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Estimating stillbirth and stillbirth-adjusted infant mortality: modeled and empirical evidence

Abstract

Introduction: Measurement of stillbirth, the loss of a pregnancy at 28 weeks of gestation or later, is a challenge in the low and middle-income country (LMIC) context. Evidence suggests that progress on addressing stillbirth has been slower than improvements in reducing neonatal, child, and maternal mortality. One-third of all neonatal deaths occur within the first day of life, and many of the same factors that cause stillbirths cause early neonatal deaths, suggesting that stillborns and newborns are developmentally similar. However, current infant mortality estimates ignore the burden of stillbirths, thereby mischaracterizing overall child health challenges in LMICs.

Methods: This article uses data from reproductive calendars collected in Demographic and Health Surveys (DHS) across 42 countries in Asia, Latin America, and Africa. First, to assess the quality of survey data on stillbirth, stillbirth rates from the DHS are compared to modeled estimates calculated by the UN-IGME in 2020. Second, to understand the extent of undermeasurement, DHS stillbirth rates are compared to rates of early neonatal mortality across countries. Third, in order to consider the amount of mortality missed by traditional measures of mortality by not including stillbirth, a "stillbirth-adjusted infant mortality rate" is calculated, and compared to the magnitude of traditional infant mortality measures.

Results: Despite high levels of uncertainty in all estimates of stillbirth, DHS survey estimates are not consistently worse than modeled estimates, and they have the advantage of being more transparent. Among the 42 countries in the study, places with worse measurement of stillbirth are those that likely have the highest rates of stillbirth. Despite likely underreporting, the "stillbirth-adjusted infant mortality rate" shows that stillbirths are a substantial portion of infant mortality that does not traditionally get counted. The "stillbirth-adjusted IMR" also reveals wider disparities in wellbeing across countries.

Conclusion: Given its substantial health implications, greater urgency to improve quality of stillbirth data, better empirical measurement of stillbirths in both household surveys and country level programming, and newer demographic measures that consider stillbirth mortality are an important priority for research and action on global population health.

1. Introduction

Stillbirth is the loss of a pregnancy at 28 weeks of gestation or later, as defined by the World Health Organization [1]. Many of these losses occur either right before birth or during labor [2], and most are preventable [3]. There are many overlaps in the factors that cause stillbirths and early neonatal deaths, with antenatal conditions impacting both sides of the threshold of live birth [4, 5]. Thus, developmentally, there is often little difference between a newborn baby and a stillborn one [6]. In fact, at approximately 2 million in 2019, the number of annual stillbirths is estimated to be nearly equivalent to the number of annual early neonatal deaths globally [1, 4]. Despite the close links with early neonatal mortality, progress on addressing stillbirth has been slower than improvements in reducing neonatal, child, and maternal mortality [2].

Attention to stillbirth has been increasing in recent years [7], however given its high burden, it has long been and remains an understudied issue [8, 9]. For example, estimates suggest that 75% of stillbirths occur in South Asia and sub-Saharan Africa [2]. Yet there was no mention of stillbirth in the UN's Millennium Development Goals, its updated Sustainable Development Goals, or its 2030 Agenda for Sustainable Development [3].

This neglect can be observed in the lack of reliable measurement of stillbirth. A 2020 joint UN and IGME Report presents estimates of stillbirths globally for 195 countries [2]. However, because of data availability and quality concerns, many estimates had to be extrapolated from data from three to ten years earlier. Estimates for 62 countries, which account for 30 percent of all stillbirths, were derived with no empirical stillbirth data at all. Issues in terms of how various countries define a stillbirth add additional bias to their estimates. These estimates are highly uncertain, highlighting the need for better measurement at both the country and sub-national levels.

Measuring stillbirth is important because the stillbirth rate is a sensitive indicator of quality of care during pregnancy and childbirth [10], which are closely linked to outcomes of child health and child mortality. It is also sensitive to other environmental or social exposures [11, 12]. Yet measurement remains a challenge in much of the world. Most of the stillbirth estimates that are missing come from low and middle-income countries (LMICs), where vital registration systems are underdeveloped, and where even the births and deaths of living children and adults are not consistently recorded [13]. These countries often rely heavily on representative sample surveys for estimates of demographic rates of stillbirth, and mortality rates more generally. The household survey that is most widely used today to estimate mortality in countries where vital registration systems lack the capacity to do so is USAID's Demographic and Health Surveys (DHS), which collects data on health and population using standardized questions across 92 countries.

Although valuable, existing research has documented substantial variation in capturing stillbirth prevalence using the DHS, downward bias in its measurement of stillbirth, as well as its very limited ability to link stillbirth with risk factors [14, 15]. In response to calls for better quality data, the DHS shifted from a birth history focused only on live births to a full pregnancy history that records the outcome of each pregnancy starting in its latest questionnaire update in 2018 [16]. While some studies suggest that pregnancy histories are better able to capture stillbirths [17], others suggest that even pregnancy histories substantially underestimate stillbirth prevalence [18]. There are not yet enough DHS data available to assess how much of an improvement the new questionnaire will bring. Still, most recent DHS datasets even before 2018 have utilized a live birth history with a reproductive calendar [15], allowing for the identification of stillbirths within a woman's reproductive history within the five years prior to the survey. This allows for a consistent comparison across countries.

In this article, I use Demographic and Health Survey data from across 42 countries in Asia, Latin America, and Africa to assess the quality of survey data on stillbirth, compared to modeled estimates that combine different sources of data across time. Next, I compare stillbirth rates in the DHS to rates of early neonatal mortality to assess the degree of poor stillbirth measurement across countries. This common practice of using a mortality indicator that is less prone to error to understand the patterns of a separate mortality indicator that is known to be inaccurate in some way [19] is a useful way to identify biases in the weaker indicator. Early neonatal mortality is death within the first seven days of life. Because child health and mortality have been an important focus of global health policy, data quality for these deaths is generally considered to be of higher quality, suffering from less underreporting compared to stillbirth [20]. Since early neonatal deaths and stillbirths are believed to be nearly equivalent in number [1], a comparison of the two rates can demonstrate the extent of underreporting within stillbirth estimates. Last, in an exercise to demonstrate the magnitude of child mortality that may be missed by traditional measures, I calculate a "stillbirth-adjusted infant mortality rate." This new measure recalculates the traditional infant mortality rate so that infant deaths and stillbirths can be combined into a richer measure that accounts for both. It also overcomes incentives of misclassification between stillbirths and neonatal deaths.

