A New Method for Deriving Global Estimates of Maternal Mortality: Supplemental Report

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1 Introduction

This report provides supplemental information on data sources, data quality and adjustment, and various methodological details to accompany a published article (Wilmoth et al., 2012). It also includes supplemental tables and graphs that are referenced in that article.

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2 Information about Data Sources

In this section we provide a more detailed discussion of the various data sources used in this study for measuring maternal mortality.

2.1 Civil Registration

A civil registration system records the occurrence of vital events for both legal and statistical purposes. Certification of deaths generally includes identifying the underlying cause of death according to the rules and conventions of the International Statistical Classification of Diseases and Health Related Problems, or ICD (World Health Organization, 2004). Periodic updates of this system reflect changes in medical knowledge and understanding, with the most recent revision being the tenth (ICD-10).

Almost all countries have a legal framework that establishes a civil registration system with the intention of recording complete, accurate and timely information. However, even where coverage is complete (i.e., 100 percent of deaths are recorded) and where cause of death is identified using standard medical certificates, maternal deaths are often misclassified and therefore underreported. A common problem is the failure to indicate on the death certificate that the deceased was pregnant.

In some countries confidential inquiries have been used to identify the extent of misclassification of maternal deaths in the registration system, yielding the adjustment factors used for this study (see Section 3 of this report). The results of such inquiries suggest an upward adjustment of around 50 percent of recorded maternal deaths, even in countries with generally reliable data systems.

2.2 Survey Data about Survival of Respondents' Sisters

This approach, commonly referred to as the direct sisterhood method, is a special case of the sibling method, which has been used for estimating adult mortality in countries that lack complete and reliable civil registration system. In general the sibling method obtains information by interviewing respondents about the survival of all their siblings, recording the age of all living siblings, and the age and year of death of those deceased. Among sisters who died when at least 12 years of age, a follow-up question is used to determine if the death occurred during pregnancy, delivery, or within two months of the end of the pregnancy (in practice, a two-

month interval serves as a proxy for the 42-day period specified in the official definition of maternal or pregnancy-related deaths).

This approach identifies pregnancy-related deaths, which includes all deaths during pregnancy, childbirth, and the puerperium regardless of cause, and thus some downward adjustment is needed to estimate maternal deaths (by removing accidental and incidental deaths). At the same time, it is widely believed that some pregnancy-related deaths go unreported when using this method, so that some form of upward adjustment is required as well. In this study such data were adjusted first by multiplying observed values by 1.1 to correct for underreporting; we removed 10 or 15 percent of the remaining deaths (depending on region) to account for accidental and incidental deaths.

The direct sisterhood method generally produces estimates referring to a seven-year period preceding the survey. This is the standard approach currently used in the Demographic and Health Surveys (DHS) and the Multiple Indicator Cluster Surveys (MICS).

2.3 Survey Data on Recent Household Deaths

Some surveys have collected information on the occurrence of deaths in the household over some specified period preceding the survey (generally a year or two). When the decedent is a women of reproductive age (12 to 49 years in general), an additional question seeks to determine whether the death occurred during pregnancy, delivery or within 42 days (or two months) after the pregnancy. More precise information about cause of death can be obtained using a verbal autopsy (see below). Like survey data from the sisterhood method, it is thought that such information both over- and undercounts maternal deaths, and thus similar adjustment factors were applied in this study.

Because maternal deaths are relatively rare events even in disadvantaged populations, such surveys require very large sample sizes. The cost is often prohibitive, and therefore this approach is much less common than the sisterhood method.

2.4 Census Data on Recent Household Deaths

A national census offers the possibility of collecting information about recent household deaths free of sampling variability. The UN Statistical Division has recommended this approach for the 2010 round of censuses for countries lacking complete and reliable registration data (United Nations Statistics Division, 2007).

The same comments about over- and underreporting mentioned earlier apply in this case as well.

A major drawback to this approach results from the fact that a census is a major operation and occurs, typically, only once in ten years for most countries. Therefore, census data cannot provide timely information about maternal mortality in other years, and they represent a small fraction of the data analyzed here. Furthermore, since a census collects information on a wide range of topics, it is difficult to assure the quality of the resulting data on pregnancy-related deaths; the training of enumerators is crucial.

2.5 Periodic Inquiries, or RAMOS-type Studies

Periodic inquiries are single, stand-alone studies conducted with the objective of identifying all deaths of reproductive-age women occurring within a defined geographic area over some specified time period. In practice, such an inquiry is often referred to as a "reproductive-age mortality study" or RAMOS. The ideal starting point for such a study is a complete listing of deaths of women of reproductive age, if available from vital registration or some other source. A key feature of an inquiry is triangulation among data sources (e.g., church records, tombstones) to identify all female deaths in the appropriate age range. Each death is then investigated further to determine whether or not it was maternal, by means of a detailed review of hospital records, health facility case notes, and/or household interviews of family members.

Inquiries may be performed using sampling if an appropriate sample frame is available. An inherent problem results from the need to identify the corresponding number of births for use in computing the MMR. Even lacking information about births, however, such studies can provide useful information about the proportion of maternal deaths among women aged 15-49.

2.6 Surveillance Systems

In the context of maternal mortality, surveillance systems are administrative initiatives used to identify maternal deaths and their causes on a routine basis. Central statistical offices work in conjunction with epidemiology units to identify all deaths among women of reproductive age and to conduct an investigation to determine if the death should be considered a maternal death. Surveillance data are often acquired in a similar fashion to inquiries (see above) but are distinguished by their on-going nature and more systematic approach.

Surveillance studies may also be done via sampling, resulting in data that are representative of different levels of administrative coverage (e.g., local vs. national). One advantage of both surveillance systems and periodic inquiries is that the case-by-case investigative process often yields information about the factors contributing to maternal mortality, by discovering the sequence of events that led to a death, identifying avoidable causes, and suggesting interventions to prevent future occurrences.

2.7 Verbal Autopsy

A verbal autopsy is an interview carried out with family members and/or caregivers of the deceased using a structured questionnaire to elicit signs and symptoms and other pertinent information for determining the probable underlying cause of death. It is a partial solution for countries lacking reliable registration data with proper medical certification of deaths. The WHO provides a standard verbal autopsy questionnaire (number 3) designed to identify all major causes of death among adolescents and adults (ages 15 and above), including deaths related to pregnancy and childbirth. A verbal autopsy can be used as a complement to household surveys, periodic inquiries, or ongoing surveillance.

One limitation of the method is that it may fail to identify maternal deaths occurring early in pregnancy (due, for example, to an ectopic pregnancy or a failed abortion) and indirect causes of maternal death in relation to some other disease process (e.g., malaria, AIDS). In general, the accuracy of results depends on the extent of family members' knowledge of the events leading to death, the skill of the interviewers, and the competence of the medical personnel who make the final diagnosis and choose appropriate codes.

3 Accuracy of Vital Registration Data

For this study, data from civil registration were extracted from the WHO mortality database for years 1985 and after. For data using ICD-10, all deaths classified in chapter O (excluding O96 and O97, which are late maternal deaths) plus A34 (maternal tetanus) were retained. These correspond to codes 630-676 in ICD-9.

With such data maternal deaths are often undercounted due to misclassification of cause of death. To determine the true number of maternal deaths, several countries have conducted special inquires, or RAMOS-type studies (see Section 2.5 of this report). The overall procedure for the assessment consists of comparing

the number of deaths recorded as maternal within the registration system to those so classified in a specialized study. The studies performed in this context are diverse along multiple dimensions: the definition of maternal mortality that is applied, the sources considered (e.g., death certificates, other vital event certificates, medical records, questionnaires, autopsy reports), and the way in which maternal deaths are identified (e.g., record linkage, assessment from experts). Similarly, there are differences in the reporting of causes of death by a civil registry, resulting from variations in the death certificate forms, the type of certifiers, and coding practices.

