EXPLANATORY NOTES

STILLBIRTH TREND SERIES TO 2019

United Nations Inter-agency Group for Child Mortality Estimation:
UNICEF, the WHO, the UN Population Division and the World Bank Group

October 2020

IGME

The United Nations Inter-agency Group for Child Mortality Estimation (UN IGME), which is led by UNICEF and includes members of the World Health Organization (WHO), the United Nations Population Division, and the World Bank Group, was established in 2004 to advance the work on monitoring progress towards the achievement of child survival goals regarding child mortality.

Since 2018, UN IGME has been working on estimating stillbirth indicators. Stillbirths are a marker of maternal health, as well as access to quality care during pregnancy and around the time of birth. Ending preventable stillbirths is one of the core goals of the UN's Global Strategy for Women's, Children's and Adolescents' Health (2016–2030)[1] and the Every Newborn Action Plan (ENAP).[2] These global initiatives aim to reduce the stillbirth rate to 12 or fewer third trimester (late) stillbirths per 1,000 total births in every country by 2030.

\The UN IGME released the stillbirth estimates in October 2020. These estimates will also be published in the next issue of UNICEF's *The State of the World's Children* and in the WHO's Global Health Observatory.

Estimates by the UN IGME may differ from the official statistics by Member States, which may use alternative equally rigorous methods.

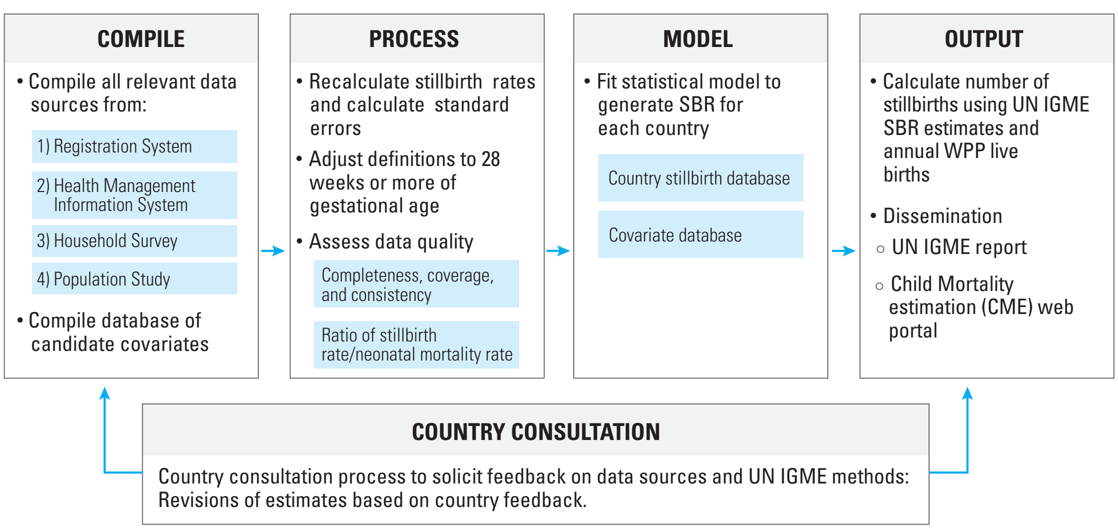
1. Strategy

The UN IGME's approach to estimate stillbirth rates (SBR) includes the following steps

1. Compile all available stillbirth data at a country level, derived from administrative sources, household surveys or population-based studies.
2. Evaluate data in accordance with the data quality criteria and produce adjustment or recalculation by applying standardized definitions.

Estimate global and country-specific trends of stillbirth rates using a smoothing time series model, supplemented with covariates associated with stillbirth rates. This process averages empirical data on stillbirths derived from the different sources for a given country. In the case of countries with sparse or no data, the identified covariates associated with stillbirth will inform the trend in stillbirth rate.