This article contributes to the literature in public health linking stillbirth prevention with the prevention of neonatal deaths [3, 8]. In addition, this article builds on a recent and growing literature on biases in survey estimates of early life mortality. For instance, Helleringer et al [21] explore the consequences of misclassification of stillbirth and neonatal death in Guineau-Bisau, and how this may have an impact on rates of neonatal mortality. Similarly, Gonzalez & Gilleskie [22] find evidence of misclassification of early neonatal deaths as stillbirths in Cuba, leading to inaccurate measurement of the infant mortality rate. The present study helps understand the extent to which concerns of mismeasurement from smaller-scale studies may be valid in nationally representative data. In countries with high-quality data on stillbirth and early neonatal mortality, the current literature suggests including stillbirth in current measures of infant mortality as a way to combat incentives to misclassify early life deaths as stillbirths in order to show improvements in infant mortality [22]. I expand this literature by creating a measure of "stillbirth-adjusted infant mortality" using data from the LMIC context that may help overcome these incentives to misclassify. In addition, I examine measures of stillbirth alongside common measures of child mortality across LMICs where stillbirth is known to be most common. I demonstrate how undermeasurement of stillbirth across places distorts our understanding of progress on child mortality globally.

2. Methods

2.1. Data

This analysis uses data from the most recent DHS survey from every country that took place in 2005 or later, that included reproductive calendars for all women in the sample. Data from a total of 42 countries are included. Table 1 includes a list of countries and survey years.

The DHS surveys include a birth history, which includes information on every birth in a woman's reproductive history. For children who died after birth, data on the number of days, months, or years they lived is also collected. Most DHS surveys do not count the number or type of pregnancy losses that each woman ever had. However, pregnancy losses are captured for the five years prior to the survey in the reproductive calendar, separately from data on live births.

The DHS reproductive calendar is a month by month history of key reproductive events for each female respondent. Depending on interview date, the reproductive calendar records a history for every month in the five to seven years prior to the start of the survey, including whether a woman was pregnant, gave birth, or had a pregnancy termination in a particular month. Pregnancies in the calendar are marked with a “P”, births are marked with a “B”, and terminations are marked with a “T”. The calendar is read from right to left in terms of chronological time, so the right end of the calendar variable is the furthest back in time, and events closer to the date of the interview are on the left end. While one cannot tell whether any given T indicates a miscarriage, abortion, or stillbirth, it is possible to separate out stillbirths: if there are terminations (“T”) with 6 or more “P”’s in front of them, they can be identified as stillbirths (i.e. “TPPPPPP”). Miscarriages and abortions are, however, indistinguishable from one another.

Across all 42 countries, the final dataset includes observations for 571,472 women who have been pregnant at some point in the five years prior to the survey. The data capture all reported pregnancies and live births that occurred in the five years prior to the survey.

2.2. Measures of stillbirth and child loss

Stillbirths are identified in the DHS through the reproductive calendar. DHS reproductive calendar data allow for the calculation of stillbirth rates for the five-year period before the survey [23]. The stillbirth rate is the number of stillbirths divided by the total number of pregnancies of seven or more months of gestation in this period.

Early neonatal deaths are identified through the birth history. Although traditionally, the early neonatal mortality rate (ENMR) is calculated with live births in the period as the denominator, for this analysis, the ENMR is calculated in the same way as stillbirths, using the same denominator for the same period to enable comparison [18]. The ENMR is the total number of deaths within the first seven days of life, divided by the total number of pregnancies of seven or more months of gestation.

Infant deaths are also identified through the birth history. A variety of methods are used to calculate infant mortality rates (IMR) from the birth history: DHS reports use the synthetic cohort life table approach to get period specific measures of IMR, others use a true cohort life table approach [24], and still others estimate deaths and person years directly [25]. For this analysis, I use a vital statistics approach to calculate IMR. In this approach, I divide deaths in a period with births in a period. This approach has several advantages. First, this method is consistent with the methods used for the stillbirth rate and early neonatal mortality rate calculations. Second, this method allows for flexibility in the denominator, so that infant mortality can be calculated both using live births as the denominator and using pregnancies that reach seven months of gestation as the denominator. Finally, given its less onerous data and estimation requirements, this approach is easier to implement in a variety of settings, including in civil registration systems and HDSS sites.

I use the term “traditional IMR” to refer to the way that IMR is commonly calculated: the total number of deaths to children under 12 months of age in a given period, divided by the total number of live births in the same period. In this analysis, the period of analysis is the same five-year period before the survey as is used for calculating stillbirth and early neonatal mortality rates. In the numerator, I include the deaths of children that occurred in the five-year period before the date of the survey, for children who were born in the six years before the date of the survey. This ensures that deaths of children before age one, who were born before the five-year analysis period, but died in the analysis period, are not missed. For the “traditional IMR” the denominator is the total number of live births in the five-year period before the survey. I use the term “stillbirth-adjusted IMR” (SA-IMR) to refer to a new measure: it is calculated with infant deaths (as calculated for the “traditional IMR”) added to stillbirths in the numerator in a given period, and the total number of pregnancies of seven or months of gestation during the period as the denominator.

Figure A1 in the appendix shows DHS stillbirth rates and DHS ENMRs for each country. The two rates are close in magnitude, validating the use of the ENMR for assessing measurement of the stillbirth rate. Figure A2 in the appendix shows DHS IMRs calculated using the synthetic cohort life table approach and the DHS IMRs calculated using the vital statistics approach for each country. Estimates using both methods are very similar, verifying that the choice of method does not change the magnitudes and patterns of the “stillbirth-adjusted IMR.” All rates are estimated using survey weights, and standard errors are clustered at the level of the primary sampling unit.

3. Results

Table 1 shows summary statistics for the 571,472 women in the sample, who have reported being pregnant at least once in the five years prior to being surveyed, across 42 countries in Asia, Latin America, and Africa. The average age of women in the sample ranges from approximately 25 to 32 years of age. Educational attainment varies more widely, with the average woman in Afghanistan having 1.3 years of education and the average woman in Armenia having 12 years of education. Large variation can also be seen in rural residence, from 11% of women living in rural areas in Jordan to almost 90% in Burundi. There is wide variation within countries in terms of women's backgrounds and resources. Although not the focus of this paper, evidence from high-income countries suggests that risk of stillbirth is greater among disadvantaged groups in individual countries [10, 12].