The table in Appendix 1 of World Health Organization et al. (2010) summarizes the results of a literature review that we conducted to identify studies of the misclassification of maternal deaths. Based on this review, we constructed adjustment factors to correct for misclassification of maternal mortality in registration data, ranging from 0.9 to 3.2 with a median value of 1.5. For countries that have conducted such studies, we used a country-specific adjustment factor (computing a mean value if there were multiple studies). For registration data from all other countries, we used the median factor of 1.5.

Misclassification of maternal deaths leading to underreporting was found to be most common in the following situations:

- Deaths in early pregnancy (because they are not linked to a reportable birth outcome);
- Deaths in the later postpartum period (because the temporal nature to pregnancy is not indicated on the death certificate); and
- Deaths due to indirect maternal causes in relation to cerebrovascular or cardiovascular diseases (because the ICD codes from the relevant chapters are not reviewed regularly to determine if the death has a maternal component).

Potential reasons cited for underreporting or misclassification include an inadequate understanding of ICD rules (either ICD-9 or ICD-10), a failure to mention a pregnancy on the death certificate (e.g., non-use of the pregnancy check-box), and a desire to avoid litigation or to suppress information (especially in cases involving abortion).

4 Age-Standardization of Sisterhood Data

Here, we describe the procedure used to compute the proportion of maternal deaths, PM, from detailed survey data on the survival (or death) of respondents' sisters (i.e., direct estimation using sisterhood data). Such data were taken directly from published reports, in most cases of the Demographic and Health Surveys (http://www.measuredhs.com/).

Let M_x^{all} and M_x^{mat} be survey-based estimates of all-cause and maternal mortality at age x (or for some age group). Assuming the two quantities refer to the same time interval, the unadjusted PM would computed as follows:

$$\text{PM} = \frac{\sum_{x=15}^{49} W_x M_x^{mat}}{\sum_{x=15}^{49} W_x M_x^{all}} \tag{S.1}$$

where W_x is the female population exposed to risk at age x. In practice, these calculations were performed using data for 5-year age groups (15-19, ..., 45-49).

Given the study design (based on sisters of respondents), the population exposed to risk may be atypical of the population at large. Therefore, we computed an age-standardized value of PM, based on the female population of households at time of survey (which should be more typical). Let P_x be the proportion of this population at age x. Then, the age-standardized value of PM is obtained as follows:

$$\text{PM} = \frac{\sum_{x=15}^{49} P_x M_x^{mat}}{\sum_{x=15}^{49} P_x M_x^{all}} \tag{S.2}$$

In most cases the time references for published values of M_x^{all} and M_x^{mat} are the same. In those cases where they differ, we have used an average interval as the time reference for purposes of this study (i.e., the starting point of the interval equals the average of the two starting points, and the same for midpoints and endpoints of the interval).

5 Constructing the Dependent Variable

After adjustment for under- or misreporting of events, plus age-standardization in the case of direct sisterhood data, the adjusted PM values were used for creating the dependent variable of the multilevel model. Further preparations were necessary to remove: (1) AIDS deaths whether connected to the pregnancy or not, and (2) non-AIDS deaths that were accidental or incidental to the pregnancy.

Thus, the dependent variable is $\log(\mathrm{PM}_i^{na})$, where $\mathrm{PM}_i^{na} = \mathrm{PM}_i^{*}/(1-a_i)$ and

$$\mathrm{PM}_i^{*} = \begin{cases} \mathrm{PM}_i^{\mathrm{adj}} - \tilde{u}_i v_i a_i & \text{if “maternal”} \\ (\mathrm{PM}_i^{\mathrm{adj}} - v_i a_i)(1-\pi_i) & \text{if “pregnancy-related”} \\ \mathrm{PM}_i^{\mathrm{adj}} - v_i a_i & \text{if “preg.-related, no accidents”} \end{cases} \tag{S.3}$$

In earlier works PM_i^{na} was called AMDF_i^{na}, while PM_i^{*} was known as PMDF_i^{na}.

The three cases of equation (S.3) correspond to the categories of pregnancy-related deaths that are typically included in available data. In the first case, only deaths meeting the true definition of a “maternal” death are included, whereas in the second case, all deaths that occur during pregnancy are included. The third case differs from the second one in that accidental deaths have been excluded.

For each observation, a_i refers to the estimated fraction of AIDS deaths among all deaths occurring to women aged 15-49, and v_i refers to the estimated fraction of AIDS deaths in this age range that occur among pregnant women (see equation 14 of the main paper). The quantity $\tilde{u}_i$ is similar to the parameter u that is used for deriving final estimates of maternal mortality (equation 13 of the main paper). However, whereas u is a universal parameter representing the fraction of AIDS deaths during pregnancy assumed to have been aggravated by the conditions of pregnancy (such that they qualify as true “maternal” deaths) and thus reflected in our final estimates, $\tilde{u}_i$ is a value associated with a given observation and represents the fraction of AIDS deaths during pregnancy that were presumably included within the observed datum. Thus, $\tilde{u}_i$ is relevant only in the “maternal” case; it equals one and is therefore omitted from equation (S.3) in the other two cases.

6 Annual Series of Predictor Variables

In order to estimate the multilevel regression model and use it to estimate trends, we collected or created complete series of annual estimates for the three predictor variables during 1988-2010.

6.1 Gross Domestic Product per capita (GDP)

The GDP variable used here is expressed in constant 2005 international dollars, or units of purchasing power parity (PPP), with most data provided by the World Bank. For years 1985-2008, published data from the World Bank were used without any manipulation (World Bank, 2010). For years 2009-2010, projected series in international dollars were not available. Therefore, the projected World Bank series of GDP per capita in constant 2005 US dollars was converted to international dollars (PPP) using PPP conversion factors. Furthermore, since the population figures used to calculate the projected GDP per capita differed from those used to calculate the estimates for the earlier years, we corrected for the inconsistency by multiplying the projected GDP per capita by the associated population estimates to obtain the total GDP, and then dividing the total GDP by population estimates from the same series used to estimate GDP per capita for the earlier period.

Data for countries not included in the World Bank dataset were obtained from other sources. Since the World Bank dataset used for most countries in the analysis did not contain estimates for Myanmar, data from an older set of World Bank estimates were used. For Afghanistan, Bahamas, Cuba, Iraq, Puerto Rico, Somalia, and Zimbabwe, GDP estimates were obtained from the Penn World Tables Version 6.3 (Heston et al., 2009). For North Korea, estimates of total GDP from the World Health Organization were divided by population estimates from the World Bank to obtain the values of GDP per capita used for this analysis.

In many cases, a complete annual series for the period between 1985 and 2010 was missing mostly because data from earlier years were lacking, or because the projected GDP estimates were not available, or both. In these cases, the data were interpolated to produce one-year estimates according to the following set of rules:

- Estimates before the first observation were assumed equal to the first observation;
- If the desired time reference fell between the reference points of two observations, the estimated value was calculated by linear interpolation between the two observations; and
- Estimates after the last observation were assumed equal to the last observation.

6.2 General Fertility Rate (GFR)

The GFR was calculated using data from the United Nations Population Division (United Nations Population Division, 2009). As with the GDP, annual series of live births and female population aged 15-49 were constructed directly using the UN data. Then, weighted averages of annual values for both births and female population were computed corresponding to each observed PM value (see section 6.4 of this report). Finally, the time-matched value of the GFR was obtained by dividing the average number of births by the average female population size for the interval.

