Measuring Maternal Mortality Through the Population Census: Examples from Africa

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Abstract

Reducing maternal mortality (by three-quarters between 1990 and 2015) is a key Millennium Development Goal, but the measurement of indicators to track progress has proved particularly elusive. Levels of maternal mortality remain high in many developing countries and evidence of progress is hard to detect, especially in low income settings. A number of survey approaches to measurement (for example sibling histories) have been developed, but results are affected by large sampling and non-sampling errors (1). Population censuses can serve as an important data source for countries where other sources are not currently available, with the advantage of eliminating sampling errors and providing robust measurement of sub-national and socio-economic differentials and trends in mortality (Stanton et al., 2001). However, non-sampling errors remain an issue, and careful data evaluation is essential. This paper presents an evaluation of census data relevant to the estimation of maternal mortality from recent censuses in Lesotho, Namibia, South Africa and Zimbabwe. The results suggest that the population census, under favorable conditions and given recent advances in data evaluation and adjustment methods, is a promising approach to monitoring maternal mortality.

Introduction

"A goal that cannot be monitored cannot be met or missed" (3). The fifth Millennium Development Goal is to improve maternal health (4). The target for the goal is to reduce the Maternal Mortality Ratio (MMR, maternal deaths per 100,000 live births) by three-quarters from 1990 to 2015. However, except in high income countries with complete civil registration systems and good cause of death ascertainment, the measurement of maternal mortality is problematic. An interagency group has recently compiled estimates of maternal mortality for the countries of the world, but notes the extreme weakness of the database (5). The group concludes that levels of maternal mortality remain high in developing countries and that there is little evidence of progress, especially in low income settings. The reasons for the apparent lack of progress are manifold and relate both to the lack of access of vulnerable women to basic care and to poor quality of care when it is available. Yet the difficulties of accurately measuring maternal mortality in settings without comprehensive systems of civil registration are formidable: events are relatively rare, and reporting of deaths as maternal is incomplete even in well-developed systems. MDG-5 is one of the MDG indicators whose tracking has proved particularly elusive. The challenge of accurately measuring levels and trends is one of the factors impeding the delivery of effective solutions. Although enough is known to inform global action, specific actions for the poorest countries with the poorest data remain uncertain(6).

The Population Census as a data source for measuring maternal mortality

Population censuses can serve as an important source of data about maternal mortality for countries where other sources are not currently available or are inaccurate, and can also provide some indication of sub-national variation. The *Principles and Recommendations for Population and Housing Censuses* recommends the inclusion of questions in the census to record household deaths by age and sex in some recent reference period, such as the last year, in countries lacking other sources of information about adult mortality, and notes that additional questions can collect information about the timing of death relative to pregnancy for deaths of women of reproductive age to identify pregnancy-related deaths. Censuses in developing countries also typically collect information on recent births, the denominator of the MMR. The advantages of using the national census to measure maternal mortality through census are substantial (7), as outlined below.

1. The census is likely to be the only household-level survey large enough to support the robust measurement of sub-national and socio-economic differentials and trends in maternal mortality.

2. Standard methods exist for evaluating and, under certain conditions, adjusting the data on overall deaths. Census questions on household deaths went out of fashion in the 1970s and 1980s because reported death rates were implausibly low. Advances in analytic methodology (8) have greatly improved the ability to evaluate and then adjust for reporting deficiencies since that time.

3. If the census has already been planned to include questions on household deaths, the marginal cost of adding the questions to identify pregnancy-related deaths is low: only about one percent of households will report the event that triggers the additional questions, namely the death of a woman of reproductive age. There is some additional cost in terms of paper and printing, but it is small and certainly less costly than conducting a special household survey to identify these deaths.

4. The methodology lends itself to potential follow-up with a verbal autopsy or other in-depth study of households reporting a death of a woman of reproductive age.

5. The additional questions on household deaths and their timing relative to pregnancy can, to reduce costs, be included only on a census long form if a country is planning a census with a short questionnaire for the majority of households and a longer questionnaire for a sample.

A workshop in 1999 (9) evaluated the use of the national population census to measure maternal mortality using data from five countries (Benin, Iran, Lao, Madagascar and

Zimbabwe), and the results suggested that the census, under favorable conditions, is a promising approach (9). In this paper we use data from more recent censuses of Lesotho, Namibia, South Africa and Zimbabwe to re-assess the performance of the methodology, reporting on results of a workshop, organized by the Health Metrics Network, the Harvard Center for Population and Development Studies, UNFPA and IMMPACT, held in June 2007 to analyse and evaluate the data in collaboration with the national statistics offices of these countries.

