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Time series analysis of maternal mortality in Africa from 1990 to 2005

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Abstract

Objectives—Most global maternal deaths occur in Africa and Asia. In response, the Millennium Development Goal (MDG-5) calls for a 75% reduction in maternal mortality from 1990 to 2015. To assess the potential for progress in MDG-5 in Africa, we examined the cross-sectional and longitudinal associations of socioeconomic, demographic and population-health factors with maternal mortality rates in Africa.

Methods—We used data from global agencies and the published literature to identify socioeconomic, demographic and population-health explanatory factors that could be correlated with maternal mortality in 49 countries of Africa for the years 1990, 1995, 2000 and 2005. We used correlation, negative binomial and mixed Poisson regression models to investigate whether there exist associations between potential explanatory factors and maternal mortality.

Results—Some African countries have made substantial progress towards achieving MDG-5 while others have fallen behind. Lower gross domestic product (GDP) and female enrolment in primary schools, but higher HIV prevalence, neonatal mortality rate and total fertility rate, were associated with higher maternal mortality.

Conclusions—Maternal mortality rates in African countries appear to be declining. The mean maternal mortality ratios in Africa decreased from 695.82 in 1990 to 562.18 in 2005. Yet some countries are more likely than others to achieve MDG-5. Better socioeconomic, demographic and population health development appear to be conducive to better maternal health in Africa.

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Contributors MD designed and implemented the statistical analysis, interpreted the results and drafted the manuscript. CAT compiled secondary data sources into a single database and assisted with the interpretation of results and manuscript revisions. OAA conceived of and supervised the study, assisted with interpretation of results, and reviewed and revised the manuscript.

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Sustained efforts on all these fronts will be needed to close the gap in maternal survival and achieve MDG-5 in Africa.

INTRODUCTION

The United Nations (UN) General Assembly adopted the Millennium Declaration in 2000, setting a number of goals, known as the Millennium Development Goals (MDGs), with the aim of reducing extreme poverty and improving health and development throughout the world by 2015.¹ Each goal has been expanded to include a number of targets and quantitative indicators to monitor progress.² MDG-5 is focused on improving maternal health, with the quantifiable target of reducing maternal mortality ratios (MMRs) by 75% between 1990 and 2015. MMR is defined as the number of maternal deaths, or the death of a woman during the course of her pregnancy, delivery or within 42 days of termination of pregnancy/100 000 live-births.³ MMR is widely recognised as a 'marker of global inequality' as it reflects access to care⁴ and is an important indicator of a country's general health profile.⁵ Indeed, poverty-stricken populations consistently report higher MMRs.⁶ Currently, the greatest challenge in reducing MMR lies in Africa. Over the past decade, this burden has been exacerbated by the HIV/AIDS epidemic, which has caused MMR to increase in a number of African countries.^{4,5,7,8} Sub-Saharan Africa alone accounted for over 50% of global maternal deaths in 2005, with 13 countries having MMR of 1000 deaths/100 000 live-births or greater.^{9,10}

McCarthy and Maine¹¹ were among the first to develop a conceptual model for analysing determinants of maternal mortality that could be used for both research and programme development. Their model groups distal determinants, such as population-health characteristics, and defines intermediate factors like health behaviours equivalent to proximal determinants. Several models for studying maternal mortality have also been developed by the United Nations Children's Fund (UNICEF)¹² and Mosley and Chen.¹³ Rogo *et al*¹⁴ used such models to develop a framework for studying maternal mortality specifically in Africa. The framework encompasses distal and proximal determinants grouped into several categories: household and community characteristics such as inequality in education, employment, or decision-making, biological and demographic variables, malnutrition and infection, health systems and national policies. Our study makes use of this framework by looking at the relationship between distal determinants and correlates of maternal mortality from these categories and MMR in Africa.

Although studying associations between MMR and other variables across time and space can be difficult due to well-established real-world data constraints^{15,16} (ie, data availability, comparability, uncertainty, etc), researchers have studied MMR in various contexts. For instance, a number of studies have used modelling approaches to estimate MMR as a function of distal and proximal determinants in combination with mortality data from various sources,^{8,10,17} while others have used correlations to assess the relationship between MMR and these factors.^{5,18} However, few studies have used time series data to assess cross-sectional and longitudinal associations between distal determinants and maternal health over time. Such distal determinants are country-level factors that impact population health,¹⁹ but are not rigorously analysed in scientific papers.