Figure 1: UN IGME approach



[i] Throughout the document, 'stillbirth' refers to third trimester (late) stillbirth.

To increase the transparency of the estimation methodology and make stillbirth data available to users worldwide, UN IGME makes all data sources and stillbirth estimates available on its web portal at www.childmortality.org.

2. Stillbirth concept and definition

In the UN IGME estimation work, consistent with International Classification of Diseases (ICD)[3], only 'late gestation fetal deaths' are included in UN IGME international stillbirth monitoring. The **stillbirth rate (SBR)** is defined as the number of fetal deaths at 28 weeks or more of gestation, per 1,000 total births.

The stillbirth rate is calculated as:

$$SBR = 1000 * \frac{sb}{(sb + lb)}$$

sb refers to the number of stillbirths ≥ 28 weeks of gestational age

lb refers to the number of live births regardless of gestational age or birthweight

As stillbirth rates using gestational age are not equivalent to those using birthweight criteria, to improve comparability of stillbirth data from different countries the Core Stillbirth Estimation Group (CSEG) of UN IGME recommends using a stillbirth definition that uses the gestational age as single criteria. Gestational age is used in preference to birthweight and length criteria as it is a better predictor of maturity and hence viability and is the most commonly used criteria across data sources including household surveys.

3. Data sources

Estimates of stillbirth rates for a country can be derived from various sources, such as administrative data (e.g. vital registration systems, birth or death registries, or health management information systems), household surveys, or from population-based studies obtained from a review of academic literature.

Data from registration systems are the preferred data source for estimating stillbirths by UN IGME. The reliability of stillbirth estimates depends on the accuracy and completeness of reporting and recording of births and deaths. Not all countries maintain a timely and complete registration system for stillbirths. As a result, stillbirth data from registries can be biased due to underreporting or misclassifications. Moreover, in many low- and middle-income countries (LMIC), stillbirths are not reported in registration systems at all.

Household surveys, such as the United States Agency for International Development (USAID)-supported Demographic and Health Surveys and the UNICEF-supported Multiple Indicator Cluster Surveys and other nationally-representative surveys, are another source of data on stillbirths in LMICs. In addition, in several LMIC countries, data from population-based studies provide an important data source on stillbirths.
Data on stillbirths are systematically collected and compiled by UN IGME: the current database contains time series of stillbirth rates which started in the year 2000. In total, the empirical data is available for 171 countries.

Administrative data

The majority of administrative data comes from registration systems and health data systems including health management information systems (HMIS). (*Data sources 1 in Figure 2*). Often data from registration systems record stillbirths and live births using detailed gestational age and/or birthweight. HMIS data are collected in health facilities and in many countries, the District Health Information System-2 (DHIS2) is the commonest HMIS data platform.[4] Few HMIS

Box 1: Key terms

Stillbirth: A stillbirth is a baby born with no signs of life after a given threshold. Stillbirth is classified as either early or late gestational stillbirth. An early stillbirth occurs at 22 to 27 completed weeks of gestation and a late stillbirth occurring at 28 weeks or more of gestation.

Gestational age: Gestational age is defined as the duration of pregnancy, measured from the first day of the last normal menstrual period. Gestational age at birth is therefore the duration measured from the first day of the last menstruation period to the day of birth.

Birthweight: Birthweight is defined as the first weight of a baby after birth. This weight should be measured as soon as possible in the hours after birth prior to onset of postnatal weight loss.

Live birth: Live birth refers to the complete expulsion or extraction from its mother of a product of conception, irrespective of the duration of the pregnancy, which, after such separation, breathes or shows any other evidence of life - e.g. beating of the heart, pulsation of the umbilical cord or definite movement of voluntary muscles - whether or not the umbilical cord has been cut or the placenta is attached.