Formulation of question and data evaluation methods

Evaluation of census data on maternal mortality requires information on the population by age and sex at two points in time, the number of deaths by age and sex and of maternal deaths over a given period of reference, and the number of live births over the same period.

Experience with census questions on household deaths in some recent reference period has typically indicated an under-reporting of deaths, so careful data evaluation and (if necessary) adjustment is essential. Such evaluation must encompass the completeness of recording of deaths, the completeness of births, and of the adequacy of the approach used to identify maternal deaths. Standard methods that evaluate coverage of deaths relative to population (10) are used to evaluate and adjust as necessary the data on overall deaths. Evaluation of data on births uses a variant of the Brass P/F ratio method, which compares synthetic cohort average parity to cumulated current fertility (11). Currently there are no established methods for evaluating the classification of adult female deaths as maternal or pregnancy-related. However, one can judge data quality by assessing the plausibility of age patterns of maternal mortality and comparing census results to expectations based on existing models (10) or to empirical regularities such as an expected J-shape in the maternal mortality ratio by age.

<u>Data</u>

Estimating maternal mortality using census data requires the application of a variety of evaluation methods (with adjustment if necessary) and the key assumption that reported pregnancy-related deaths approximate true maternal deaths. The data needed are as follows:

1. Two population age and sex distributions from successive censuses separated by not more than about 15 years;
2. An age and sex distribution of household deaths reported for some relatively short time period prior to at least one (and preferably both) of the censuses;
3. For deaths of women of reproductive age, information on whether the woman was pregnant, in childbirth, or within 6 weeks (or 2 months) of delivery at the time of death.
4. Information (typically births by age of mother reported for some relatively short reference period before one or both of the censuses, together with similar information on numbers of children ever born) to estimate the number of births in the reference period covered by the deaths.

The population censuses of Lesotho (1986 and 1996), Namibia (1991 and 2001), South Africa (1996 and 2001) and Zimbabwe (1992 and 2002) meet these basic needs. Table 1 shows the data availability for each country. Observations missing age or sex were distributed proportionately as necessary.[1] The 2006 census of Lesotho also included the necessary questions, but the data are not yet available. Information from the Namibia census of 2001 does not as yet include tabulations of proportions of deaths that were pregnancy-related, so the analysis is at this stage partial.

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[1] No persons with non-response on age or sex were reported in the basic population tabulations used. In all three countries, however, there were deaths with missing information on age or sex. These missing cases were distributed proportionately, first distributing those missing sex within age categories and then those missing age within sex. The proportion of deaths with missing sex was small except in Paraguay, where it exceeded 6%; proportions with missing age were somewhat greater, ranging from 2.9% in Nicaragua to 7.4% in Paraguay.

Information on household deaths was collected in all four censuses in the form of a question about deaths in the 12 months prior to the census.

Methods

There are three key elements in the use of census data to measure the MMR: the evaluation and adjustment of numbers of deaths from all causes, the evaluation of the proportion of deaths of women of reproductive age reported to be pregnancy-related, and the evaluation and adjustment if necessary of the number of births in the period covered by the deaths. Different methods are used for each part of the analysis.

Evaluation of Coverage of Deaths

A number of methods based upon equations of population dynamics have been developed to evaluate the coverage of reported deaths relative to populations (14-17). The methods all make certain assumptions about the nature of the population and any data errors. Here we use a method derived from the Demographic Balancing Equation which expresses the identity that the growth rate of the population is equal to the difference between its entry rate and exit rate (17). This identity holds for open-ended age segments $x+$, and in a closed population the only entries are through birthdays at age x. The "birthday" rate $x+$ minus the growth rate $x+$ thus provides a residual estimate of the death rate $x+$. If the residual estimate can be calculated from population data from two population censuses and compared to a direct estimate using the recorded deaths, the completeness of death recording relative to population recording can be estimated.

The method, referred to here as General Growth Balance (GGB), has been described in detail elsewhere (19). It makes strong assumptions: that the population is closed to migration, that the completeness of recording of deaths is constant by age, that the completeness of recording of population is constant by age, and that ages of the living and the dead are reported without error. It should also be noted that the method compares an age distribution of deaths to an intercensal population; thus strictly it estimates intercensal completeness of recording, not the completeness at the beginning or end of the intercensal period.