Therefore, this study used a pooled multicountry time series design with data from African countries to assess the cross-sectional and longitudinal ecological relationships between MMR and a set of distal determinants between 1990 and 2005. First, we investigated the associations of socioeconomic development, demographic and population-health indicators with MMR in Africa at each of four time points, namely 1990, 1995, 2000 and 2005. Second, we explored whether these associations varied over time.

METHODS

Study population and data

This study focused on 49 countries of Africa. These countries are Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Libyan Arab Jamahiriya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Swaziland, Togo, Tunisia, Uganda, United Republic of Tanzania, Zambia and Zimbabwe. We excluded Sao Tome and Principe and Seychelles due to the unavailability of data for these countries.

Country-level data from WHO,²⁰ UN,²¹ the World Bank (WB),²² Institute for Health Metrics and Evaluation (IHME)²³ and National Accounts Estimates of Main Aggregates (NAMA)²⁴ from each country for the years 1990, 1995, 2000 and 2005 were merged into one database.

Outcome

The outcome of interest in this study was MMR (measured/100 000 live-births) in African countries. We used a modelled estimate of MMR provided by WB.²⁰

Explanatory factors

Explanatory variables were identified based on a review of the literature on MDG-5, published theory regarding determinants of and indicators associated with MMR and correlations between potential predictors of MMR. Our literature review was based on all published articles on MDG-5 between 2000 and 2011 in the PubMed database. This body of literature suggested that distal socioeconomic, demographic and population health factors could be important determinants or correlates of maternal mortality. Time is also used as an explanatory variable in a set of our models.

To reflect socioeconomic factors, we used per capita gross domestic product (GDP) measured in current prices and US dollars (obtained from NAMA) and the ratio of female-to-male primary school enrolment (obtained from WB). Total fertility rate (TFR), that is, the number of children per woman, was chosen as a demographic factor relevant to maternal health and survival (obtained from WHO and UN). For population-health explanatory factors, we used neonatal mortality rate (NMR: number of deaths occurring within the first 28 days of life/1000 live-births, obtained from IHME), prevalence of HIV (percentage of

population aged 15–49 years that was HIV positive, obtained from WB) and sanitation (measured as % of population with access to improved sanitation facilities, obtained from WB). Data on each indicator for all countries and years were extracted from the same source except in the case of TFR, for which 1990 estimates were obtained from WHO and 1995, 2000 and 2005 estimates were obtained from UN.

Analytical strategies

Our analytical strategies consisted of descriptive statistics, correlations, year-specific multivariable regressions and pooled mixed models with random intercept by country for longitudinal data analysis. First, we described the explanatory factors and outcome variables using means and SDs. Second, we examined bivariate correlations between each explanatory factor and MMR at both contemporaneous and one-period lagged time points to gain insights into the crude associations between the factors and the outcome, MMR using Pearson's correlation coefficients. Third, we assumed MMR followed a Poisson distribution and fit a multivariable-adjusted Poisson regression model for MMR at each time point in order to explore cross-sectional associations between MMR and the explanatory factors. After discovering evidence of poor fit and overdispersion, we proceeded to use a negative binomial regression, which had a better fit than the Poisson model. Scatter plots of log-transformed MMR and explanatory factors were used to check linearity assumptions. The plots indicated that log-transformed per capita GDP and log-transformed MMR should be included in the model. In addition to the concurrent or contemporaneous models, we also fit separate models for 1995, 2000 and 2005 relating the MMR from each of those years to the explanatory factors from the previous (lagged) time point. We used the lagged explanatory factors in these models in order to explore whether the values of these indicators from 5 years previously are associated with current MMR levels, as it could take some time before the effects of these indicators on MMR were felt. Finally, we used generalised linear mixed models with a Poisson distribution and log link, or simply a Poisson mixed model, to conduct a longitudinal analysis of MMR over the four time points. Before building any models, we graphically explored time trends in log mean MMR over time with profile plots and empirical summary plots in order to explore the need for random slope effects in our models. These plots indicated a slight downward trend in the outcome over time, but did not justify the use of random slope mixed models. Therefore, we used random-intercept mixed Poisson models to account for clustering of observations within countries. We checked our results against similar mixed models that used the negative binomial distribution and found similar results. Thus, we report the results of only the mixed Poisson models here. We fit two separate series of mixed Poisson regression models: in the first series of models, MMR is regressed on the vector of explanatory factors and time, while in the second series of models MMR is regressed on the vector of explanatory factors and time, and additionally on the vector of predictors lagged by one time point. Time was entered in the model as a continuous variable ranging from one to four, where a one-unit increase in this variable corresponded to an actual 5-year jump to reflect the structure of our data.