The final two columns show women's experiences of pregnancy and childbearing. Women in the sample report having an average of between 2 and 4.1 children ever born alive. Many women have experienced the deaths of their children, from 4.1% of women in Colombia to 38.2% of women in Mali.

Table 1. Summary statistics of women in sample, by country

Country & Year	**Number of women**	**Average age**	**Average years of education**	**Fraction living in rural areas**	**Average number children born**	**Fraction experienced a child's death**
Afghanistan 2015	22,630	29.0	1.3	77.7%	4.1	21.5%
Angola 2016	9,978	28.3	5.0	34.8%	3.6	21.9%
Armenia 2016	1,992	29.7	12.0	41.8%	1.9	10.9%
Azerbaijan 2006	2,791	29.9	10.7	47.1%	2.1	22.1%
Bangladesh 2014	8,649	25.8	6.0	72.6%	2.1	18.0%
Benin 2018	10,239	29.4	2.4	60.6%	3.5	30.9%
Bolivia 2008	7,580	29.3	7.9	40.7%	3.1	20.9%
Burundi 2017	9,589	30.7	3.1	89.7%	3.9	27.5%
Cambodia 2014	7,741	29.5	5.1	84.5%	2.3	21.4%
Colombia 2015	12,418	27.9	10.0	25.7%	1.9	4.1%
Egypt 2014	13,297	28.9	8.8	67.9%	2.5	7.7%
Ethiopia 2016	8,011	29.6	2.3	86.0%	3.9	29.4%
Ghana 2014	5,235	30.7	6.4	50.4%	3.0	27.5%
Guatemala 2015	11,605	28.3	5.4	60.5%	2.8	18.1%
Guinea 2018	6,380	29.2	1.9	69.3%	3.4	33.6%
Guyana 2009	1,959	28.5	8.7	74.6%	2.6	17.9%
India 2016	225,035	26.9	6.9	69.5%	2.1	10.8%
Indonesia 2017	19,006	31.1	9.8	51.6%	2.1	12.7%
Jordan 2018	9,071	31.4	12.0	10.9%	3.0	21.0%
Kyrgyz Republic 2012	3,818	29.6	12.2	67.7%	2.5	20.4%
Lesotho 2014	3,133	28.0	8.0	69.6%	2.3	18.6%
Madagascar 2009	10,138	28.8	3.6	86.3%	3.6	25.9%
Malawi 2016	15,547	28.1	5.7	84.8%	3.2	24.0%
Maldives 2017	3,295	30.6	10.0	64.8%	2.0	14.3%
Mali 2018	7,116	28.9	2.0	77.6%	4.0	38.2%
Myanmar 2016	4,896	31.5	5.3	76.6%	2.5	18.8%
Nepal 2016	4,957	26.8	5.3	42.5%	2.2	15.8%
Nigeria 2018	24,609	29.9	5.7	59.7%	3.9	34.7%
Pakistan 2018	9,968	29.6	4.5	65.5%	3.3	31.4%
Papua New Guinea 2018	7,417	29.9	5.5	88.4%	3.2	25.1%
Peru 2008	16,661	29.9	8.9	36.9%	2.6	13.0%
Rwanda 2015	6,999	30.6	4.6	82.6%	3.1	31.6%
Senegal 2018	5,354	30.5	3.0	58.9%	3.4	22.8%
South Africa 2016	3,683	29.2	10.6	34.7%	2.1	16.8%
Swaziland 2007	2,475	27.5	8.0	75.9%	2.9	28.5%
Tajikistan 2017	5,086	28.6	10.2	77.6%	2.6	9.1%
Tanzania 2016	8,158	29.1	6.0	68.9%	3.4	30.3%
Timor-Leste 2016	5,559	30.7	7.5	69.8%	3.4	24.0%
Turkey 2013	3,683	30.6	7.3	19.1%	2.2	5.1%
Uganda 2016	11,675	28.6	6.3	75.8%	3.8	24.2%
Zambia 2018	8,392	28.6	6.8	60.4%	3.4	34.1%
Zimbabwe 2015	5,647	29.0	9.1	66.3%	2.8	25.1%

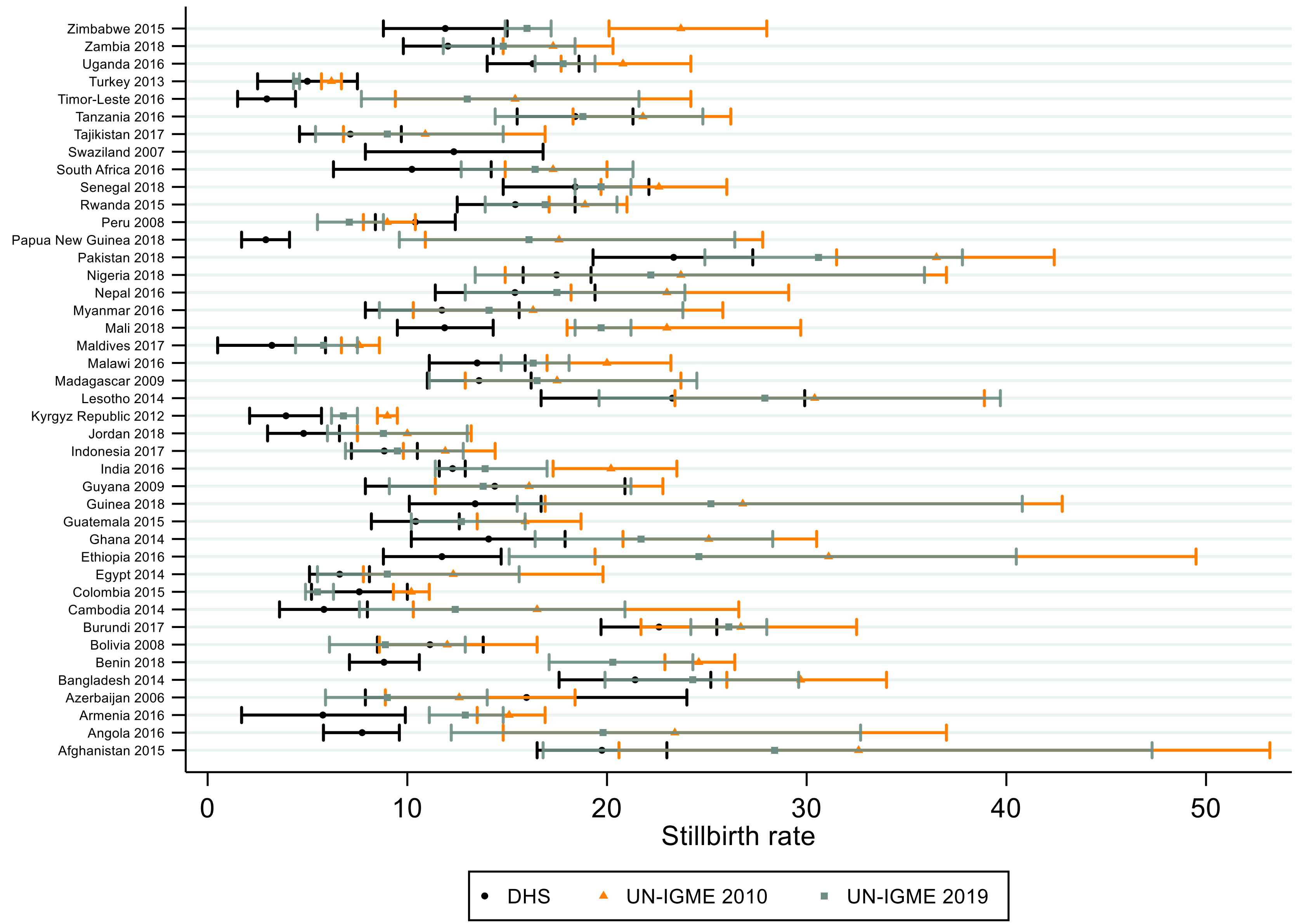
Note: All summary statistics in Table 1 are calculated using survey weights. Data source: Demographic and Health Surveys (DHS).