This issue is of particular importance when a distribution of deaths comes from data on household deaths collected by the latter of the two censuses. Say the deaths pertain to the year before the second census. Their age pattern will reflect the age distribution of the population shortly before the second census, not the average age distribution of the population over the intercensal period. In order to take this into account, we first use the deaths and the population from the second census to calculate age-specific death rates, and then estimated average annual deaths for the intercensal period by applying the death rates to an estimate of the age distribution of the intercensal population.

The assumption that the population is closed to migration is also of importance to the four countries studied, since each of them may have experienced recent net migration. The method uses information on deaths and growth rates cumulated above a series of ages x. If there is some age x above which net migration is negligible, the performance of the method above that age will be unaffected. Though we present results for all ages, we focus on results from age 35 to 75 as being most robust to possible distortions introduced by migration.

Proportion of Deaths that are Pregnancy-Related

No formal methods exist for evaluating the information on the proportion of deaths reported to be pregnancy related. Evaluation is therefore based on the plausibility of observed patterns rather than formal analysis.

A WHO/Unicef/UNFPA report provides estimates of maternal mortality for all countries of the world for the year 2005 (20). It presents a model of the proportion pregnancy-related of deaths of women of reproductive age (*PMDF*). Although developed to provide estimates of maternal mortality for countries lacking appropriate alternative sources of data, the model can be used to check the broad plausibility of the proportions recorded by the population censuses. The model is as follows:

$$\ln\left(\frac{PMDF}{1-PMDF}\right) = -6.15 + 1.24*\ln(GFR) - 0.014*SA - 0.26*\ln(GDP/cap) + 0.53*LASSAME - 0.62*VRComplete \quad (3)$$

where *GFR* is the General Fertility Rate, *SA* is the percentage of births assisted by a skilled attendant, *GDP/cap* is per capita GDP in purchasing power parity dollars, *LASSAME* is a dummy variable identifying countries of Latin America, sub-Saharan Africa and the Middle East-North Africa (from Pakistan to Morocco), and *VRComplete* is a dummy variable for countries identified by WHO as having complete death registration.

A second plausibility test is the pattern of proportions pregnancy-related by age of woman. Since the risk of dying in pregnancy or shortly thereafter is related to the proportion of time that women spend pregnant during the reference period , the proportions should follow approximately the age pattern of fertility in the population.

Fertility

Brass proposed a method (21) for assessing the completeness of recording of births by comparing cumulated age-specific fertility rates to women's reports of lifetime fertility, the underlying idea being that women would report recent births with a completeness that was approximately constant with age, thus providing an accurate age pattern of fertility, whereas younger women would report their lifetime fertility accurately, providing a level to which the age pattern could be scaled. As originally developed, the method assumed constant fertility, but when information on lifetime fertility is available for two or more time points this assumption can be relaxed (22,23). All four countries studied here included questions on children ever born in both the censuses analyzed; three of the four also experienced substantial fertility change in recent decades. We therefore apply the intercensal methodology (23) to evaluate the reporting of births.

Results

Completeness of Death Recording

The performance of the method for evaluating coverage of deaths is most conveniently portrayed graphically, showing the consistency of results across a range of ages. Figure 1 plots the observed death rates x+ against the residual estimates for ages x from 5 to 75 for the female populations of Lesotho (part (a)), Namibia (part (b)), South Africa (c) and Zimbabwe (d). Table 2 summarizes the parameters (intercept and slope) of the straight line fitted by orthogonal regression to the points for age ranges 5+ to 65+; the lines fitted to points 5+ to 65+ are shown in Figure 1.

If the method's assumptions are met, the points for different open-ended age groups should all lie on a straight line. Figure 1 confirms the concern about net emigration: the points for all three countries show a distinct irregularity at younger ages (the points close to the origin are for younger ages, where death rates are lowest), and the intercepts are all greater than zero, indicating higher census coverage at the first than at the second census, consistent with net intercensal emigration.

In all four cases, the growth balance methodology indicates some degree of under-recording of deaths relative to population ranging from about 14% in the case of Namibia to close to 45% in the case of South Africa. These are substantial adjustments, and given the rather erratic results by age of the methodology raise doubts about the likely accuracy of the estimates.