The two separate series of mixed Poisson regression models took the following forms:

$$\ln[E(\text{MMR}_{it} | X_{it})] = \beta_0 + x_{it}\beta_1 + \nu_i \quad (a)$$

$$\ln[E(\text{MMR}_{it} | x_{it}, x_{it-1})] = \gamma_0 + x_{it}\gamma_1 + x_{it-1}\gamma_2 + \psi_i \quad (b)$$

where $i=1\ldots 49$ countries; $t=1\ldots 4$ time points (1990, 1995, 2000, 2005); β_0 , γ_0 =intercept in models (a) and (b), respectively; β_1 , γ_1 =vectors of regression estimates for the effect of concurrent predictors in models (a) and (b), respectively; γ_2 =vector of regression estimates for the effect of lagged predictors in model (b); x_{it} =vector of predictors per country for each time point; x_{it-1} =vector of predictors lagged one time point (5 years); ν_i , ψ_i =vectors of random effects coefficients in models (a) and (b), respectively.

All statistical analyses were carried out in SAS (V.9.2, SAS Institute Inc, Cary, North Carolina, USA, 2001).

RESULTS

Table 1 shows descriptive statistics for MMR and predictors used in our analysis, for Africa overall and by countries' WB-designated income levels. The mean MMR in the region decreased steadily from 695.82 in 1990 to 562.18 in 2005. Decreases in MMR occurred for all three income levels over the 15-year time period. MMR estimates at each of the four time points for all countries in our study are provided in the web appendix.

Table 2 shows correlations between MMR and explanatory factors from concurrent and subsequent years. TFR (Pearson's correlation coefficient r ranged from 0.71 to 0.80) and NMR (r ranged from 0.76 to 0.87) were most strongly correlated with the outcome variable, whereas prevalence of HIV had the weakest correlations (between -0.35 and 0.01) with MMR.

Table 3 presents results from the first set of multivariable-adjusted regression models of MMR at each time point. When only concurrent predictors were entered into the models, TFR and log-transformed NMR consistently showed large associations with MMR at each time point. Log per capita GDP was negatively associated with MMR at all time points. The sanitation variable was not associated with MMR. Similarly, prevalence of HIV and female-to-male primary school enrolment ratio were only weakly associated with MMR. Results from the model of MMR as a function of lagged predictors only are shown in table 4. Lagged log-transformed per capita GDP was negatively associated with MMR, although not as strongly as concurrent log GDP per capita. Lagged TFR and log NMR were also positively associated with MMR.

Table 5 presents results from the longitudinal analysis regressing MMR on contemporaneous explanatory factors using mixed models and adjusting for time, and table 6 presents similar models while adjusting for lagged explanatory factors. In almost every case (except for TFR and sanitation), the regression coefficient for contemporaneous factors decreased from table 5 to 6. Concurrent log NMR, TFR and lagged log NMR had large positive associations with MMR. Most of the regression coefficient estimates produced by

the mixed model were small in magnitude. As expected, the fit statistics (not shown) for our models showed improvement from the model with only concurrent predictors to the model that included concurrent and lagged predictors.

DISCUSSION

Our findings support previous studies reporting that a number of factors, including per capita GDP, are related to maternal mortality. While it is known that economic indicators such as GDP or gross national product are related to MMR, they do not completely explain the discrepancies seen between countries,⁵²⁵ as our results also show. Neonatal mortality and total fertility are also important and have large magnitudes even after controlling for the lagged versions of these factors in models with contemporaneous predictors. Since the overall regression estimates attenuate with increasing paths of effects, we expected that regression coefficients from longitudinal models with lagged variables would be attenuated compared with cross-sectional coefficients.