Figure 2: Data sources for stillbirth data in countries

1. Administrative data

Collected data from registration systems and health data systems including data from Health Management Informative Systems

2. Household survey data

Collected data through pregnancy histories or reproductive calendars

3. Population study data in LMIC

Literature review of population studies

systems currently report detailed gestational age and/or birthweight data on stillbirths.

Household survey data

Information on stillbirths in household surveys can be collected in two different ways: with a full pregnancy history; or with a reproductive calendar (*Data source 2 in Figure 2*).[5] In the pregnancy history (PH), women of reproductive age are asked about all pregnancies in their lifetime. For each pregnancy they are asked to provide information on the duration of the pregnancy, the outcome of the pregnancy (e.g. miscarriage, stillbirth or livebirth) and the date of birth or end of pregnancy. In the reproductive calendar (RC), women are asked about the duration and month of pregnancy end for pregnancies that did not end in a live birth in the last 60 months. RCs are usually administered alongside a full birth history.

In pregnancy histories, the stillbirth rate is the number of stillbirths with the end of the pregnancy in the seventh month or later divided by the number of stillbirths plus livebirths. In some surveys with PH modules the women were only asked whether they had a stillbirth and the date of the stillbirth. In these cases, a seven month duration of pregnancy was assumed. In some survey-specific cases, a stillbirth was defined by the questionnaire as a fetal death occurring at the fifth or sixth month or later. In reproductive calendars the stillbirth rate is the number of pregnancies that are terminated in the seventh month or later of pregnancy divided by the number of pregnancies that reached at least the seventh month. PH data allow the calculation of stillbirth rates for specific time periods in the past. Where the microdata were available, UN IGME recalculated the stillbirth estimates with standard errors from PH and RC. For PH data, the stillbirth estimates for 5-year calendar periods, for 5 intervals (e.g. 25 years), before the survey date were calculated. The most recent 5-year calendar period was included in the estimation model. The RC data allow the calculation of stillbirth rates for the 5-year period preceding the survey. However, stillbirth estimates from the RC were not included in the model if estimates from the PH in the same survey were available.

Population studies on stillbirth

Another source for data on stillbirths is sub-national population-based studies (*Data source 3 in Figure 2*). Sub-national population-based study data were sought for all countries without high coverage of routine administrative data. The literature review undertaken for the previous stillbirth estimates[6] was updated through to 29 January 2019. In addition, further reanalysed population-based stillbirth data were obtained from a WHO data call to maternal-newborn health experts.

Comparability of stillbirth data across data sources

The lack of a standard application of definitions for stillbirth in many data sources results in comparability challenges for the assessment of stillbirth rates between settings and over time. Stillbirths are reported by different gestational age week cut-offs, ranging from 16 weeks to 28 weeks or more, or by birthweight ranging

Table 1: Selected covariates indicators and data sources

Indicator	Data source
Antenatal care 4+ visits: Percentage of women (age 15–49) attended at least four times during pregnancy by any provider.	WHO/UNICEF: DHS, MICS and other national household surveys
C section rate: Percentage of deliveries by Caesarean section	UNICEF: DHS, MICS, and other national household surverys
Low birthweight: Percentage of live births that weighed less than 2,500 grams (less than 5.51 pounds).	UNICEF/WHO Low birthweight (LBW) estimates, 2019 Edition
Mean years of schooling (female): Average number of years of education received by females ages 25 and older, converted from educational attainment levels using official durations of each level.	UNDP: Estimated by Barro and Lee (2016) using population census, MICS, DHS and other national surveys
Neonatal mortality rate: Probability of dying in the first 28 weeks of life, expressed per 1,000 live births.	UN IGME: Modelled based on data from vital registration, household survey and population census
GNI per capita based on purchasing power parity (PPP). PPP GNI is gross national income (GNI) converted to international dollars using purchasing power parity rates.	World Bank: World Development Indicators database, World Bank

from 500 grams to 1,000 grams or more, or by a combination of gestational age and birthweight. In several cases no clear definition in the data source is given. Using different gestational age and birthweight thresholds will inevitably produce different estimates of the stillbirth rate. Missing information on gestational age or birthweight can also impact overall data comparability, especially when the proportion missing such information is large. As a result, UN IGME adjusts stillbirth data to the 28 weeks of gestation or more definition, taking into account missing gestational age or birthweight data where possible (see section 4.2).

