use are constructed from these files, and then sequenced into a cascade. The measures at each step of the cascade can be referred to generically as E and C variables.

The C variables are binary and take only the values 0 and 1. The E variables are interval-level and are initially constructed with a theoretical range between 0 and 100. Within the analysis described here, the E variables will be divided by 100, and can theoretically take the values 0 or 1 or anything in between. An intermediate value can be interpreted as a proportion of a "perfect" value of 1.

The cascades are an important extension of the original conceptualization of effective coverage. It will be helpful to review a simple example. Suppose that the outcome of interest is antenatal care. With reference to a recent birth, a woman in a DHS survey is given a score C=1 if she reached some threshold level of antenatal care, such as four or eight antenatal visits. Otherwise, C=0. The service environment is assessed in terms of the quality or effectiveness of antenatal services, using facility data. Effective coverage, EC, is calculated as the product of the mean value of E and the mean value of C. This product is defined to be the effective coverage of antenatal care. The calculation is affected equally by the quality of services and the use of services.

E and C come from different data sources or samples. Standard methods can be used to calculate a confidence interval for the mean of E and C. However, a confidence interval for the product of those two means lies outside the usual statistical framework. In earlier DHS reports, the confidence interval for the product was estimated with the "delta" method (Wang, Mallick, Allen, and Pullum 2018). This approach was compared with alternatives by Sauer et al. (Sauer, Pullum, Wang, Mallick, and Leslie 2020). The delta method was successful at matching simulated samples from specified populations. The extension to cascades requires confidence intervals for products of three or four means, and potentially more. It is desirable to find an alternative procedure, with a more automated framework, to calculate EC and confidence intervals.

The procedure in this report can be described summarily as the "stacking" of constructed variables and the use of a Stata command (nlcom) to calculate standard errors and confidence intervals for nonlinear combinations of coefficients. Returning to the two-sample situation with a constructed variable C from a DHS survey, describing the use of antenatal care, and a constructed variable E from a SPA, and describing the quality of antenatal care, we proceed through the following steps:

- E is divided by 100, so that it takes values between 0 and 1. We keep the same name, E.
- The SPA and DHS files are stacked (using the Stata command "append"). If the two files have n1 cases and n2 cases, respectively, the stacked file has n1+n2 cases. n1 cases come from the SPA and the remainder come from the DHS.

- A new variable Y is defined. In the SPA file, Y=E; in the DHS file, Y=C. Within the SPA portion of the combined file, the mean of Y is the mean of E. Within the DHS portion, the mean of Y is the mean of C. We need to extract those two means as coefficients, construct their product, and calculate a confidence interval for the product.

- The values of Y in the SPA portion of the combined file are between 0 and 1, and in the DHS portion Y can take only the values 0 or 1. Y values below 0 or greater than 1 are impossible. A generalized linear model appropriate for both E and C is “glm Y, family(binomial) link(logit).” This model is identical with a logit or logistic model when Y is strictly binary. However, it is sufficiently general to encompass values *between* 0 and 1, inclusive. In Stata, logit and logistic models require binary (0/1) outcomes.

- In order to obtain separate coefficients for Y in the two subfiles, we construct two dummy or indicator (0/1) variables. In the SPA portion of the combined file, we define x1=1 and x2=0. In the DHS portion of the file, x1=0 and x2=1. These two dummy variables have a perfect negative correlation of -1, and normally both could not be included as covariates. By removing the constant term, we can include both x1 and x2. Thus, the model is “glm Y x1 x2, family(binomial) link(logit) nocons”.

  This model will return two coefficients, which can be called b1 and b2. b2 is the logit of the fitted probability that Y=1 in the DHS portion of the combined file. That is, the antilogit of b2, exp(b2)/[1+exp(b2)], is the fitted probability that C=1. The antilogit of b2 is also the mean of C, because the probability that C=1 is exactly the same as the mean of C. The interpretation of b1 is somewhat different, because X1 is not strictly binary, but the antilogit of b1, exp(b1)/[1+exp(b1)], is the mean of E.

- The coefficients b1 and b2 can thus be combined to produce the effective coverage estimate, the product of the mean of Q and C. Specifically, the point estimate of effective coverage is

$$EC = \frac{\exp(b1)}{[1+\exp(b1)]} * \frac{\exp(b2)}{[1+\exp(b2)]}$$

- In Stata, nlcom is a post-estimation command that gives the values, standard errors, and confidence intervals for nonlinear combinations of coefficients such as the one just described. Following the glm statement, we extract b1 and b2 from the saved vector of coefficients, construct the function just given, and Stata will return a value which is the product of the two means. It will also return the estimated standard error of that product.

- The method Stata uses to calculate (or, more accurately, to estimate) the standard error s is a very general and automated application of the delta method. A 95% confidence interval is calculated by adding +/-1.96s to the point estimate. The confidence interval for the product is symmetric around the point estimate.

- The components of effective coverage are between 0 and 1, inclusive, and therefore the product must be between 0 and 1. A correctly calculated confidence interval for the product, EC, must be entirely between 0 and 1. To ensure this, the symmetric intervals produced by Stata’s nlcom command are shifted slightly, by treating the EC estimate as if it were a probability whose logit has a normal sampling distribution. We calculate

$$b' = logit(EC) = lov[\frac{EC}{1-EC}] \ ,$$

estimate the standard error of b' with

$$s' = s/[\frac{EC}{1-EC}] \ ,$$

calculate a 95% interval as

$$b' +/-1.96s' \ ,$$

and finally calculate the antilogits of the lower and upper ends of the interval. The resulting confidence intervals have almost exactly the same width as those produced by nlcom, but with the slight asymmetry implied by a logit distribution.

We have confirmed that the calculations of effective coverage that arise from the stacked glm model and nlcom agree exactly with the simpler strategy of calculating means in two files and multiplying them.

This approach is readily extended to a cascade. For example, when effective coverage is interpreted to be a product of three terms, we simply stack the three files; define Y to encompass the key outcome in the three files, and apply a glm model with three dummies and no constant. The nonlinear function of coefficients that is then analyzed by nlcom is

$$EC = \frac{\exp(b1)}{[1+\exp(b1)]} * \frac{\exp(b2)}{[1+\exp(b2)]} * \frac{\exp(b3)}{[1+\exp(b3)]} \ .$$

Similarly, this can be done with four or more components. In this analysis, we prepare stacked working files that include all the components needed for any of the models, and then apply models that select only the components needed for a specific sequence.

The models include standard adjustments for sample weights, clustering, and stratification. Any restrictions to specific regions and facility types that may be desired can be accomplished in Stata with the svy subpop option.