Our research builds on previous studies by exploring associations between MMR in Africa and lagged and concurrent predictors. A major strength of this study is the use of time series data and longitudinal methods to explore associations between our vector of predictors and MMR in Africa. While several past studies have focused on estimation of MMR globally, in this study we focused on Africa and aimed to identify distal correlates of health that were associated with MMR in this region. In addition, we use more years of observation compared with earlier longitudinal studies of MMR in Africa. Our results support previous research showing that NMR and TFR are strongly associated with maternal mortality.⁴²⁶ Decreasing TFR, NMR and MMR often go hand in hand. Social programmes that target reduction in either one of these indicators also help achieve reductions in the other two indirectly.^{26–29} In addition, our models showed null or positive associations between sanitation and MMR, although we expected to find a negative relationship between these variables. Countries with high MMR are often among the poorest countries which may be receiving increased aid for sanitation programmes to improve access, for instance, to latrines in villages and slums. Such improvements in sanitation do not necessarily translate directly to improvements in maternal health and decreased MMR, and this might explain the unexpected associations in our results.

GDP was also an important predictor in our models. Our results show concurrent GDP to be more strongly associated with MMR than lagged GDP, which is a reasonable expectation since funding for public health programmes are often closely tied to a country's economic well-being. Taken altogether, our findings seem to indicate that while immediate changes in GDP are likely to affect MMR, focusing solely on economic improvement over time will not suffice to reduce MMR.³⁰³¹ When designing programmes to alleviate the burden of maternal mortality, governments and organisations must also consider medical, social and cultural factors that will improve access and quality of care. However, our study does not provide definitive answers as to what the most effective intervention or the most appropriate indicator to target would be. Further research is necessary to this end.

Our study has a number of limitations. The MMR estimates used in this study were developed by WB in association with WHO, UNICEF and the United National Population Fund (UNFPA). As highlighted by Hogan *et al*⁸ and Hill *et al*,¹⁰ MMR is often presented as a modelled estimate due to the absence of reliable data.¹⁴ While modelled estimates are based on established demographic and statistical methods, a country specific MMR estimate may not represent that country's true MMR accurately. Statistical models can result in overestimates and underestimates of MMR depending on the source of data and methodology used. Data on maternal deaths are often unavailable due to the absence of vital registrations with accurate information on causes of death or the complete lack of maternal mortality records in many countries.³² In addition, household surveys conducted using various methods and reproductive age mortality surveys alone may not provide the best possible estimates of MMR due to under-reporting or misclassification of maternal deaths.^{33,34} Therefore, we felt that using WB-modelled MMR estimates, which adjust for existing data to account for the poor quality of available data and use regression models for countries that completely lack or have incomplete maternal death data, was appropriate. We also used MMR estimates recently produced by Hogan *et al*^{8,23} to repeat our analysis (results not shown) and found that there were no substantive differences in our results.

Our study is the first to assess the effect of concurrent predictors on MMR while also exploring relationships with lagged predictors. However, the study is limited by the availability of data measuring pertinent variables that represent proximal determinants or correlates of health over time. The availability of time series data was an important consideration in our decision regarding which variables to include in the study, and thus, while the variables included in the analysis are consistent with those discussed by Rogo *et al*,¹⁴ our vector of explanatory variables is not exhaustive. For instance, skilled-birth attendance at delivery is closely related to MMR, since women whose deliveries are conducted by midwives, nurses or physicians are less likely to experience complications and death,⁴⁵ and is an important determinant of maternal mortality in Rogo *et al*'s¹⁴ framework for maternal mortality in Africa. Unfortunately, these data were only available for a very limited number of countries. The same was true for measures of physician, community health worker, or midwife density, antenatal care, adolescent fertility rate and contraceptive prevalence. Such proximal variables are expected to have a greater effect on reduction of MMR than distal variables as they prevent maternal death directly through the use of medical care and the prevention of pregnancy. However, several other authors have reported that skilled-birth attendance is collinear with neonatal mortality, education and GDP;⁸ thus, this may not be a severe problem.