Covariates

To inform stillbirth rates in the case of countries with little or no data, the estimation model included factors associated with stillbirth rates as covariates. The candidate covariates were based on a conceptual framework identified from published literature in 2016 by Blencowe et al.[6] The framework includes distal determinants such as socio-economic factors, interacting and overlapping demographic and biomedical factors, associated perinatal outcome markers and access to health care. The covariate data are smoothed with a time series trend to reduce small fluctuations in measured covariates. The covariates which had the most explanatory power were selected for inclusion in the model. *Table 1* lists the selected covariates for the estimation model.

4. Methodology to estimate stillbirth rates

To reconcile differences across data sources and better account for the systematic biases associated with the various types of data inputs, members of the Core Stillbirth Estimation Group (CSEG) of UN IGME have developed a new approach to make decisions regarding data exclusion, analyse the definitional adjustments needed and fit a smoothed trend curve to a set of observations that are described below. The estimated trends are extrapolated to provide estimates through to 2019.

4.1 Data quality assessment

The UN IGME assessed the quality of the stillbirth data from the four types of data sources used to evaluate completeness and consistency. Data were excluded if: they lacked a clear source of definition or clear information on data collection systems; a high proportion of reported stillbirths had unknown gestational age or birthweight; data were internally inconsistent; or coverage of live births in administrative data systems was estimated below 80 per cent. Vital registration data with incomplete coverage of child deaths were also excluded. Consistency across data sources was further assessed by comparing stillbirth estimates to similar data sources within the same country and expected global and regional patterns in mortality.

As part of the assessment of data quality, the plausibility of the ratio of stillbirth rates (measured as per 28 weeks of gestation or more definition) to neonatal mortality rates was assessed, by comparing these ratios to the distribution of ratios obtained from high-quality LMIC study data. High-quality LMIC study data is defined as population-based prospectively-collected data with recruitment prior to 28 weeks of gestation, and follow-up to at least 28 days of age of live births.

In assessing the SBR:NMR ratio in the input database, the NMR from the data source was used where available. Where data sources had missing NMR data, the estimated NMR by UN IGME[7] was used. For observations from HMIS and population studies on stillbirths, the ratio of observed SBR to the UN IGME NMR was calculated and the same exclusion approach applied so that observations with extremely low SBR compared to national level NMR were excluded. In summary, the mean and variance of the setting-specific SBR:NMR ratios is estimated, assuming that each observed SBR:NMR ratio is the sum of a setting-specific SBR:NMR ratio and random stochastic error.

If stillbirths were under-reported relative to neonatal deaths for a specific observation, its associated observed ratio of SBR to NMR would be lower than the true ratio. To quantify whether an observed ratio is ‘extremely’ low, the probability of observing a ratio that is smaller than the observed ratio was calculated (taking account of the uncertainty associated with the observed ratio) using the distribution of ratios obtained from the high-quality data. If this probability was less than 0.05, the observation was excluded from the database. This approach was applied to all observations in the database with 28 weeks of gestation or more definitions and adjusted 28-week definitions.

4.2 Definitional adjustment of stillbirth data

SBR estimates are constructed based on using a stillbirth at 28-week gestation or more definition. If information based on the 28-week definition was not available, observations recorded using alternative definitions are adjusted as described below prior to being used in the model fitting. Bias and additional uncertainty associated with alternative definitions are taken into account in the model fitting for such observations.