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Proportion of Deaths that are Pregnancy-Related

The first test of the proportion of deaths that is pregnancy-related (*PMDF*) is a comparison with the WHO/Unicef/UNFPA model (20). Table 3 shows the values of the independent variables used in the model (the values are the same as those used in the

2000 exercise except for the GFR, the values of which have been changed on the basis of census data, adjusted where necessary, analyzed here; Table 3 also shows both the *PMDF* predicted by the model and that observed in each census. For the two countries with data currently available, the *PMDF* reported in the census is considerably lower than that predicted by the WHO/Unicef/UNFPA model, but it must be borne in mind that these countries have mature HIV epidemics which are likely to drive down the *PMDF*.

Though it is impossible to evaluate the *PMDF*'s in any formal way, the results appear to be broadly plausible, both in level and in variation by age.

Fertility

Table 4 shows the ratios of synthetic cohort parity for the intercensal period to cumulated average intercensal fertility rates. The ratio for the age group 15-19 is usually disregarded since it is sensitive to the exact shape of the age-specific fertility distribution, so discussion focuses on the remaining ratios. All four countries have experienced fertility decline, to a greater or lesses extent, over recent decades. The P/F ratios in Table 4, however, are in general remarkably consistent by age, underlining how well the intercensal P/F ratio methodology works in the face of changing fertility; the exception is South Africa, where the ratios fall steadily with age, consistent with under-reporting of lifetime births by older women. That said, the estimated levels of reporting of recent births vary, being less than 50% in Namibia, close to 100% for South Africa and Zimbabwe, and around 90% for Lesotho. The consistency of the ratios with age gives considerable confidence in the final correction factor based on an average of the ratios for women aged 20-24 and 225-29.

Putting the Pieces Together: The Pregnancy-Related Mortality Ratio PRMR

The Pregnancy-Related Mortality Ratio (*PRMR*) is calculated as the number of pregnancy-related deaths divided by the number of live births (and multiplied by a factor of 100,000). The final calculation for each country is thus made by adjusting the number of deaths of women aged 15-49 for estimated coverage, multiplying by the proportion pregnancy-related (*PMDF*), and then dividing by an adjusted number of live births. Reported deaths of women at ages 15-49 are divided by the estimates of coverage in the last row but one of Table 2. The *PMDF*'s are taken without adjustment from Table 3. The adjustment factors chosen for births are the average of the ratios of lifetime to cumulated current fertility for the intercensal period for women aged 20-24 and 25-29. Table 5 shows the calculations. Given the data available at the time of drafting the paper, we are unable to come up with estimates for Namibia because we lack the information on pregnancy-related deaths (we hope to have this information by the time of the Conference). For the other three countries, the estimated PRMR's are high – ranging from just under 500 per 100,000 live births for Zimbabwe to 820 for South Africa. The high figure for South Africa is surprising, and may indicate that the adjustment factor for deaths, of about 1.8, may be excessive.

Conclusions and Recommendations

Clearly the conclusions and recommendations arrived at will depend on the analysis of the data. However, we anticipate that the analysis will confirm the potential of the census as a vehicle for estimating maternal mortality, not only at the national level but also for some differentials. As the year 2015 is approaching, prompting for monitoring of the MDGs, for countries able to mount a census, the 2010 Round of Population and Housing Census is a key opportunity to capture maternal mortality. Indeed the questions pertaining to this have been endorsed by the Principles and Recommendations for the 2010 Population and Housing Censuses for countries lacking complete death registration.

References

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Table 1: Census data available for estimating maternal mortality: Lesotho, Namibia, South Africa and Zimbabwe

	Lesotho	Namibia	South Africa	Zimbabwe
First Census:				
Date	1 April 1986	1991	10 October 1996	18 August 1992
Second Census:				
Date	14 April 1996	2001	10 October 2001	18 August 2002
Open Age Group	80+	95+	85+	75+
Time period of deaths	12 months prior to second census	12 months prior to second census	12 months prior to both censuses	12 months prior to both censuses

Table 2: Summary Estimates of Coverage and the Adjusted Probabilities of Dying between 15 and 60, $_{45}q_{15}$, of Application of General Growth Balance Method: Lesotho, Namibia, South Africa and Zimbabwe