The children and child deaths included in Table 1 include only those born alive, and the deaths that we are used to considering when thinking of child mortality, such as neonates, infants, and children under the age of five. The remainder of the results focus on stillbirths.

Figure 1 shows DHS stillbirth estimates, alongside UN-IGME estimates from 2010 and 2019 for each country. DHS rates are based on women's reporting in household surveys, with uncertainty coming from reporting bias and measurement error. The UN estimates are modeled incorporating predictions of stillbirth rates based on covariates and using temporal smoothing. They also account for biases from differences in stillbirth definitions, the use of various sources of data, and measurement error [2].

Out of the 42 countries in the analysis, 41 have both DHS and UN estimates. Overall, there is large uncertainty in all estimated rates. In eight cases, the DHS stillbirth rates are clearly underestimated, with confidence bounds falling even below the lower bounds of the 2019 UN IGME estimates. However, in all other cases, the confidence bounds of the DHS estimates overlap with UN estimates. While there are clear limitations to the stillbirth estimation techniques used in DHS surveys, as noted by several teams who have attempted to assess global rates of stillbirth in the past decade [2, 14, 26], modeled estimation techniques also have large uncertainty and are not as transparent. This suggests the possibility of improvement in stillbirth data collection from empirical sources like the DHS.

Figure 1. Comparison of stillbirth rates in DHS, UN-IGME 2010, and UN-IGME 2019, by country



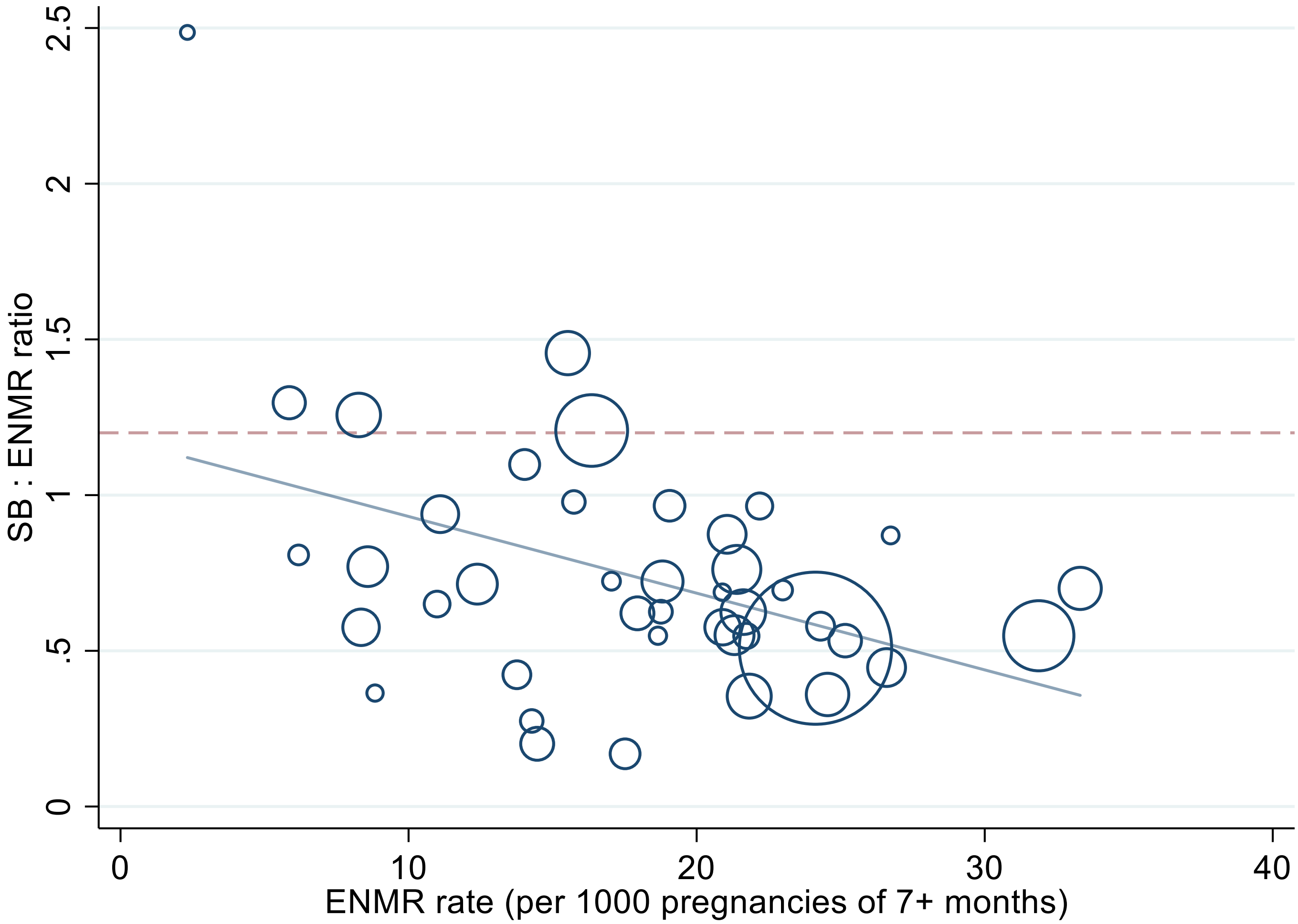
Note: The stillbirth rate is the number of stillbirths out of 1000 pregnancies that reached 7 months of gestation or more. DHS estimates are calculated using survey weights, and 95% confidence intervals are calculated using standard errors that are clustered at the level of the primary sampling unit. UN-IGME estimates and confidence intervals come from the 2020 UN-IGME report on stillbirths [2]. Swaziland was not included in the UN-IGME report's estimates thus Swaziland only has DHS estimates in Figure 1.