For LMIC, high-quality data from LMIC studies were used to calculate the conversion, while for high-income countries, national administrative data were used. For each conversion, the mean and variance associated with the ratio of the expected SBR, based on an alternative definition to the expected SBR based on the 28 weeks of gestation or more definition, is estimated. The mean is used as a bias-adjustment parameter in the model fitting, and the variance is used to account for additional uncertainty associated with the alternative definition.

Data limitations necessitated some assumptions regarding definitional adjustments. For survey data, a seven-month duration of pregnancy is assumed to be equal to a 28 weeks or more definition. Further, in LMICs it is assumed that the SBR observed using a stillbirth definition of a birthweight of 1,000 grams or more is equal to the SBR observed using the 28 weeks of gestation or more definition, and similarly that the SBR observed with a birthweight of 500 grams or more definition equals the SBR observed with a 22 week of gestational age or more definition.

4.3 Estimation of stillbirth rates

Estimation and projection of stillbirth rates is undertaken using a statistical model for all country-years. In the model, the SBR is estimated assuming that the

Observed log(SBR) = log (true SBR) + bias + measurement error

where the true SBR in a country for years 2000 to 2019 = country-intercept + SBR predicted by covariates + country-specific temporal smoothing process (explained further below). The model produces estimates of the SBR for years 2000 to 2019 with uncertainty.

True SBR component

The model for the true SBR includes three terms: (1) country-intercept; (2) SBR predicted by covariates; and (3) country-specific temporal smoothing process. Covariates were used to inform SBR levels and trends, i.e., the NMR is found to be predictive of SBR, NMR-driven estimates of the SBR are higher in country-periods with higher NMR. *Figure 3* illustrates how the trend estimates (green) are a weighted combination of information from country data and covariates. If data are precise, the SBR estimates follow the country data. In the case of no data or imprecise data, the estimates are covariate based.

Country-year estimates can deviate from covariate-based ones through the country intercept and the temporal smoothing process. The country intercept is estimated using a multilevel model so that information on the level of SBR is exchanged across countries within the same region.[8] For countries with data meeting inclusion criteria, the intercept is a weighted average of country data and the regional intercept, with weights taking account of the quantity and uncertainty associated with the country data and the variability of the estimated country intercepts. The process results in data-driven intercepts in countries with precise data. For countries without data included, the intercept is equal to the regional intercept. The temporal smoother allows deviations away from 'covariate + intercept-based' estimates based on the data so that estimates can follow precise data where available.