6.3 Skilled Attendant at Birth (SAB)

According to the MDG manual, the proportion of births attended by skilled health personnel (SAB) is defined as "the percentage of deliveries attended by personnel trained to give the necessary supervision, care and advice to women during pregnancy, labor and the postpartum period; to conduct deliveries on their own; and to care for newborns" (United Nations Development Group, 2003). Furthermore, the manual limits the qualified health personnel to "those who are properly trained and who have appropriate equipment and drugs. Traditional birth attendants, even if they have received a short training course, are not to be included."

Available SAB data originate from health surveys and other sources. The information used for this analysis was obtained from a database maintained by UNICEF (UNICEF, 2010). Although other sources of SAB data were consulted, only the UNICEF data were used because they adhere strictly to the definition given above.

Multiple SAB observations are available for most countries. However, since the data are collected only periodically through surveys or other means, they refer to various time intervals. Annual data series were constructed by fitting a linear logit (i.e., linear log-odds) model of the SAB proportion with time as the sole covariate. Such a model was estimated separately for each country.

When a country had only one observation, it was assumed that the SAB proportion remained constant over time. For some countries where the linear logit model did not fit well (including Fiji, Guyana, Montenegro, New Zealand and Thailand), annual values were estimated using the interpolation algorithm described above for producing one-year GDP estimates for countries with limited data. For the following countries, we had no properly documented SAB data:

Cyprus, Germany, Denmark, Greece, Iceland, Israel, Italy, Norway, Puerto Rico, Spain, Sweden, and Switzerland. We assumed access to a skilled attendant at birth was universal in these countries and assigned a value of one to the SAB for all time points.

There were 12 countries (7%) with no SAB observations, 18 countries (10%) with one SAB observation, 24 countries (14%) with two observations, and 118 countries (69%) with three or more observations.

6.4 Multi-year Averages of Predictor Variables

For estimating the regression model, we computed average values of predictor variables over time intervals corresponding to each of the 484 dependent observations. In general, each of the time-matched covariate values equals a weighted average of annual estimates, with weights equal to the fraction of the total observation interval contained in the given year. For example, if an observation interval for the dependent observation extends from 1 June 2000 through 31 May 2003, the time-matched GDP equals:

$$\frac{1}{3}\left[\frac{7}{12}\mathrm{GDP}_{2000}+\mathrm{GDP}_{2001}+\mathrm{GDP}_{2002}+\frac{5}{12}\mathrm{GDP}_{2003}\right] \tag{S.4}$$

For an observation interval of less than one year, the time-matched predictor variable equals the (annual) estimate for the year that contains the interval mid-date (rather than an average value if the interval straddles two years).

Similarly, when using the model for predictive purposes, we computed averages values corresponding to the desired time period of the estimates. In these cases, however, simple averages over 5-year time periods were used.

7 Assessing the Uncertainty of Estimates

As described in the main paper, the first step in the assessment of estimation uncertainty was to create by simulation a number of replicates ($N_1 = 100$) depicting the external components of variability. These replicates differ due to simulated random variation in assumptions about parameters and adjustment factors, and in data inputs used for calculations outside the multilevel regression model. Each replicate includes a set of assumptions about the various parameters, adjustment factors, and data inputs, as well as its own data matrices for use in model estimation and prediction. The model was estimated separately for each

replicate, and then a second set of simulations was performed ($N_2 = 10$) to depict the internal components of variability (or the stochastic component in the case of vital registration data).

7.1 Distributional Assumptions for External Uncertainty

The probability distributions used to create the N_1 replicates are described in the following sub-sections.

7.1.1 Adjustment Factors for PM Data

As noted earlier, an adjustment factor was applied to all observations of the proportion maternal, PM, among deaths to women aged 15-49. This adjustment factor was 1.5 for vital registration data (or else some country-specific value), and 1.1 for all other types of data. Each adjustment factor, F, was simulated using a log-normal distribution with a mean located at the assumed value. We assumed that the standard deviation of $log(F)$ was 0.05, and thus that likely errors in these adjustment factors fall in a range of, roughly, plus or minus 10%.

7.1.2 Input Parameters (c, k, u, and π)

Input parameters were represented by log-normal or beta distributions. The beta was used for parameters with values between 0 and 1 only, either by definition as with u and π, or by choice as with k. A log-normal distribution for k seemed overly lopsided, so we used a beta distribution for greater symmetry around the assumed mean value of 0.4. Although in theory k could have any positive value, as reviewed in the main paper the available evidence suggests that it is almost certainly below one.

Thus, three parameters were simulated according to a beta distribution, with assumed means and standard errors as follows:

Parameter	Mean	Standard error
k	0.40	0.15
u	0.50	0.20
π non-SSA	0.10	0.04
π SSA	0.15	0.06

The choice of mean values is explained in the main paper (sections 2.3.3 and 2.7.2). The assumed value for π differs between Sub-Saharan Africa and other regions; note that in relative terms the standard errors for the two values are equal.

Finally, the c parameter was simulated using a log-normal distribution. The assumed value of c used for computing best estimates was 1. For simulating possible errors in this assumption, we assumed that $log(c)$ has a mean and standard error of 0 and 0.04, respectively.

7.1.3 Additional Data Inputs

The number of live births and the number of deaths among women aged 15-49 are additional data inputs needed for converting an estimate of PM into an estimate of MMR. In addition, the estimated proportion of AIDS deaths, a, among all deaths of women aged 15-49 was another necessary data input for calculations that occur outside the regression model. For all three of these data inputs, simulated values were generated for each replicate.

The birth and death counts were assumed to follow a bivariate log normal distribution, with means equal to the logarithm of the estimated values, standard deviations equal to 0.05 (like the adjustment factors), and a correlation of 0.7 (reflecting the fact that both quantities were derived using the same set of population estimates from the UN Population Division). Similarly, we assumed that logit(a) had a normal distribution, with a mean equal to the logit of the estimated value and a standard deviation of 0.05.

7.1.4 Correlation of Errors across Countries

We assumed that the errors for the various external components of uncertainty are likely to show substantial positive but not perfect correlation across countries. That is, if an assumed value is too high for one country, it is likely to be too high as well for many other countries but not necessarily for all countries. In general, two extreme scenarios were judged to be very unlikely: that there is either no correlation or perfect correlation of these errors across countries. These two scenarios, however, were the most convenient to compute, and for this reason we performed all simulations for these two cases only. Thus, for one set of simulations, we drew separate (independent) values for each country; for the other, we drew one value and applied it to all countries (within a given replicate). Our final estimates of all uncertainty intervals are the average of these two sets of results.

In short, we avoided the inconvenience of trying to simulate correlated values in a more general way. Rather, in the absence of evidence about the actual degree of correlation of errors in these assumed values across countries, we took the midpoint of the two extremes (either no or perfect correlation) as our best estimate for all uncertainty intervals. This choice has no effect on uncertainty estimates at the country level but only for regional and global aggregates. When we assume no correlation across countries, the errors made at the country level tend to cancel out in the aggregate, implying less uncertainty for regional and global estimates. When we assume perfect correlation, the regional and global uncertainty is greater because country errors are tied together and do not cancel out.

Although we assumed a positive correlation of error across countries for individual parameters (or adjustment factors), it seems unlikely that there is a significant correlation of errors across these items. On the other hand, there is plausibly a very strong correlation over time within countries for errors associated with a given item. Therefore, we have assumed constant errors over time for a given country and have sampled each item within (a), (b), and (d) independently of the others. The one exception involved estimated counts of live births and deaths of women aged 15-49, which are likely to be correlated (positively) because they are linked to the same set of population estimates: in that case only, we assumed a positive correlation of errors across items.