A common way to assess the quality of stillbirth data in the DHS is to compare rates of stillbirth to rates of early neonatal mortality [1, 18]. The use of the early neonatal mortality rate as a comparator is justified for two reasons: first, almost one third of neonatal deaths happen on the first day of life [26] and many of the same factors that cause stillbirths cause early neonatal deaths, verifying the close relationship between early neonatal mortality and stillbirth. Second, much attention has been paid to child mortality [19, 28-30] with global organizations setting specific targets for countries to meet, thus measures of early neonatal mortality are far more developed and of higher quality than those of stillbirth. Using a historical review of ratios of stillbirth to early neonatal mortality in countries with developed vital registration systems, the World Health Organization [1] suggests using 1.2 as the ratio to translate between the two rates. This ratio has been used by researchers as a method to assess the quality of stillbirth data [14, 18, 30]. Countries with ratios further below the 1.2 mark are considered to have poorer measurement of stillbirth [18].

For all countries in the dataset, Figure 2 graphs the ratio of the stillbirth rate to the early neonatal mortality, over the period of the past five years using DHS data. Each circle represents one country, and the size of the circle represents the number of pregnancies recorded for all women in that country's sample. The dotted line shows the level of the 1.2 stillbirth to ENMR ratio. The downward sloping trend line shows that places with worse early neonatal mortality (and thus presumably higher rates of stillbirth) have poorer measurement of stillbirth than places with better early life health. This suggests that undermeasurement is not uniform across places, and that we may be undermeasuring by far more in the places that need the most improvement.

It is worth noting that most countries do not reach the 1.2 ratio. Most do not even come within 0.5 of the 1.2 ratio. This is not surprising given that the reproductive calendar's main purpose is to track contraceptive use, not pregnancy loss. These low ratios also likely reflect widespread underreporting of stillbirth [14, 18]. Studies suggest that underreporting occurs due to stigma borne by the mother [31], and because stillbirth is often not seen as a real loss, which has resulted in legal, political, and demographic indifference [32-34].

Figure 2. Association between likely stillbirth rates and measurement of stillbirth across countries



Note: Each circle represents one country, and the size of the circle represents the number of pregnancies recorded for all women in that country's sample. We expect that the stillbirth (SB) to early neonatal mortality (ENMR) ratio should be around 1.2 (the dotted maroon line). Countries further from 1.2 are considered as having worse measurement of stillbirth. The downward sloping trendline shows that places with the highest rates of early neonatal mortality (and thus likely the highest rates of stillbirth) have worse measurement of stillbirth. Data source: Demographic and Health Surveys (DHS).

If we know that stillbirth is undermeasured in the places where it is likely happening the most, what does this mean for our understanding of child mortality and wellbeing in individual countries and globally?

Figure 3 plots the "traditional IMR," alongside the "stillbirth-adjusted infant mortality rate" as it is calculated in the data, alongside the upper bound of the "stillbirth-adjusted infant mortality rate," which is what it would be without underreporting of stillbirth. The lightest maroon bars show each country's "traditional IMR." The darker (middle) maroon bars show the mortality that is left out of current measures of infant mortality if stillbirths are not included. The smallest gap of 2.8 deaths per 1,000 births between the "traditional IMR" and the "stillbirth-adjusted IMR" is in Papua New Guinea, and the largest gaps of 21.9 deaths per 1,000 births are found in Pakistan and Lesotho. Gaps here are reported as deaths per 1,000 "births", rather than specifying "live birth" or "pregnancy of seven or more months of gestation" because of the difference in denominator between the "traditional IMR" measure and the "stillbirth-adjusted IMR" measure.