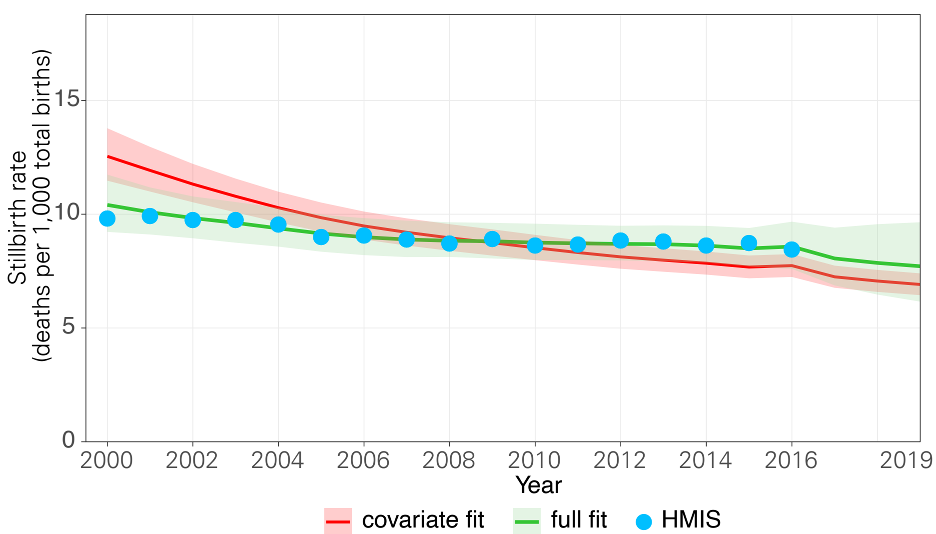
Bias component

The *bias* refers to the *definitional adjustment bias + source type bias*, where *definitional adjustment bias* is equal to zero for observations based on the 28 weeks of gestation or more definition and given by estimated adjustments (4.2), and the *source type bias* is equal to zero for all observations except for observations from surveys. In the model fitting, bias terms are included to account for the bias associated with use of definitions other than the 28 week of gestation or more definition, and with the use of different types of data source.

Measurement error component

To account for *measurement error*, varying levels of uncertainty (error variance) affect the weighting of individual observations in the model. Observations with lower error variance carry a higher weight in determining estimates as compared to observations with higher error variance.