Fitting Range and Result	Lesotho	Namibia	South Africa	Zimbabwe
Age Range 5+ to 65+				
Slope of Fitted Line	1.473	1.156	1.813	1.271
Intercept of Fitted Line	.0094	-.0094	-.0182	-.0010
Coverage of Census 1 Relative to Census 2	1.099	0.910	0.913	0.990
Adjusted $_{45}q_{15}$	0.357	0.532	0.512	0.714

Table 3: Comparison of Observed and Model-Predicted Proportions of Deaths Pregnancy-related: Lesotho, Namibia, South Africa and Zimbabwe

Country	GFR	SA	INC	Regional Dummy	VR Dummy	PDPR Predicted (WHO model)	PDPR Observed (census data)
Lesotho							0.104
Namibia							*
South Africa	83.6	92	10880	0	0	0.097	0.052
Zimbabwe	134.2	73	1950	0	0	0.232	0.109

Table 4: Ratios of Synthetic Cohort Parity for Intercensal Period to Cumulated Intercensal Fertility: Lesotho, Namibia, South Africa and Zimbabwe

Age Group	Lesotho	Namibia	South Africa	Zimbabwe
15-19	1.25	2.36	1.07	0.97
20-24	1.11	2.39	1.02	1.05
25-29	1.13	2.29	0.96	1.05
30-34	1.15	2.21	0.94	1.05
35-39	1.19	2.13	0.89	1.04
40-44	1.21	2.02	0.82	1.02
Average 20-24 &25-29	1.12	2.34	0.99	1.05

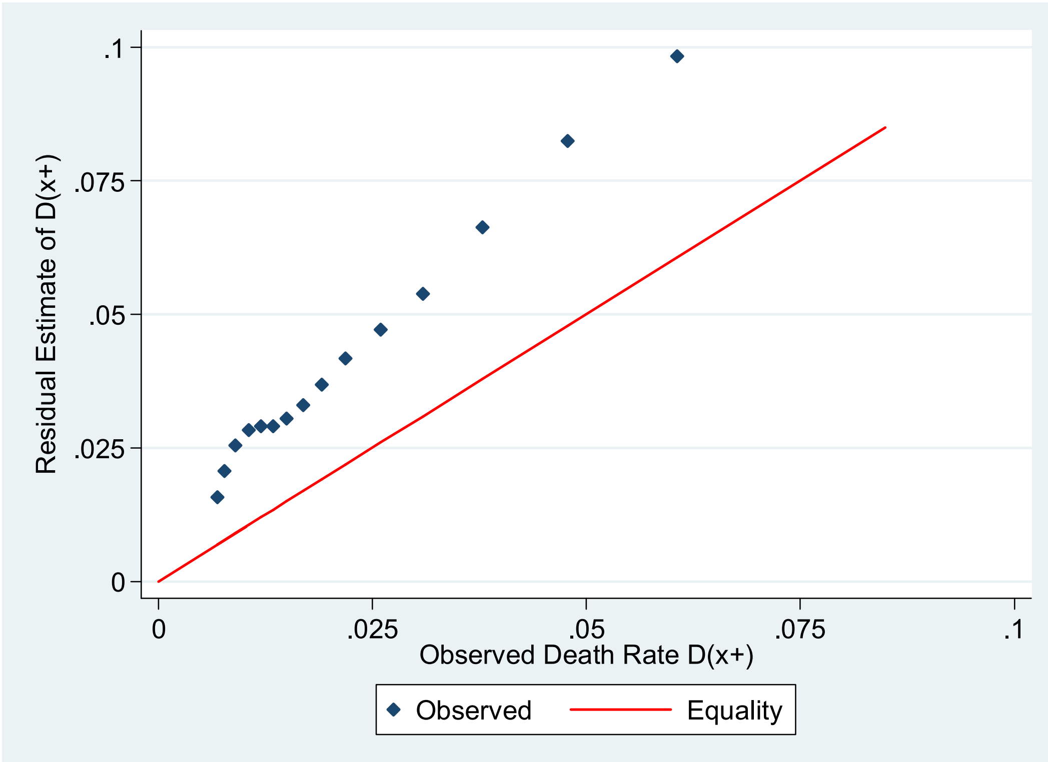
Table 5: Calculation of Population Census Based Pregnancy-Related Mortality Ratios