7.2 Formulas for Simulating Internal Uncertainty

After creating a set of replicates as described above, the second step of the uncertainty evaluation involved estimating the multilevel regression model for each replicate and then simulating distributions of model coefficients. Using these simulated results, we approximated the distribution of the estimated $log(\text{PM}^{na})$ in order to quantify the inferential uncertainty. As noted in section 2.8.2 of the main paper, we did not include the predictive uncertainty associated with an individual data point.

For describing these simulations, let us write the multilevel regression model as follows:

$$y_i = \beta_0 + \beta_1 log(\text{GDP}_i) + \beta_2 log(\text{GFR}_i) + \beta_3 \text{SAB}_i + \alpha^C_{j[i]} + \alpha^R_{k[i]} + \varepsilon_i, \qquad \text{(S.5)}$$

for $i = 1, \ldots n$, where y_i is a shorthand for the transformed dependent variable, $log(\text{PM}^{na}_i)$. The internal uncertainty was derived by simulating a range of values

for each term of equation (S.5) except the error term; such distributions reflect the inferential uncertainty of estimates. For estimating the predictive uncertainty of individual observations, a random draw of the error term is included as well. We did not simulate errors in predictor variables, as it seems that the resulting uncertainty is reflected already in the predictive errors of the regression equation.

The key distributional assumptions of the model are as follows:

$$\varepsilon_i \sim N(0, \sigma_y^2)\ ,\ \alpha_j^C \sim N(0, \sigma_C^2)\ \text{, and }\ \alpha_k^R \sim N(0, \sigma_R^2)\,. \tag{S.6}$$

Table 4 of the main paper provides best estimates of the β parameters, or $\hat{\beta}$. Table 5 includes estimates of the three variance components: $\hat{\sigma}_y$, $\hat{\sigma}_C$, and $\hat{\sigma}_R$. Table A (of this report) gives estimated values for the country and region effects: $\hat{\alpha}_j^C$ and $\hat{\alpha}_k^R$.

Let $\mathbf{\Sigma}$ represent the estimated variance-covariance matrix for the vector of β coefficients. This matrix is shown here in Table E. The β parameters of equation (S.5) were simulated as follows:

$$\underset{\rightarrow}{\beta} \sim N(\underset{\rightarrow}{\hat{\beta}}, \mathbf{\Sigma}). \tag{S.7}$$

Likewise, the α parameters were simulated as follows:

$$\alpha_j^C \sim N\left(\hat{\alpha}_j^C, \left(\frac{n_j^C}{\sigma_y^2} + \frac{1}{\sigma_C^2}\right)^{-1}\right)\ \text{ and }\ \alpha_k^R \sim N\left(\hat{\alpha}_k^R, \left(\frac{n_k^R}{\sigma_y^2} + \frac{1}{\sigma_R^2}\right)^{-1}\right) \tag{S.8}$$

for $j = 1, \ldots, J$ and $k = 1, \ldots, K$, where n_j^C and n_k^R are the number of observations for each country or region, respectively. Note that $n = \sum_{j=1}^{J} n_j^C = \sum_{k=1}^{K} n_k^R$ is the total number of observations. In practice, n, n_j^C, and n_k^R are defined in terms of the total weight for observations in that class; as noted in section 2.6.4 of the main paper, weights for individual observations equal 1 in almost all cases.

The three σ's were allowed to vary across simulations using the following distributional assumptions:

$$\sigma_y^2 \sim \frac{\hat{\sigma}_y^2\, df_y}{\chi^2_{df_y}}\ ,\ \sigma_C^2 \sim \frac{\hat{\sigma}_C^2\, df_C}{\chi^2_{df_C}}\ \text{, and }\ \sigma_R^2 \sim \frac{\hat{\sigma}_R^2\, df_R}{\chi^2_{df_R}}\,. \tag{S.9}$$

We were ourselves uncertain about the proper choice for the degrees of freedom in these formulas; nevertheless, within a reasonable range the exact choice makes

little difference. For these simulations we chose to use the degrees of freedom implied by model output. Thus, the degrees of freedom required for the above formulas were obtained as follows:

$$df_y = \frac{\sum_{i=1}^{I}(y_i - \hat{y}_i)^2}{\hat{\sigma}_y^2}\,, df_c = \frac{\sum_{j=1}^{J}(\hat{\alpha}_j^c)^2}{\hat{\sigma}_c^2}\,, \text{and } df_r = \frac{\sum_{k=1}^{K}(\hat{\alpha}_k^r)^2}{\hat{\sigma}_r^2}\,. \tag{S.10}$$

7.3 Formulas for Simulating Stochastic Uncertainty

The stochastic uncertainty of data from vital registration was assessed by assuming:

$$Var[log(\text{PM})] \approx \frac{1-\text{PM}}{D_{mat}} = \frac{1-\text{PM}}{\text{PM} * D_{all}} \tag{S.11}$$

where D_{mat} and D_{all} represent the number of maternal and total deaths among women aged 15-49, and PM is the probability that a randomly chosen female death in this age range is, in fact, a maternal death. This formula was derived using the delta method assuming a binomial probability model.

8 Country Consultation Process

The generation of global, regional, and country-level estimates of levels and trends in morbidity and mortality is one of the core functions of the World Health Organization (WHO), which is the agency within the UN system that led the production of the new estimates described here. In 2001, the WHO Executive Board endorsed a resolution (EB.107.R8) seeking to "establish a technical consultation process bringing together personnel and perspectives from Member States in different WHO regions." A key objective of this consultation process is "to ensure that each Member State is consulted on the best data to be used." Since we view this process as an integral step in the overall estimation strategy, we describe it here briefly.

The Country Consultation process for the new set of maternal mortality estimates was initiated on 28 June 2010 by an official communication sent from WHO to all Member States. This letter informed Member States of the ongoing exercise in maternal mortality estimation and requested the designation of an

official contact (typically within the national health ministry and/or the central statistical office) to participate in the consultation. The designated officials received the following items by email: (1) a copy of official communication, (2) draft estimates, (3) a summary of the methodology used. They were asked to review the draft estimates and known data sources in order to provide advice on any other primary sources of data not previously reported or used.

The formal consultation process was completed by 30 August 2010. Of the 172 Member States included in the study, the WHO was in contact with 262 designated officials from 119 Member States (in cases where more than one official was appointed from a given country or territory, they were required to submit a unified response to the query). During the consultation period, new data meeting the study's inclusion criteria were received from 30 countries and consisted primarily of updates to civil registration data. Following revision of the input data set, the complete model was re-estimated, with the result that predicted values were revised (at least slightly) for a majority of the populations included in the analysis. This revision changed MMR estimates by an average of 4.7% for countries with new data but only by 0.22% globally, as the 30 countries with new data accounted in 2008 for a mere 4% of global maternal deaths and only 7% of live births.