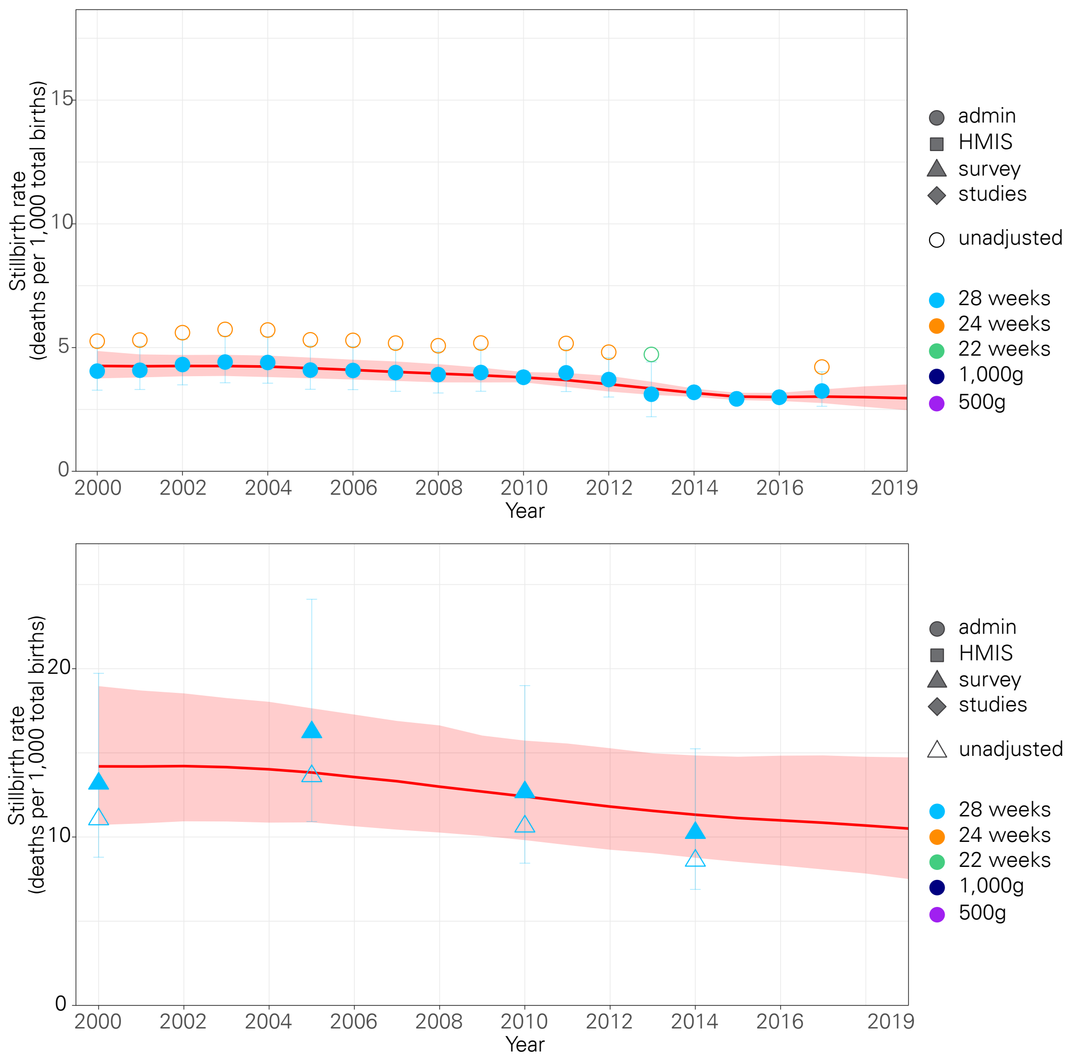
Figure 3: Covariates and country data



Note: The above figure shows estimated SBR trends with 90% uncertainty intervals and source data. The dots represent observed SBR data in the country. The red line shows the estimated SBR trend based on model covariates alone with the uncertainty interval shown with the pink shaded area. The green line, with the uncertainty interval shown with the light green shaded area, shows the estimated SBR trend based on the country-specific data, via a country-specific intercept, and applying temporal smoothing process to the red line. Note that the green line more closely fits the observed data, as it is a weighted combination of the covariate estimates and country data.

The measurement error refers to the stochastic/sampling error + random definitional adjustment error + source type error, where each error is expected to be zero on average, but has a variance term associated with it that reflects how much uncertainty is associated with the error. The stochastic/sampling error is due to observing a finite number of events and/or survey sampling design, the random definitional adjustment error which is equal to zero for observations based on the 28 weeks or more of gestation definition and non-zero otherwise. The source type error refers to a random error with source-type specific variance, to account for random errors that may

Figure 4: Estimated uncertainty in country data and trend estimates



Note: The above figures illustrate the bias component and measurement error incorporated into SBR estimates. The top panel shows data with definitional adjustments applied. The hollow orange and green circles show unadjusted SBR country data using a non "28-weeks or more of gestation" definition (e.g. 22- or 24-week definition). To use the observed, non-28 weeks SBR data in the model fitting procedure, a definitional adjustment is applied, resulting in an adjusted SBR with a 28-weeks definition. Bias adjusted SBR data are indicated by the solid blue circles with the respective standard errors shown with the vertical bands. Note that the standard error around adjusted data points is larger than for data points where no definitional adjustment is applied (e.g. adjusted 2012 data point versus unadjusted 2014 data point), due to the added measurement error from bias adjustment.

The bottom panel shows data with source type adjustments applied. Household surveys have been shown to underreport SBRs, thus observed SBRs and corresponding standard errors obtained from surveys are adjusted. The hollow triangles show the observed SBR from the survey, and the filled triangle show the adjusted SBR. The adjusted standard errors include the source type specific measurement error and are represented with the vertical lines extending from the solid triangles.

occur in the data collection process and potential non-representativeness of the observation. The different data source types are (1) national administrative, (2) HMIS, (3) household surveys, and (4) population studies.

The uncertainty associated with the measurement error in the SBR estimates depends on data availability and precision for the respective country-period; uncertainty decreases as data availability and precision increases. Uncertainty in SBR estimates increases when extrapolating to periods without data.

Figure 4 shows the effect of varying levels of uncertainty associated with different observations. The dots show country data by definition and source type and the vertical line illustrates uncertainty associated with each observation. The red line is the trend estimate and the pink area represents the uncertainty. Varying levels of uncertainty (error variance) affect the uncertainty in final estimates. Observations with lower-error variance carry higher weight in determining estimates compared to observations with higher-error variance.

5. Calculation of stillbirths

The number of stillbirths in each country is calculated using the following formula: Number of stillbirths=live births * SBR/(1-SBR). The annual estimate of the number of live births in each country from the World Population Prospects: the 2019 revision[9] are used along with the UN IGME SBR estimates to calculate the estimated numbers of stillbirths.

References

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