Data or Indicator	Country			
	Lesotho	Namibia	South Africa	Zimbabwe
Female Deaths 15-49 Reported	2122	5758	97811	12991
Adjustment Factor	1.473	1.156	1.813	1.271
Proportion of Deaths Pregnancy-Related	0.104	*	0.052	0.109
Maternal Deaths (Adjusted)	3 112	*	9165	1804
Reported Births	43 439	45157	1129500	358886
Adjustment Factor	1.12	2.34	0.99	1.05
Estimated PRMR/100000 births	668	*	820	479

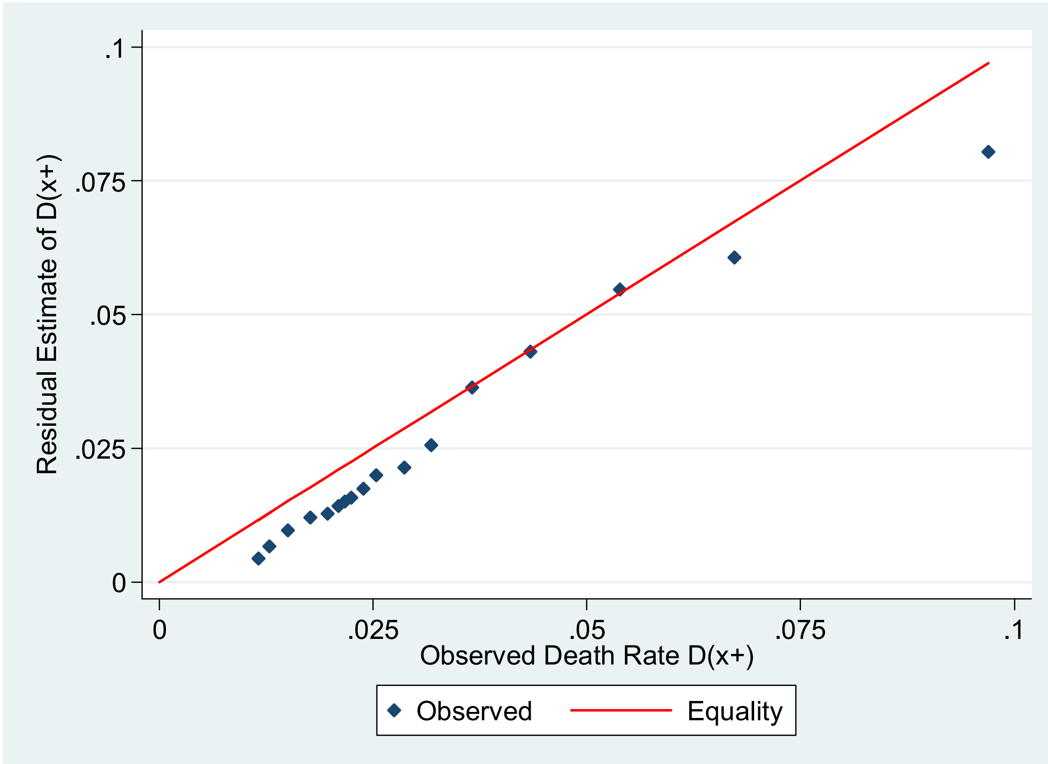
* To be completed

Figure 1: Application of General Growth Balance Method: Observed Death Rates x+ vs. Residual Estimates of Death Rates x+