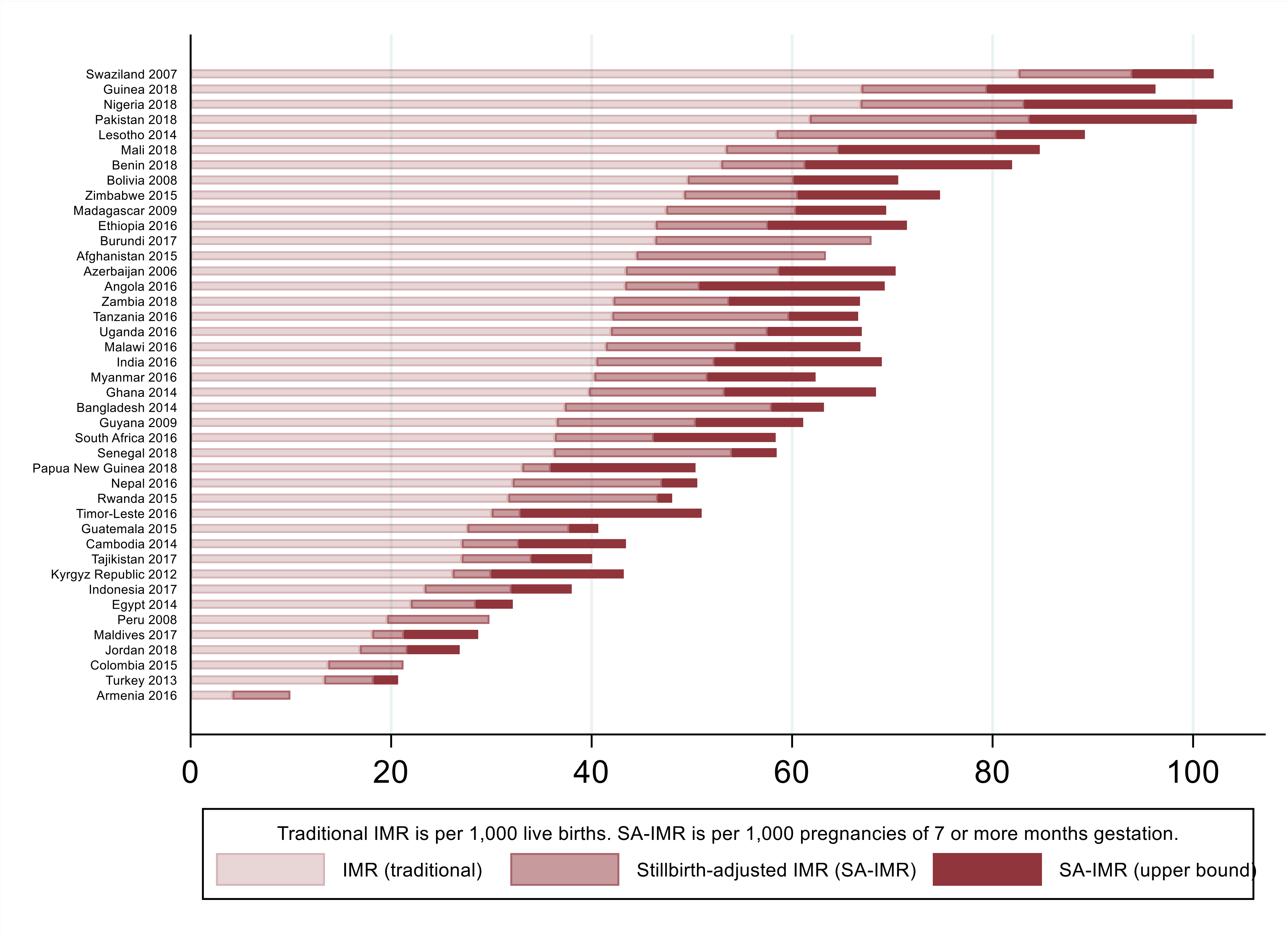
Another important aspect to note in Figure 3 is the larger inequality visible between countries' "stillbirth-adjusted IMR" (the darker maroon bars), compared to the inequality visible between countries' "traditional IMR" (the lightest maroon bars). Before adjusting the IMR to include stillbirths, the difference between the country with the lowest "traditional IMR" (Armenia) and the country with the highest "traditional IMR" (Swaziland) is 78.4 deaths per 1000 live births. Using the "stillbirth-adjusted IMR," the difference between the same two countries with the highest and lowest rates is 84.0 deaths per 1000 pregnancies of seven or more months of gestation. The "stillbirth-adjusted IMR" in this analysis shows greater inequality despite the undermeasurement of stillbirth in the DHS.

The "stillbirth-adjusted IMR" gives a starker and more complete picture of inequality between countries. This is because, in reality, places with high rates of stillbirth are likely to be those with high rates of infant mortality. Thus we would be adding high stillbirth numbers to high infant mortality numbers for the places with the highest burden, like in South Asia and sub-Saharan Africa. In low-burden places, we would be adding low stillbirth rates to low infant mortality rates. In terms of Figure 3, without underreporting, the darker maroon bars would be larger for all countries, but relatively larger for countries towards the top of the figure compared to those towards the bottom. Stillbirth-adjusted infant mortality rates would therefore show even larger differences in wellbeing, compared to the differences seen in the "traditional IMR."

It is important to remember that since stillbirths tend to be underreported, the darker maroon bar would be even larger in the absence of underreporting. To show that the darker maroon bars are lower bounds of the "stillbirth-adjusted IMR," the upper bound of the "stillbirth-adjusted IMR" is calculated by multiplying the early neonatal mortality rate for each country by

1.2. These upper bounds are shown using the darkest maroon bars in Figure 3. There are five countries for which no darkest maroon bar is visible (Afghanistan, Armenia, Burundi, Colombia, and Peru). This is because multiplying the ENMR by 1.2 results in a value that is less than the calculated “stillbirth-adjusted IMR” as a result of DHS estimates of stillbirth rates in these countries already exceeding ENMR estimates. Further research would be required to understand clearly why this is the case, but one reason could be misclassification of early neonatal deaths as stillbirths [21].

Figure 3. Traditional IMR compared to "stillbirth-adjusted IMR" and upper bounds of "stillbirth-adjusted IMR", by country



Note: The lightest maroon bars on the left show "traditional IMR," or infant deaths out of 1000 live births. The darker maroon bars in the middle show "stillbirth-adjusted IMR," or infant deaths plus stillbirths out of pregnancies of 7 or more months of gestation. The darkest maroon bars on the right show the upper bound of the "stillbirth-adjusted IMR," calculated by multiplying each country's ENMR by 1.2. Five countries, Afghanistan, Armenia, Burundi, Colombia, and Peru, do not have the darkest maroon bars because DHS estimates of stillbirth rates in these countries exceed ENMR estimates. Estimates are calculated using survey weights. Data source: Demographic and Health Surveys (DHS).

4. Discussion

This analysis focuses on the measurement of stillbirth, showing that while there is a high level of uncertainty in its measurement, both in direct and modeled estimates, even existing measures have meaningful consequences for our understanding of child health and mortality. Although survey data on average show lower estimates of stillbirth than modeled estimates, survey data such as that of the Demographic and Health Survey (DHS) do not always under-report stillbirths. This suggests that monitoring from empirical sources can be improved. Survey data sources are also much more transparent. In many countries, DHS data are the only empirical data that exists on stillbirth. A comparison of stillbirth rates to rates of early neonatal mortality using DHS data from across 42 countries in Asia, Latin America, and Africa shows that the places with the worst measurement are those that likely have the highest rates of stillbirth. Finally, this article considers what it would look like to include stillbirths in the infant mortality rate (IMR), calculating a "stillbirth-adjusted IMR" to show how much mortality we are missing by not including these losses in traditional measures. The "stillbirth-adjusted IMR" also shows more clearly the disparities in wellbeing across countries. The aim of this article is to call attention to stillbirth itself, and to its measurement, as incorporating these losses into our understanding of child mortality will lead to a richer and more nuanced understanding of the health challenges that children in the world face.

The implications of this analysis for public health are clear. A majority of neonatal deaths occur very close to the time of birth, and at least some of the factors that cause stillbirth overlap with those that cause early neonatal death. For decades, we have continuously improved upon our methods to count childhood deaths [19, 28-30, 35, 36], in order to track these losses and ultimately to prevent them from happening. A lack of attention to stillbirth likely contributes to biases in the measurement of child mortality, and tardy progress on reducing its burden.