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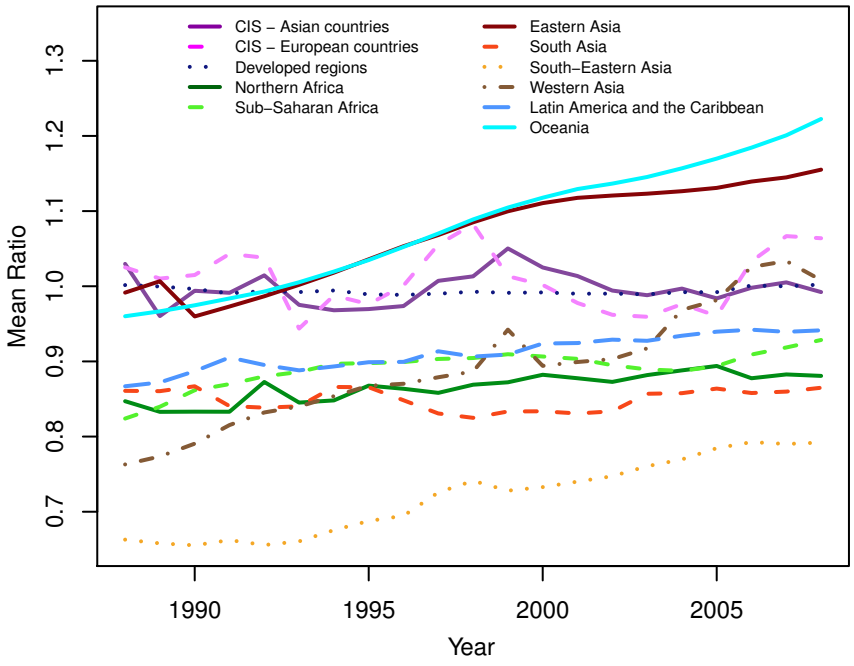

Figure A: Ratio of IHME to WHO estimates of ${}_{45}q_{15}$ by region, 1988 to 2008 (Note: ${}_{45}q_{15}$ is the conditional probability of dying between 15 and 60. Values shown are weighted averages of country-specific values, with weights equal to the female population aged 15-59.)

Table A: Estimated region and country parameters of multilevel model

Country	Group	Country Effect	Region	Region Effect
Afghanistan	B	0.149	Southern Asia	0.196
Albania	B	0.261	Transition countries of south-eastern Europe	-0.470
Algeria	B	0.274	Northern Africa	0.626
Angola	C	–	Sub-Saharan Africa	0.329
Argentina	A	0.018	Latin America	0.501
Armenia	B	-0.080	CIS in Asia	-0.229
Australia	A	0.167	Developed regions	-0.800
Austria	A	-0.113	Developed regions	-0.800
Azerbaijan	B	-0.076	CIS in Asia	-0.229
Bahamas	A	-0.346	Caribbean	0.332
Bahrain	B	0.163	Western Asia	-0.168
Bangladesh	B	-0.062	Southern Asia	0.196
Barbados	A	0.321	Caribbean	0.332
Belarus	A	-0.169	CIS in Europe	-0.302
Belgium	A	-0.416	Developed regions	-0.800
Belize	A	-0.003	Latin America	0.501
Benin	B	-0.042	Sub-Saharan Africa	0.329
Bhutan	B	0.275	Southern Asia	0.196
Bolivia (Plurinational State of)	B	-0.020	Latin America	0.501
Bosnia and Herzegovina	B	-0.405	Transition countries of south-eastern Europe	-0.470
Botswana	B	-0.429	Sub-Saharan Africa	0.329
Brazil	B	-0.082	Latin America	0.501
Brunei Darussalam	B	0.208	South-eastern Asia	0.012
Bulgaria	A	-0.043	Transition countries of south-eastern Europe	-0.470
Burkina Faso	B	-0.333	Sub-Saharan Africa	0.329
Burundi	C	–	Sub-Saharan Africa	0.329
Cambodia	B	0.358	South-eastern Asia	0.012
Cameroon	B	0.207	Sub-Saharan Africa	0.329
Canada	A	-0.042	Developed regions	-0.800
Cape Verde	C	–	Sub-Saharan Africa	0.329
Central African Republic	B	-0.042	Sub-Saharan Africa	0.329
Chad	B	0.099	Sub-Saharan Africa	0.329
Chile	A	-0.179	Latin America	0.501
China	B	0.128	Eastern Asia	-0.028
Colombia	A	0.347	Latin America	0.501
Comoros	C	–	Sub-Saharan Africa	0.329

Continued on Next Page...

Table A: Estimated region and country parameters of multilevel model

Country	Group	Country Effect	Region	Region Effect
Congo	B	0.546	Sub-Saharan Africa	0.329
Costa Rica	A	-0.148	Latin America	0.501
Cote d'Ivoire	B	0.074	Sub-Saharan Africa	0.329
Croatia	A	-0.007	Developed regions	-0.800
Cuba	A	0.187	Caribbean	0.332
Cyprus	C	–	Western Asia	-0.168
Czech Republic	A	-0.080	Developed regions	-0.800
Democratic People's Republic of Korea	C	–	Eastern Asia	-0.028
Democratic Republic of the Congo	B	-0.297	Sub-Saharan Africa	0.329
Denmark	A	-0.438	Developed regions	-0.800
Djibouti	C	–	Sub-Saharan Africa	0.329
Dominican Republic	B	0.530	Caribbean	0.332
Ecuador	B	0.342	Latin America	0.501
Egypt	B	-0.315	Northern Africa	0.626
El Salvador	B	0.092	Latin America	0.501
Equatorial Guinea	C	–	Sub-Saharan Africa	0.329
Eritrea	B	-0.008	Sub-Saharan Africa	0.329
Estonia	A	0.510	Developed regions	-0.800
Ethiopia	B	-0.336	Sub-Saharan Africa	0.329
Fiji	B	-1.131	South-eastern Asia	0.012
Finland	A	-0.377	Developed regions	-0.800
France	A	0.090	Developed regions	-0.800
Gabon	B	0.492	Sub-Saharan Africa	0.329
Gambia	C	–	Sub-Saharan Africa	0.329
Georgia	B	0.386	CIS in Asia	-0.229
Germany	A	0.029	Developed regions	-0.800
Ghana	B	0.130	Sub-Saharan Africa	0.329
Greece	A	-0.535	Developed regions	-0.800
Guatemala	A	-0.645	Latin America	0.501
Guinea	B	0.058	Sub-Saharan Africa	0.329
Guinea-Bissau	C	–	Sub-Saharan Africa	0.329
Guyana	B	0.446	Latin America	0.501
Haiti	B	-0.135	Caribbean	0.332
Honduras	B	-0.119	Latin America	0.501
Hungary	A	-0.177	Developed regions	-0.800
Iceland	A	-0.014	Developed regions	-0.800
India	B	0.226	Southern Asia	0.196

Continued on Next Page...