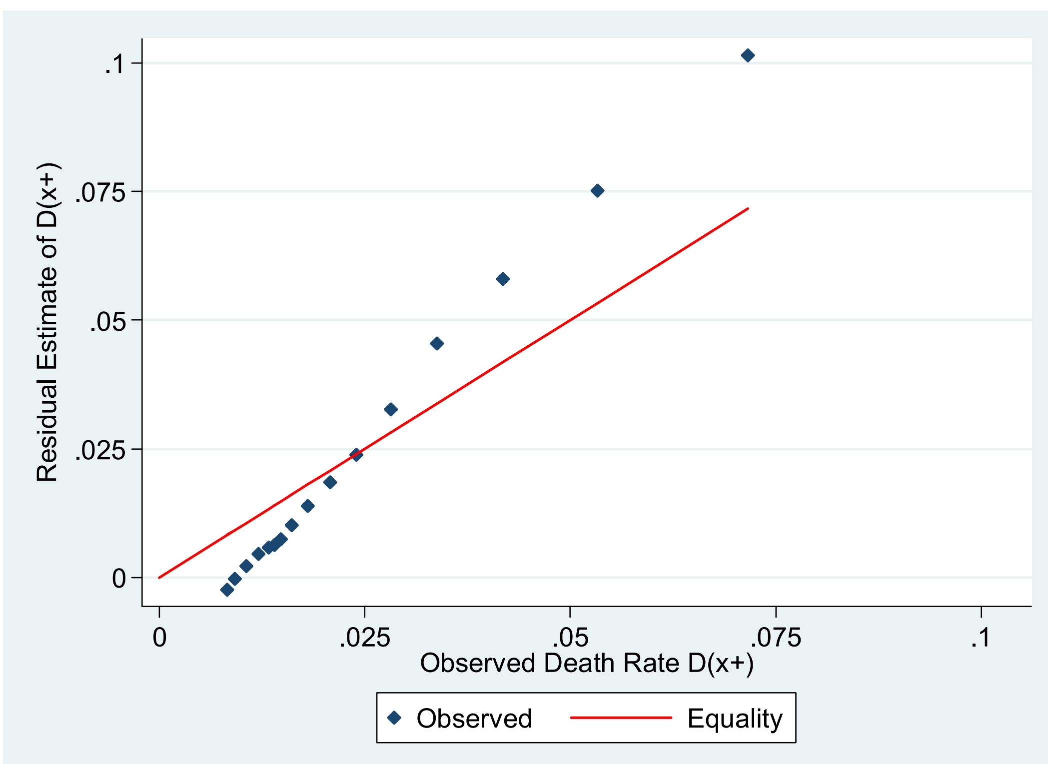
(a) Lesotho



(b) Namibia



(c) South Africa



(d) Zimbabwe

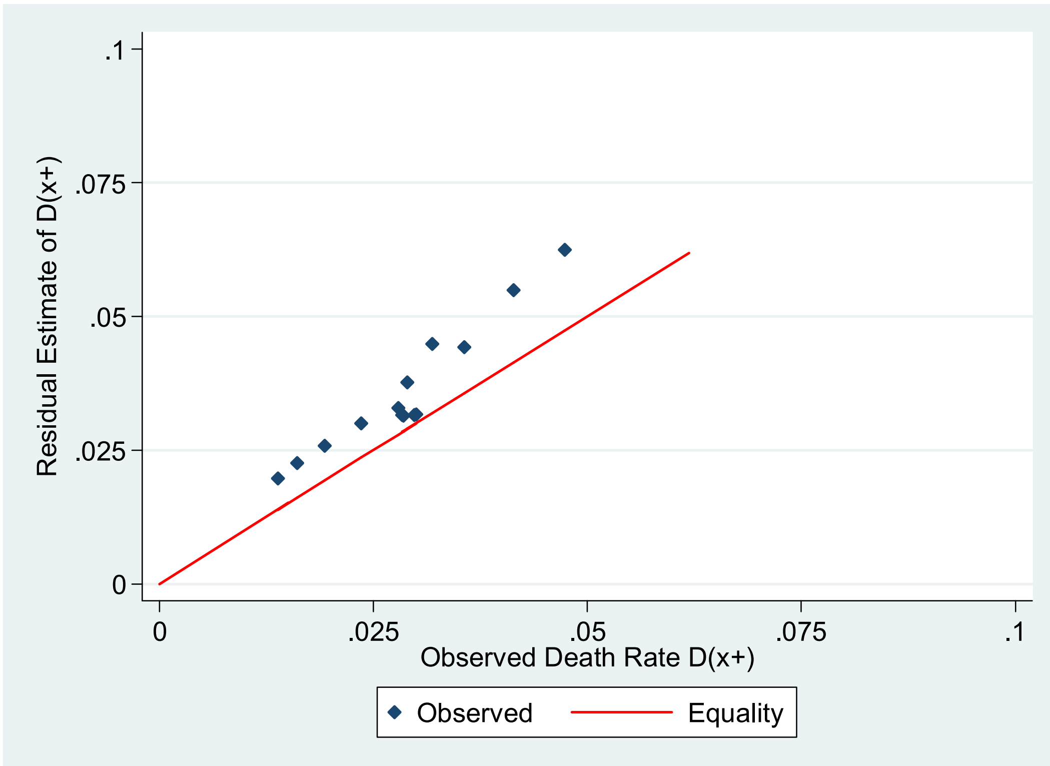


FIGURE 2: Ratios of the Proportion of Pregnancy-Related Deaths in Each Age Group to the Proportion of Births Reported for that Age Group: Censuses of

(*to be completed*)