This analysis thus also has potential implications for population theory, and underlying assumptions in demographic measurement. The clarity and simplicity of using live birth for purposes of defining entry into a population for demographic accounting are beyond doubt. However, a researcher of bioethics whose work focuses on stillbirth [6] asks,

> In most countries a baby who is born alive, breathes a few breaths but dies a few hours later is counted as a neonatal death, a life lost. However, third-trimester or intrapartum stillbirths are not typically classified as deaths. If the

> 35-week-old stillborn baby and the 35-week-old neonate who dies of respiratory failure 24 hours after delivery are developmentally indistinguishable, why the paradox in our mortality statistics?

Thus in addition to consequences for child health, stillbirth is an important form of mortality in itself that deserves attention. Not counting stillbirth well means that we may be undermeasuring a large portion of what we would consider mortality [37]. Improving our measurement of stillbirth would enable the use of measures like the "stillbirth-adjusted IMR" alongside traditional measures of IMR, giving us the ability to measure mortality in early life in a more complete way, and allowing for a more comprehensive assessment of the health of societies.

Of course, many questions remain in terms of stillbirth measurement and classification. For example, definitional ambiguities highlight more sharply the scale of the problem of stillbirth undermeasurement. The 28-week definitional threshold for stillbirths is based on when a fetus can survive outside of the womb. As technology develops, this line of viability inches ever earlier in pregnancy. Many developed countries have earlier cutoffs, such as 20 weeks in Australia and the United States, and 24 weeks in the United Kingdom [3]. Thus, some losses that are counted in high-income countries may remain uncounted in low and middle-income countries. If low and middle-income countries had earlier cutoffs, many of the rates presented here and in the UN-IGME estimates would be higher.

While historically stillbirth measurement has been considered too complex to contemplate seriously, most of these losses are preventable, and the need for better quality data on stillbirth is urgent. There are several fruitful avenues for future research. First, more work is needed to understand the reasons behind such widescale underreporting of stillbirth in different contexts, in addition to social stigma and legal/political indifference that has been documented [31-34]. The DHS has recently shifted to a full pregnancy history, which should be able to capture more stillbirths, but previous studies suggest that this may not fully resolve issues of underreporting [18]. Further, it is important to begin moving away from thinking about stillbirth primarily as it effects women's future fertility, as has historically been the case [38]. One way to do this may be quantifying stillbirth as mortality from the perspective of the women who experience it [39], in order to shed light on the effects of these losses on women's physical and emotional health [40], and thereby the health of their children.

Many puzzles also remain in terms of the details of measurement. For example, the 1.2 stillbirth to early neonatal mortality rate ratio was derived from populations in present day high-income countries. It is possible that the ratio is different in the low and middle-income countries where DHS surveys are currently undertaken. As progress on addressing early neonatal mortality continues, this ratio may be even higher today if stillbirth reduction does not keep up, possibly suggesting even greater levels of "stillbirth-adjusted IMR" than shown in this analysis. Another measurement issue is one of misclassification of stillbirths and early neonatal deaths in cases when signs of life at birth are unclear. Depending on definitions of stillbirth, cultural norms, and health provider incentives, it may be more likely in some countries for early neonatal deaths to be classified as stillbirths, while in other countries, it may be more likely for stillbirths to be classified as early neonatal deaths [21]. Research on classification and its impact on measures of stillbirth will be useful. Lastly, there are important issues of selection into live birth that remain to be explored, that may shed light on which populations and subgroups are most likely to experience the burden of stillbirth, and additionally help us reach a more accurate understanding of which children are most likely to survive.

Most global health assessments of child health report only on measures such as the neonatal mortality rate and the infant mortality rate to compare progress on health worldwide. This analysis is an attempt to look across the line of the moment of birth, in recognition of the fact that "to understand the death or disease of the newborn infant it is necessary to take into account the circumstances through which the infant's organism has passed before birth…" [4]. Without considering stillbirth as we try to make progress on child mortality, we risk focusing too much policy, research, and resources on postnatal factors, and not enough on antenatal factors and the birthing process that also have an important impact on child health. Paying greater attention to stillbirth and its measurement will help us more accurately assess health and wellbeing at the population level. Better measurement will ultimately feed into a better understanding of stillbirth, which can help ensure that the babies who are born are born healthier.