Table A: Estimated region and country parameters of multilevel model

Country	Group	Country Effect	Region	Region Effect
Indonesia	B	0.690	South-eastern Asia	0.012
Iran (Islamic Republic of)	B	-0.261	Southern Asia	0.196
Iraq	B	-0.121	Western Asia	-0.168
Ireland	A	-0.566	Developed regions	-0.800
Israel	A	-0.427	Western Asia	-0.168
Italy	A	-0.201	Developed regions	-0.800
Jamaica	B	0.060	Caribbean	0.332
Japan	A	0.312	Developed regions	-0.800
Jordan	B	0.446	Western Asia	-0.168
Kazakhstan	A	0.078	CIS in Asia	-0.229
Kenya	B	-0.038	Sub-Saharan Africa	0.329
Kuwait	A	-0.218	Western Asia	-0.168
Kyrgyzstan	B	0.004	CIS in Asia	-0.229
Lao People's Democratic Republic	B	0.426	South-eastern Asia	0.012
Latvia	A	0.523	Developed regions	-0.800
Lebanon	B	-0.011	Western Asia	-0.168
Lesotho	B	-0.054	Sub-Saharan Africa	0.329
Liberia	B	0.172	Sub-Saharan Africa	0.329
Libyan Arab Jamahiriya	C	–	Northern Africa	0.626
Lithuania	A	0.058	Developed regions	-0.800
Luxembourg	A	0.259	Developed regions	-0.800
Madagascar	B	-0.074	Sub-Saharan Africa	0.329
Malawi	B	-0.106	Sub-Saharan Africa	0.329
Malaysia	C	–	South-eastern Asia	0.012
Maldives	B	0.313	Southern Asia	0.196
Mali	B	0.013	Sub-Saharan Africa	0.329
Malta	A	0.492	Developed regions	-0.800
Mauritania	B	0.358	Sub-Saharan Africa	0.329
Mauritius	A	-0.220	Sub-Saharan Africa	0.329
Mexico	A	0.257	Latin America	0.501
Mongolia	C	–	Eastern Asia	-0.028
Montenegro	B	-0.150	Transition countries of south-eastern Europe	-0.470
Morocco	B	0.311	Northern Africa	0.626
Mozambique	B	-0.267	Sub-Saharan Africa	0.329
Myanmar	B	0.038	South-eastern Asia	0.012
Namibia	B	0.037	Sub-Saharan Africa	0.329
Nepal	B	-0.182	Southern Asia	0.196

Continued on Next Page...

Table A: Estimated region and country parameters of multilevel model

Country	Group	Country Effect	Region	Region Effect
Netherlands	A	0.198	Developed regions	-0.800
New Zealand	A	0.229	Developed regions	-0.800
Nicaragua	B	-0.098	Latin America	0.501
Niger	B	-0.232	Sub-Saharan Africa	0.329
Nigeria	B	0.085	Sub-Saharan Africa	0.329
Norway	A	-0.004	Developed regions	-0.800
Oman	C	–	Western Asia	-0.168
Pakistan	B	0.084	Southern Asia	0.196
Panama	A	0.195	Latin America	0.501
Papua New Guinea	C	–	South-eastern Asia	0.012
Paraguay	B	0.091	Latin America	0.501
Peru	B	0.248	Latin America	0.501
Philippines	B	0.129	South-eastern Asia	0.012
Poland	A	-0.226	Developed regions	-0.800
Portugal	A	-0.048	Developed regions	-0.800
Puerto Rico	B	-0.489	Caribbean	0.332
Qatar	C	–	Western Asia	-0.168
Republic of Korea	A	-0.147	Eastern Asia	-0.028
Republic of Moldova	A	-0.156	CIS in Europe	-0.302
Romania	A	0.790	Transition countries of south-eastern Europe	-0.470
Russian Federation	A	0.241	CIS in Europe	-0.302
Rwanda	B	0.109	Sub-Saharan Africa	0.329
Saudi Arabia	B	-0.176	Western Asia	-0.168
Senegal	B	0.097	Sub-Saharan Africa	0.329
Serbia	A	-0.458	Transition countries of south-eastern Europe	-0.470
Sierra Leone	B	0.050	Sub-Saharan Africa	0.329
Singapore	A	-0.370	South-eastern Asia	0.012
Slovakia	A	-0.089	Developed regions	-0.800
Slovenia	A	0.160	Developed regions	-0.800
Solomon Islands	C	–	South-eastern Asia	0.012
Somalia	C	–	Sub-Saharan Africa	0.329
South Africa	B	0.297	Sub-Saharan Africa	0.329
Spain	A	-0.323	Developed regions	-0.800
Sri Lanka	B	-0.415	Southern Asia	0.196
Sudan	B	0.539	Sub-Saharan Africa	0.329
Suriname	A	-0.079	Latin America	0.501
Swaziland	B	-0.089	Sub-Saharan Africa	0.329

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Table A: Estimated region and country parameters of multilevel model

Country	Group	Country Effect	Region	Region Effect
Sweden	A	-0.282	Developed regions	-0.800
Switzerland	A	0.010	Developed regions	-0.800
Syrian Arab Republic	C	–	Western Asia	-0.168
Tajikistan	C	–	CIS in Asia	-0.229
Thailand	B	-0.340	South-eastern Asia	0.012
The former Yugoslav Republic of Macedonia	A	-0.302	Transition countries of south-eastern Europe	-0.470
Timor-Leste	C	–	South-eastern Asia	0.012
Togo	B	-0.062	Sub-Saharan Africa	0.329
Trinidad and Tobago	A	0.089	Caribbean	0.332
Tunisia	B	0.139	Northern Africa	0.626
Turkey	B	-0.025	Western Asia	-0.168
Turkmenistan	C	–	CIS in Asia	-0.229
Uganda	B	-0.502	Sub-Saharan Africa	0.329
Ukraine	A	-0.113	CIS in Europe	-0.302
United Arab Emirates	C	–	Western Asia	-0.168
United Kingdom of Great Britain and Northern Ireland	A	0.202	Developed regions	-0.800
United Republic of Tanzania	B	-0.027	Sub-Saharan Africa	0.329
United States of America	A	0.177	Developed regions	-0.800
Uruguay	A	-0.487	Latin America	0.501
Uzbekistan	A	-0.461	CIS in Asia	-0.229
Venezuela (Bolivarian Republic of)	A	0.153	Latin America	0.501
Viet Nam	C	–	South-eastern Asia	0.012
Yemen	B	0.258	Western Asia	-0.168
Zambia	B	-0.582	Sub-Saharan Africa	0.329
Zimbabwe	B	0.598	Sub-Saharan Africa	0.329

Table B: Maternal mortality ratio in 1990 and 2008, and average annual rate of decline during 1990-2008, by country, with 95% uncertainty intervals

	Maternal Mortality Ratio (per 100,000)						Rate of decline (%)		
	1990			2008					
Country	Est.	Lower	Upper	Est.	Lower	Upper	Est.	Lower	Upper
Afghanistan	1700	870	3400	1400	740	2600	1.0	0.7	1.4
Albania	48	30	77	31	19	50	2.4	1.7	3.2
Algeria	250	130	480	120	61	220	4.1	3.3	5.0
Angola	1000	440	2600	610	270	1400	2.9	-2.8	9.2
Argentina	72	64	81	70	61	77	0.2	-0.1	0.4
Armenia	51	33	83	29	18	45	3.2	2.7	3.7
Australia	10	8	12	8	6	10	1.4	-0.2	2.9
Austria	10	9	12	5	5	6	3.7	3.4	3.9
Azerbaijan	64	40	100	38	24	60	2.9	2.3	3.5
Bahamas	55	40	69	49	38	57	0.7	-0.7	1.5
Bahrain	25	14	42	19	11	30	1.6	0.8	2.4
Bangladesh	870	440	1700	340	170	660	5.3	4.5	6.0
Barbados	120	110	140	64	55	72	3.5	3.0	4.0
Belarus	37	31	45	15	12	20	4.8	3.3	6.3
Belgium	7	6	8	5	4	7	1.2	-0.2	2.6
Belize	72	51	100	94	56	140	-1.5	-4.6	1.6
Benin	790	480	1300	410	250	690	3.6	3.0	4.3
Bhutan	940	480	1900	200	110	370	8.6	6.9	10.3
Bolivia (Plurinational State of)	510	320	830	180	120	280	5.8	5.2	6.4
Bosnia and Herzegovina	18	10	32	9	5	16	3.8	2.7	4.9
Botswana	83	27	240	190	84	380	-4.7	-11.1	1.9
Brazil	120	78	180	58	38	87	4.0	3.3	4.8
Brunei Darussalam	28	16	48	21	13	34	1.4	0.8	2.1
Bulgaria	24	21	28	13	11	15	3.7	3.0	4.5
Burkina Faso	770	450	1300	560	330	950	1.8	1.2	2.3
Burundi	1200	510	2700	970	410	2300	1.0	-4.6	7.0
Cambodia	690	410	1200	290	180	480	4.8	3.9	5.6
Cameroon	680	400	1200	600	360	960	0.7	-0.5	1.5
Canada	6	4	10	12	7	20	-3.7	-7.4	0.3
Cape Verde	220	100	500	94	39	210	4.9	-1.1	10.7
Central African Republic	880	470	1600	850	490	1400	0.2	-0.9	0.8
Chad	1300	710	2200	1200	670	2100	0.3	-0.1	0.6
Chile	56	33	88	26	15	43	4.3	0.4	8.2
China	110	65	190	38	23	60	6.0	5.0	6.9
Colombia	140	130	160	85	74	94	2.9	2.7	3.1