Our use of secondary data also presents a limitation in that the data were not collected for conducting longitudinal analysis, may have inconsistencies, suffer from biases that we are unaware of and lack comparability from year to year and source to source. The TFR variable used in the analysis is most likely to suffer from this as we used TFR estimates from the WHO database for 1990 and 1995 and estimates from the UN database for 2000 and 2005. It is also important to note that we used population level variables, and thus we must be cautious of the ecological fallacy or cross-level inference bias when interpreting these results.

CONCLUSION

We have presented a time series analysis of the relationship between maternal mortality and socioeconomic, demographic and population-health indicators from 1990 to 2005 in Africa. Given the limitations of this study and the ecological design, we can only draw general conclusions from this study and interpret results cautiously. Barring the uncontrolled systematic errors, our results could be interpreted as supporting the statement that while socioeconomic improvement is important for reducing MMR in Africa, a holistic approach that considers public health and social programmes should also be taken into consideration.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Key messages

- ▶ Several African countries are on their way to achieving 75% reductions in maternal mortality ratios (MMR), as indicated by Millennium Development Goal 5, while others lag far behind.
- ▶ National neonatal mortality rate remains one of the most important predictors of maternal mortality, thus lending empirical support to the recent integrated focus on maternal, newborn and child health emphasized in global health.
- ▶ This study indicates that socioeconomic, demographic and general population-health factors all play important roles in reducing MMR over time, but focusing on these factors only or separately will not be enough.

What is already known on this subject?

- ▶ African countries consistently report the highest maternal mortality rates in the world. The HIV epidemic has worsened the problem of maternal death in the region. Maternal mortality is a major public health problem that the United Nations hopes to address through Millennium Development Goal 5, which aims to reduce maternal mortality ratios by 75% by 2015.

What this study adds?

- ▶ Several African countries are on their way to achieving 75% reductions in maternal mortality ratios (MMR), as indicated by Millennium Development Goal 5, while others lag far behind.
- ▶ This study indicates that socioeconomic, demographic and general population-health factors all play important roles in reducing MMR over time, but focusing on these factors only or separately will not be enough.

Table 1
Descriptive statistics for predictors used in the study overall and by income level (N=49)

	By income level					
	Overall (N=49)		High/upper middle income countries (N=8)		Lower middle income countries (N=13)	
	Mean	SD	Mean	SD	Mean	SD
MMR (per 100 000 live-births)						
1990	695.82	380.85	271.88	303.82	537.69	322.57
1995	674.53	389.57	255.25	269.60	510.00	331.34
2000	623.16	337.71	236.50	153.67	488.69	298.15
2005	562.18	306.09	220.00	137.55	462.85	278.93
GDP per capita (current prices, US\$)						
1990	994.34	1383.19	3257.77	2278.33	894.93	324.66
1995	939.01	1254.02	3115.61	1741.75	898.10	539.63
2000	969.54	1359.62	3438.45	1727.20	918.36	529.49
2005	1583.61	2337.46	5995.40	2756.29	1416.99	722.41
Prevalence of HIV (%)						
1990	2.15	3.53	1.45	1.64	1.30	1.54
1995	4.85	6.00	6.27	6.71	4.69	4.94
2000	5.92	7.63	9.37	9.81	6.66	9.25
2005	5.66	7.19	9.90	9.57	6.46	9.30
Total fertility rate (children per woman)						
1990	5.97	1.14	4.56	1.19	5.58	1.11
1995	5.64	1.15	4.26	1.11	5.25	1.18
2000	5.22	1.29	3.69	1.17	4.72	1.29
2005	4.88	1.31	3.33	1.12	4.31	1.32
Ratio of female to male primary enrolment (%)						
1990	81.35	17.74	100.00	9.74	87.19	14.87
1995	82.47	16.20	97.85	4.67	86.90	11.90
2000	87.12	11.82	97.63	3.15	89.26	8.06
2005	90.80	9.55	97.27	2.73	92.04	5.42
Neonatal mortality rate (per 1000 live-births)						
1990	81.35	17.74	100.00	9.74	87.19	14.87
1995	82.47	16.20	97.85	4.67	86.90	11.90
2000	87.12	11.82	97.63	3.15	89.26	8.06
2005	90.80	9.55	97.27	2.73	92.04	5.42