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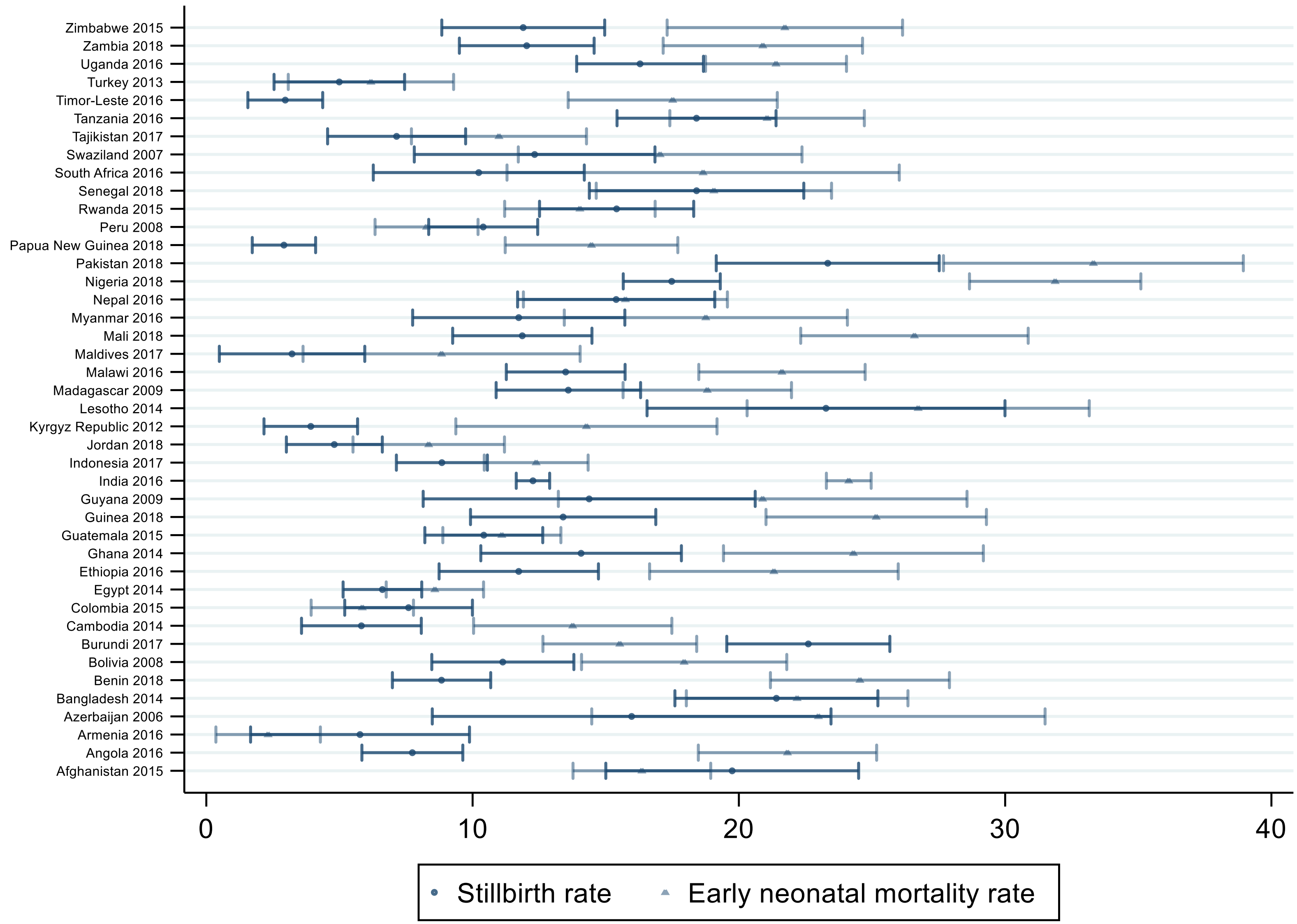
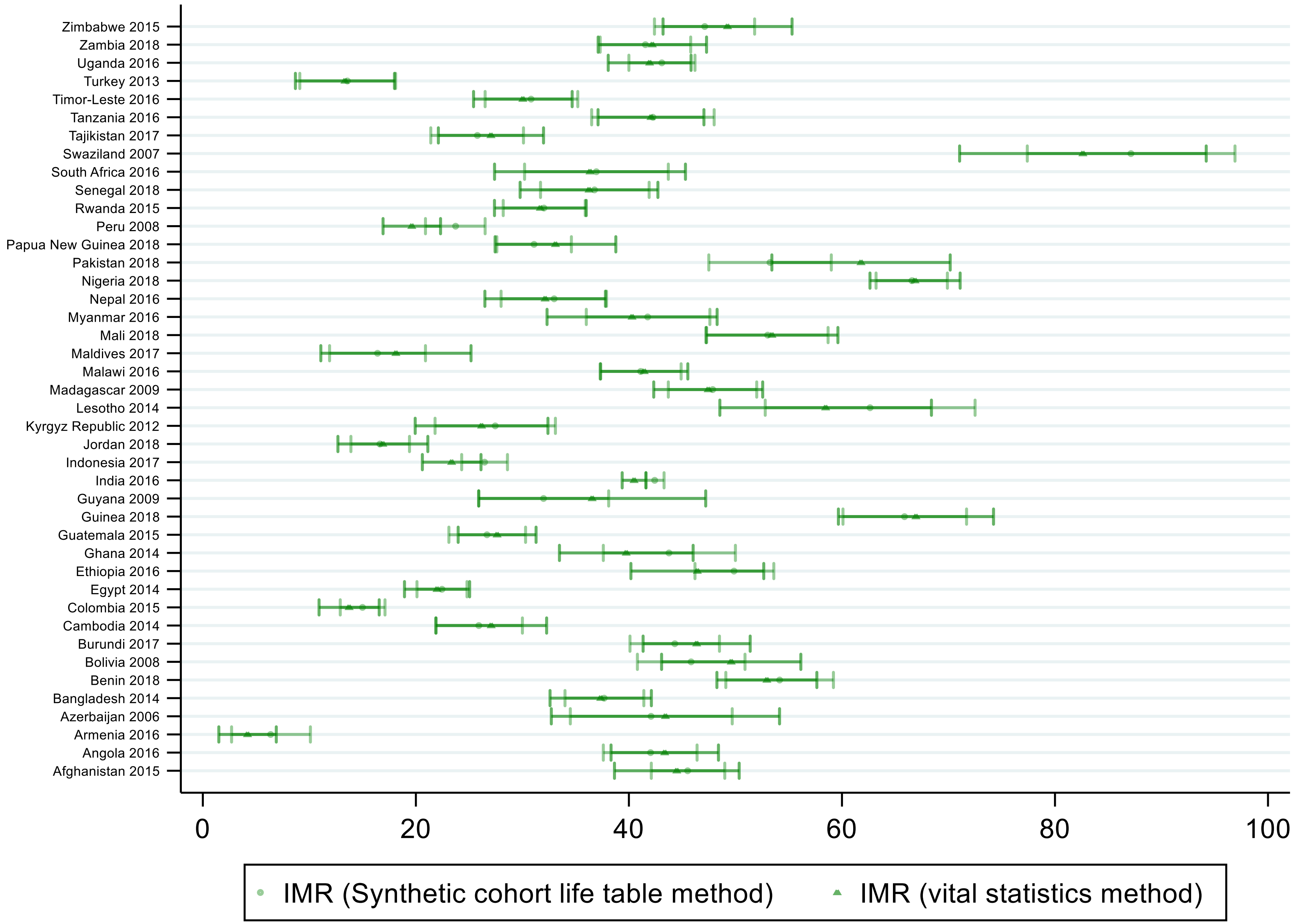
Appendix

Table A1. DHS stillbirth and early neonatal mortality rates with confidence intervals, by country



Note: The stillbirth rate is the number of stillbirths out of 1000 pregnancies that reached 7 months of gestation or more. The early neonatal mortality rate is the number of deaths in the first seven days of life out of 1000 pregnancies that reached 7 months of gestation or more. Estimates are calculated using survey weights, and 95% confidence intervals are calculated using standard errors that are clustered at the level of the primary sampling unit. Data source: Demographic and Health Surveys (DHS).

Table A2. DHS IMR estimates using synthetic cohort life table method and vital statistics method with confidence intervals, by country



Note: IMR calculated using the synthetic cohort life table method and the vital statistics method are very similar. Estimates are calculated using survey weights, and 95% confidence intervals are calculated using standard errors that are clustered at the level of the primary sampling unit. Data source: Demographic and Health Surveys (DHS).