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Table B: Maternal mortality ratio in 1990 and 2008, and average annual rate of decline during 1990-2008, by country, with 95% uncertainty intervals

	Maternal Mortality Ratio (per 100,000)						Rate of decline (%)		
	1990			2008					
Country	Est.	Lower	Upper	Est.	Lower	Upper	Est.	Lower	Upper
Comoros	530	230	1200	340	140	780	2.5	-3.4	8.4
Congo	460	250	870	580	330	1000	-1.3	-2.1	-0.8
Costa Rica	35	21	61	44	24	82	-1.3	-5.5	3.2
Cote d'Ivoire	690	390	1200	470	290	730	2.1	0.6	3.0
Croatia	8	7	10	14	11	17	-2.8	-4.1	-1.5
Cuba	63	45	88	53	36	76	1.0	-1.6	3.5
Cyprus	17	8	39	10	4	23	3.0	-3.1	9.0
Czech Republic	15	11	22	8	5	12	3.8	1.0	6.7
Democratic People's Republic of Korea	270	93	760	250	84	690	0.4	-5.4	6.5
Democratic Republic of the Congo	900	470	1700	670	340	1300	1.7	-0.1	3.5
Denmark	7	6	8	5	5	6	1.8	1.6	1.9
Djibouti	370	160	860	300	140	610	1.2	-4.8	6.6
Dominican Republic	220	130	370	100	62	170	4.1	3.0	4.8
Ecuador	230	140	390	140	81	230	2.9	2.4	3.4
Egypt	220	130	370	82	51	130	5.5	4.5	6.5
El Salvador	200	120	320	110	71	170	3.2	2.5	3.9
Equatorial Guinea	1000	410	2500	280	130	630	7.3	0.8	13.1
Eritrea	930	480	1700	280	160	510	6.6	5.6	7.4
Estonia	48	42	56	12	9	14	7.9	6.8	9.1
Ethiopia	990	540	1800	470	270	790	4.2	3.5	4.7
Fiji	40	21	75	26	14	48	2.3	1.9	2.8
Finland	7	6	7	8	7	8	-0.8	-1.1	-0.5
France	13	10	17	8	5	14	2.4	-0.5	5.3
Gabon	260	140	490	260	150	420	0.1	-2.2	1.7
Gambia	750	320	1700	400	190	910	3.4	-2.4	9.4
Georgia	58	38	92	48	30	76	1.0	0.5	1.6
Germany	13	11	15	7	6	8	3.0	2.1	4.0
Ghana	630	340	1200	350	210	600	3.3	2.3	3.8
Greece	6	5	7	2	2	3	5.2	5.0	5.3
Guatemala	140	78	280	110	56	190	1.7	-3.0	6.5
Guinea	1200	670	2100	680	390	1100	3.2	2.6	3.7
Guinea-Bissau	1200	530	2700	1000	440	2300	1.0	-4.8	6.7
Guyana	310	190	510	270	180	410	0.7	-0.4	1.6
Haiti	670	380	1200	300	180	520	4.4	3.6	5.2
Honduras	210	130	360	110	71	180	3.5	2.8	4.2

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Table B: Maternal mortality ratio in 1990 and 2008, and average annual rate of decline during 1990-2008, by country, with 95% uncertainty intervals

	Maternal Mortality Ratio (per 100,000)						Rate of decline (%)		
	1990			2008					
Country	Est.	Lower	Upper	Est.	Lower	Upper	Est.	Lower	Upper
Hungary	23	18	28	13	10	17	3.2	1.5	4.9
Iceland	8	7	8	5	5	6	2.2	2.1	2.4
India	570	360	880	230	150	350	4.9	4.4	5.5
Indonesia	620	380	1100	240	140	380	5.4	4.4	6.4
Iran (Islamic Republic of)	150	88	260	30	18	50	8.9	7.7	10.1
Iraq	93	49	170	75	41	140	1.2	0.4	2.1
Ireland	6	6	7	3	2	3	4.6	4.3	4.9
Israel	12	11	13	7	6	7	3.1	2.8	3.4
Italy	10	8	12	5	4	6	4.2	4.1	4.3
Jamaica	66	45	97	89	60	120	-1.7	-2.4	-1.1
Japan	12	10	15	6	5	8	3.7	2.4	5.0
Jordan	110	65	200	59	35	100	3.6	2.9	4.4
Kazakhstan	78	64	95	45	34	61	3.0	1.3	4.6
Kenya	380	220	680	530	320	850	-1.8	-3.1	-1.0
Kuwait	10	9	11	9	8	10	0.4	0.2	0.7
Kyrgyzstan	77	46	130	81	50	130	-0.3	-1.0	0.5
Lao People's Democratic Republic	1200	640	2100	580	320	1000	4.0	3.3	4.8
Latvia	57	52	65	20	18	23	5.7	5.2	6.1
Lebanon	52	29	93	26	14	48	3.8	3.1	4.7
Lesotho	360	200	630	530	260	850	-2.0	-6.5	1.8
Liberia	1100	600	2200	990	520	1800	0.8	0.2	1.4
Libyan Arab Jamahiriya	100	44	250	64	26	140	2.7	-3.0	8.6
Lithuania	34	30	40	13	11	16	5.2	4.5	5.9
Luxembourg	6	6	7	17	15	19	-5.5	-5.6	-5.4
Madagascar	710	440	1100	440	270	700	2.6	2.0	3.2
Malawi	900	520	1600	510	300	760	3.2	0.7	5.1
Malaysia	56	25	130	31	14	68	3.2	-2.4	9.0
Maldives	510	300	890	37	21	64	14.6	13.2	16.0
Mali	1200	720	2000	830	520	1400	2.1	1.7	2.5
Malta	14	13	16	8	7	9	2.9	2.7	3.3
Mauritania	780	420	1400	550	300	980	2.0	1.4	2.6
Mauritius	72	63	85	36	30	41	3.9	3.0	4.7
Mexico	93	82	100	85	74	95	0.5	0.1	0.9
Mongolia	130	55	300	65	27	150	3.6	-2.2	9.7
Montenegro	15	8	28	15	8	26	0.0	-0.3	0.2

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Table B: Maternal mortality ratio in 1990 and 2008, and average annual rate of decline during 1990-2008, by country, with 95% uncertainty intervals