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By income level						
Overall (N=49)		High/upper middle income countries (N=8)		Lower middle income countries (N=13)		Lower income countries (N=28)
Mean	SD	Mean	SD	Mean	SD	Mean
1990	40.00	13.35	24.98	9.17	35.56	10.93
1995	37.71	12.57	23.41	9.97	34.00	11.14
2000	34.59	11.23	22.12	10.69	32.11	10.88
2005	31.24	9.95	21.22	11.17	29.63	10.58
Improved sanitation facilities (% of population with access)						
1990	31.66	25.46	67.67	30.47	43.20	18.36
1995	34.33	24.68	63.38	27.42	45.33	18.39
2000	36.39	24.62	64.88	26.86	46.62	19.58
2005	38.76	25.04	66.13	26.91	49.54	21.62
						25.93
						16.45

GDP, gross domestic product; MMR, maternal mortality ratios.

Table 2

Pearson correlation coefficients for predictors and maternal mortality ratios at concurrent and subsequent time points.

Maternal mortality ratio (modelled estimate, per 100 000 live-births)				
	1990	1995	2000	2005
Per capita GDP				
1990	−0.581 *	−0.554 *	−0.539 *	−0.501 *
1995		−0.652 *	−0.631 *	−0.584 *
2000			−0.630 *	−0.604 *
2005				−0.532 *
Prevalence of HIV				
1990	−0.229	−0.098	0.008	0.020 *
1995		−0.349 *	−0.155	−0.041 *
2000			−0.190	−0.057 *
2005				−0.095 *
Total fertility rate				
1990	0.801 *	0.789 *	0.755 *	0.663 *
1990–1995		0.763 *	0.727 *	0.638 *
1995–2000			0.773 *	0.684 *
2000–2005				0.707 *
Ratio of female to male primary enrolment (%)				
1990	−0.616 *	−0.543 *	−0.456 *	−0.389 *
1995		−0.697 *	−0.578 *	−0.462 *
2000			−0.585 *	−0.542 *
2005				−0.527 *
Neonatal mortality rate				
1990	0.859 *	0.836 *	0.762 *	0.681 *
1995		0.867 *	0.806 *	0.728 *
2000			0.812 *	0.750 *
2005				0.750 *
Improved sanitation facilities (% population with access),				
1990	−0.678 *	−0.632 *	−0.613 *	−0.563 *
1995		−0.615 *	−0.622 *	−0.592 *
2000			−0.618 *	−0.598 *
2005				−0.599 *

* Significant at the $p < 0.05$ level.

GDP, gross domestic product.

Table 3

Regression coefficients (CIs) for associations between contemporaneous explanatory factors and maternal mortality ratios (MMR) at four time points (1990, 1995, 2000, 2005)

Contemporaneous explanatory factors	1990 (N=29)			1995 (N=30)			2000 (N=40)			2005 (N=36)		
	β estimate (CI)	p Value		β estimate (CI)	p Value		β estimate (CI)	p Value		β estimate (CI)	p Value	
Log per capita GDP	-0.31 (-0.53 to -0.08)	0.01		-0.20 (-0.38 to -0.01)	0.04		-0.19 (-0.37 to -0.003)	0.05		-0.14 (-0.30 to 0.01)	0.08	
Prevalence of HIV	-0.01 (-0.05 to 0.02)	0.52		-0.0005 (-0.02 to 0.02)	0.96		0.02 (0.01 to 0.04)	<0.01		0.02 (0.01 to 0.04)	0.01	
Total fertility rate	0.24 (0.04 to 0.44)	0.02		0.16 (-0.004 to 0.33)	0.06		0.23 (0.04 to 0.42)	0.02		0.15 (-0.03 to 0.33)	0.09	
Ratio of female to male primary enrolment	-0.006 (-0.01 to 0.003)	0.19		-0.01 (-0.02 to 0.003)	0.18		-0.004 (-0.02 to 0.01)	0.50		-0.01 (-0.02 to 0.01)	0.25	
Log neonatal mortality rate	0.50 (-0.27 to 1.28)	0.20		0.73 (0.20 to 1.26)	0.01		0.61 (0.04 to 1.12)	0.03		1.04 (0.44 to 1.63)	<0.01	
Improved sanitation facilities	0.004 (-0.004 to 0.013)	0.33		0.003 (-0.003 to 0.01)	0.33		0.001 (-0.01 to 0.01)	0.77		0.002 (-0.01 to 0.01)	0.59	

GDP, gross domestic product.