	Maternal Mortality Ratio (per 100,000)						Rate of decline (%)		
	1990			2008					
Country	Est.	Lower	Upper	Est.	Lower	Upper	Est.	Lower	Upper
Morocco	270	150	490	110	63	190	5.0	4.0	6.0
Mozambique	1000	540	1900	550	310	870	3.5	1.4	4.9
Myanmar	420	240	750	240	140	410	3.1	2.4	3.7
Namibia	180	100	320	180	93	270	0.2	-4.0	3.3
Nepal	870	470	1600	380	210	650	4.6	3.9	5.2
Netherlands	10	9	12	9	7	10	1.0	-0.3	2.1
New Zealand	18	16	20	14	12	15	1.4	1.2	1.5
Nicaragua	190	100	350	100	57	180	3.2	2.5	3.9
Niger	1400	820	2500	820	470	1400	3.1	2.5	3.7
Nigeria	1100	600	2000	840	460	1500	1.5	1.0	1.9
Norway	9	7	13	7	4	12	1.3	-1.8	4.5
Oman	49	21	120	20	9	45	5.1	-0.8	11.2
Pakistan	490	250	950	260	140	490	3.6	3.1	4.1
Panama	86	75	100	71	58	84	1.1	0.2	1.9
Papua New Guinea	340	140	790	250	110	560	1.6	-4.5	7.7
Paraguay	130	77	230	95	57	150	1.8	1.2	2.5
Peru	250	150	430	98	62	160	5.2	4.4	5.9
Philippines	180	120	270	94	61	140	3.6	3.2	4.0
Poland	17	10	32	6	2	13	6.2	0.3	12.0
Portugal	15	11	19	7	5	10	3.9	1.9	5.9
Puerto Rico	29	19	46	18	12	26	2.6	1.2	3.6
Qatar	15	7	38	8	4	19	3.4	-2.6	9.5
Republic of Korea	18	16	20	18	16	20	0.0	-0.4	0.3
Republic of Moldova	62	55	70	32	28	35	3.7	3.6	3.9
Romania	170	110	270	27	17	44	10.3	7.0	13.8
Russian Federation	74	63	87	39	33	46	3.6	2.7	4.4
Rwanda	1100	660	1900	540	320	910	3.9	3.3	4.6
Saudi Arabia	41	21	79	24	13	45	3.0	2.2	3.8
Senegal	750	420	1300	410	240	680	3.3	2.9	3.7
Serbia	13	12	15	8	7	9	2.8	2.5	3.2
Sierra Leone	1300	690	2400	970	530	1800	1.6	1.4	1.7
Singapore	6	5	7	9	8	10	-2.3	-2.7	-1.8
Slovakia	15	13	17	6	5	6	5.4	5.2	5.7
Slovenia	11	10	13	18	15	20	-2.6	-3.1	-2.1
Solomon Islands	130	54	300	100	44	240	1.4	-4.6	7.6
Somalia	1100	440	2500	1200	510	2800	-0.6	-6.4	5.3
South Africa	230	120	400	410	240	610	-3.3	-7.3	-0.8

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Table B: Maternal mortality ratio in 1990 and 2008, and average annual rate of decline during 1990-2008, by country, with 95% uncertainty intervals

	Maternal Mortality Ratio (per 100,000)						Rate of decline (%)		
	1990			2008					
Country	Est.	Lower	Upper	Est.	Lower	Upper	Est.	Lower	Upper
Spain	7	6	8	6	5	7	0.8	-0.1	1.6
Sri Lanka	91	61	140	39	26	57	4.8	4.4	5.2
Sudan	830	440	1500	750	420	1300	0.5	-1.2	2.2
Suriname	84	75	95	100	86	110	-1.0	-1.5	-0.6
Swaziland	260	72	680	420	180	800	-2.7	-10.2	3.6
Sweden	7	5	9	5	3	8	1.6	-1.8	4.8
Switzerland	8	7	9	10	8	11	-1.1	-1.5	-0.8
Syrian Arab Republic	120	50	270	46	20	100	5.2	-0.7	11.1
Tajikistan	120	51	270	64	29	140	3.3	-2.4	9.4
Thailand	50	31	79	48	32	68	0.2	-1.7	1.6
The former Yugoslav Republic of Macedonia	16	12	22	9	6	14	3.2	0.2	5.8
Timor-Leste	650	280	1500	370	150	860	3.2	-2.6	8.9
Togo	650	340	1200	350	210	600	3.5	2.0	4.5
Trinidad and Tobago	86	54	130	55	35	82	2.5	-1.1	6.0
Tunisia	130	68	250	60	32	110	4.3	3.5	5.1
Turkey	68	43	110	23	15	36	6.0	5.4	6.5
Turkmenistan	91	39	210	77	33	190	0.9	-4.9	7.1
Uganda	670	370	1100	430	240	670	2.5	1.3	3.2
Ukraine	49	42	57	26	20	33	3.5	2.0	4.9
United Arab Emirates	28	11	70	10	4	24	5.4	-0.4	11.3
United Kingdom of Great Britain and Northern Ireland	10	9	12	12	11	14	-1.0	-1.7	-0.3
United Republic of Tanzania	880	530	1500	790	470	1300	0.6	-0.3	1.1
United States of America	12	11	14	24	20	27	-3.7	-4.2	-3.2
Uruguay	39	33	46	27	22	33	2.0	0.9	3.1
Uzbekistan	53	46	63	30	25	35	3.2	2.3	4.2
Venezuela (Bolivarian Republic of)	84	75	94	68	59	75	1.2	1.0	1.4
Viet Nam	170	72	400	56	27	120	6.0	0.0	11.6
Yemen	540	270	1100	210	110	400	5.3	4.6	6.0
Zambia	400	140	760	470	250	680	-1.0	-5.3	1.1
Zimbabwe	390	200	690	790	410	1200	-3.9	-8.3	-0.8

Table C: Estimated ratio of maternal to pregnancy-related deaths, various studies

Country	Source	Ratio of maternal to pregnancy-related deaths
Bangladesh	BMMS 2001	0.846
Honduras	RAMOS 1998	0.739
Iran	Census 1996	0.700
Republic of Korea	MMR/COD 1995-1996	0.935
Nepal	NMMS 2008/9	0.930
Saudi Arabia	Official statistics 1997	0.958
Suriname	Confidential enquiry 1991-1993	0.940
Tunisia	Maternal mortality study 1993-1994	0.921
Mean / Median		0.871/ 0.926

Note: Percentages may not sum to 100 due to rounding.

Table D: Maternal mortality ratio (MMR) in 2008 with and without AIDS-related deaths, plus 95% uncertainty intervals, for the world and major regions

	MMR			MMR non-AIDS			MMR AIDS		
Region	Est.	Lower	Upper	Est.	Lower	Upper	Est.	Lower	Upper
World	260	200	380	250	180	360	15	7	27
Developed regions	14	13	16	13	12	15	1	0	2
CIS	40	35	49	38	33	47	2	0	4
Developing regions	290	220	420	280	210	400	17	7	30
Africa	590	440	860	540	380	810	52	22	93
Northern Africa	92	61	140	92	61	140	0	0	0
Sub-Saharan Africa	640	480	950	590	410	890	58	24	100
Asia	190	130	280	180	130	270	2	1	5
Eastern Asia	41	26	67	41	25	67	0	0	1
South Asia	280	180	420	270	180	420	3	0	7
South-Eastern Asia	160	120	250	160	110	240	3	1	6
Western Asia	68	44	110	68	44	110	0	0	0
Latin America and the Caribbean	85	72	110	81	68	100	4	2	8
Oceania	230	100	540	220	100	540	2	0	5

Table E: Estimated variance-covariance matrix, $\mathbf{\Sigma}$, for β coefficients of multilevel regression model

	β_0	β_1	β_2	β_3
β_0	0.17100	-0.01656	0.01515	0.03512
β_1	-0.01656	0.00291	0.00127	-0.00614
β_2	0.01515	0.00127	0.01428	0.01292
β_3	0.03512	-0.00614	0.01292	0.06127