Table 4

Regression coefficients (CIs) for associations between explanatory factors lagged one time period and maternal mortality ratios (MMR) at subsequent time points (1995, 2000, 2005)

Lagged explanatory factors	1995 (N=24)			2000 (N=30)			2005 (N=35)		
	β Estimate (CI)	p Value		β Estimate (CI)	p Value		β Estimate (CI)	p Value	
Log per capita GDP	-0.19 (-0.43 to 0.04)	0.11		-0.03 (-0.3 to 0.24)	0.82		-0.19 (-0.39 to 0.02)	0.08	
Prevalence of HIV	0.01 (-0.03 to 0.05)	0.56		0.03 (0 to 0.06)	0.02		0.03 (0.02 to 0.05)	<0.01	
Total fertility rate	0.25 (0.05 to 0.46)	0.02		0.15 (-0.08 to 0.39)	0.20		0.17 (-0.05 to 0.39)	0.12	
Ratio of female to male primary enrolment	-0.01 (-0.02 to 0.002)	0.15		-0.01 (-0.02 to 0.01)	0.32		-0.01 (-0.02 to 0.01)	0.28	
Log neonatal mortality rate	0.64 (-0.18 to 1.45)	0.13		0.85 (0.11 to 1.59)	0.03		0.56 (-0.08 to 1.20)	0.09	
Improved sanitation facilities	0.01 (-0.003 to 0.02)	0.17		-0.0004 (-0.01 to 0.01)	0.93		-0.001 (-0.01 to 0.01)	0.91	

GDP, gross domestic product.

Table 5

Mixed model regression coefficients (CIs) for associations between contemporaneous explanatory factors and maternal mortality ratios (MMR), adjusting for time (N=135)

Predictors	Estimates (CI)	p Value
Time	0.04 (0.019 to 0.056)	<0.01
Log GDP per capita	−0.02 (−0.05 to 0.001)	0.06
Prevalence of HIV	0.02 (0.016 to 0.022)	<0.01
Total fertility rate	0.06 (0.029 to 0.095)	<0.01
Ratio of female to male primary enrolment	−0.002 (−0.003 to −0.0001)	0.04
Log neonatal mortality rate	1.51 (1.386 to 1.643)	<0.01
Improved sanitation facilities	0.004 (0.002 to 0.007)	<0.01
<i>Random intercept, variance (SE)</i>	0.1224 (0.03)	

GDP, gross domestic product.

Table 6

Mixed model regression coefficients (CIs) for associations between contemporaneous and lagged explanatory factors and maternal mortality ratios (MMR), adjusting for time (N=118)

Predictors	Estimates (CI)	p Value
Time	0.03 (0.005 to 0.063)	0.02
Log GDP per capita	−0.06 (−0.094 to −0.024)	<0.01
Lagged log GDP per capita	0.02 (0.001 to 0.047)	0.05
Prevalence of HIV	0.01 (0.005 to 0.015)	<0.01
Lagged prevalence of HIV	0.02 (0.015 to 0.023)	<0.01
Total fertility rate	0.12 (0.077 to 0.164)	<0.01
Lagged total fertility rate	−0.03 (−0.065 to −0.003)	0.03
Ratio of female to male primary enrolment	0.0005 (−0.001 to 0.002)	0.59
Lagged ratio of female to male primary enrolment (lagged)	−0.004 (−0.006 to −0.003)	<0.01
Log neonatal mortality rate	1.28 (1.116 to 1.446)	<0.01
Lagged log neonatal mortality rate	0.07 (0.003 to 0.138)	0.04
Improved sanitation facilities	0.004 (0.0003 to 0.008)	0.03
Lagged improved sanitation facilities	0.002 (0.001 to 0.004)	<0.01
<i>Random intercept, variance (SE)</i>	0.1321 (0.03)	

GDP, gross domestic product.