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ASSOCIATION BETWEEN ECONOMIC GROWTH, COVERAGE OF MATERNAL AND CHILD HEALTH INTERVENTIONS, AND UNDER-FIVE MORTALITY: A REPEATED CROSS-SECTIONAL ANALYSIS OF 36 SUB-SAHARAN AFRICAN COUNTRIES

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Association among Economic Growth, Coverage of Maternal and Child Health Interventions, and Under-Five Mortality: A Repeated Cross-Sectional Analysis of 36 Sub-Saharan African Countries

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Preface

One of the most significant contributions of The DHS Program is the creation of an internationally comparable body of data on the demographic and health characteristics of populations in developing countries.

The *DHS Comparative Reports* series examines these data across countries in a comparative framework. The *DHS Analytical Studies* series focuses on analysis of specific topics. The principal objectives of both series are to provide information for policy formulation at the international level and to examine individual country results in an international context.

While *Comparative Reports* are primarily descriptive, *Analytical Studies* provide in-depth, focused studies on a variety of substantive topics. The studies are based on a varying number of data sets, depending on the topic being examined. These studies employ a range of methodologies, including multivariate statistical techniques.

The DHS Program staff, in conjunction with the U.S. Agency for International Development (USAID), select the topics covered in *Analytical Studies.*

It is anticipated that the *DHS Analytical Studies* will enhance the understanding of analysts and policymakers regarding significant issues in the fields of international population and health.

Sunita Kishor
Director, The DHS Program

Executive Summary

Infant and child mortality rates are among the most important indicators of child health, nutrition, implementation of key survival interventions, and the overall social and economic development of a population. In this report, using data from 99 Demographic and Health Surveys (DHS) conducted in 36 sub-Saharan African countries, we investigate factors that have contributed to the declines in under-five mortality rates (U5MR) in sub-Saharan Africa. Specifically, we focus on the extent to which changes in country-level economic growth and changes in the coverage of key maternal, neonatal, and child health (MNCH) interventions have contributed to reductions in under-five mortality.

For this analysis we constructed two distinct data structures: (1) an *ecological time series* (with countries repeatedly observed) and (2) a *multilevel repeated cross-section* (which in addition took account of the variability between children within a country at any time). We employed a country-level fixed effects regression to model changes in U5MR across survey periods as a function of changes in economic growth and coverage of MNCH interventions for ecological time series data. The multilevel repeated cross-sectional data was used to examine the probability of a child being reported to have died at age 0-59 months, corresponding with different levels of economic growth and coverage, while accounting for within-country between-child factors that could influence both child mortality and the country-level economic development and coverage indicators.

Our results show that changes in country-level per capita GDP (pcGDP) are not consistently associated with a reduction in U5MR across different model specifications. In ecological time series models, a unit increase in pcGDP is associated with a reduction in U5MR of 11.6 deaths per 1000 live births (95% CI: -29.1, 5.9), while a composite index of MNCH interventions is associated with a reduction in U5MR of 31.9 deaths per 1000 live births (95% CI: -48.6, -15.3). The results of the multilevel repeated cross-section data structure suggest that MNCH coverage indicators are important. For example, pcGDP is associated for a decreased likelihood of child mortality with an odds ratio of 0.96 (95% CI: 0.92 -1.00) and an increase of 1 standard deviation in the composite coverage index (CCI) is also associated with a decrease in child mortality [odds ratio 0.92 (95% CI: 0.88 - 0.96)]. A measure of improvements in sanitary facilities is associated with an odds ratio of 0.57 (95% CI: 0.50-0.65) for child mortality.

Together, these results indicate that MNCH interventions are important in reducing U5MR, while the effects of economic growth in sub-Saharan Africa remain weak and inconsistent. Sub-Saharan Africa continues to have the highest U5MR globally, and progress toward reducing mortality rates has been slow. Our findings indicate that improved coverage of proven life-saving interventions and access to clean water and sanitation will likely contribute to further reductions in U5MR in sub-Saharan Africa in the future.

Background

Infant and child mortality rates are among the most important indicators of child health, nutrition, implementation of key survival interventions, and the overall social and economic development of a population.[1] Researchers have proposed several conceptual and analytical frameworks for studying child mortality and survival in low-income countries.[2] Perhaps the most widely cited of these is the model developed by Mosley and Chen[3], which integrated the social science and medical disciplines and introduced the idea that background socioeconomic and cultural variables operate through proximate determinants that directly influence childhood disease. In this report, we further extend this model by expanding and conceptualizing the socioeconomic background variables as a hierarchy of 'distal' determinants, which include country-level factors relating to economic growth, rates of fertility and education, and health systems and policy factors, such as coverage of MNCH interventions.

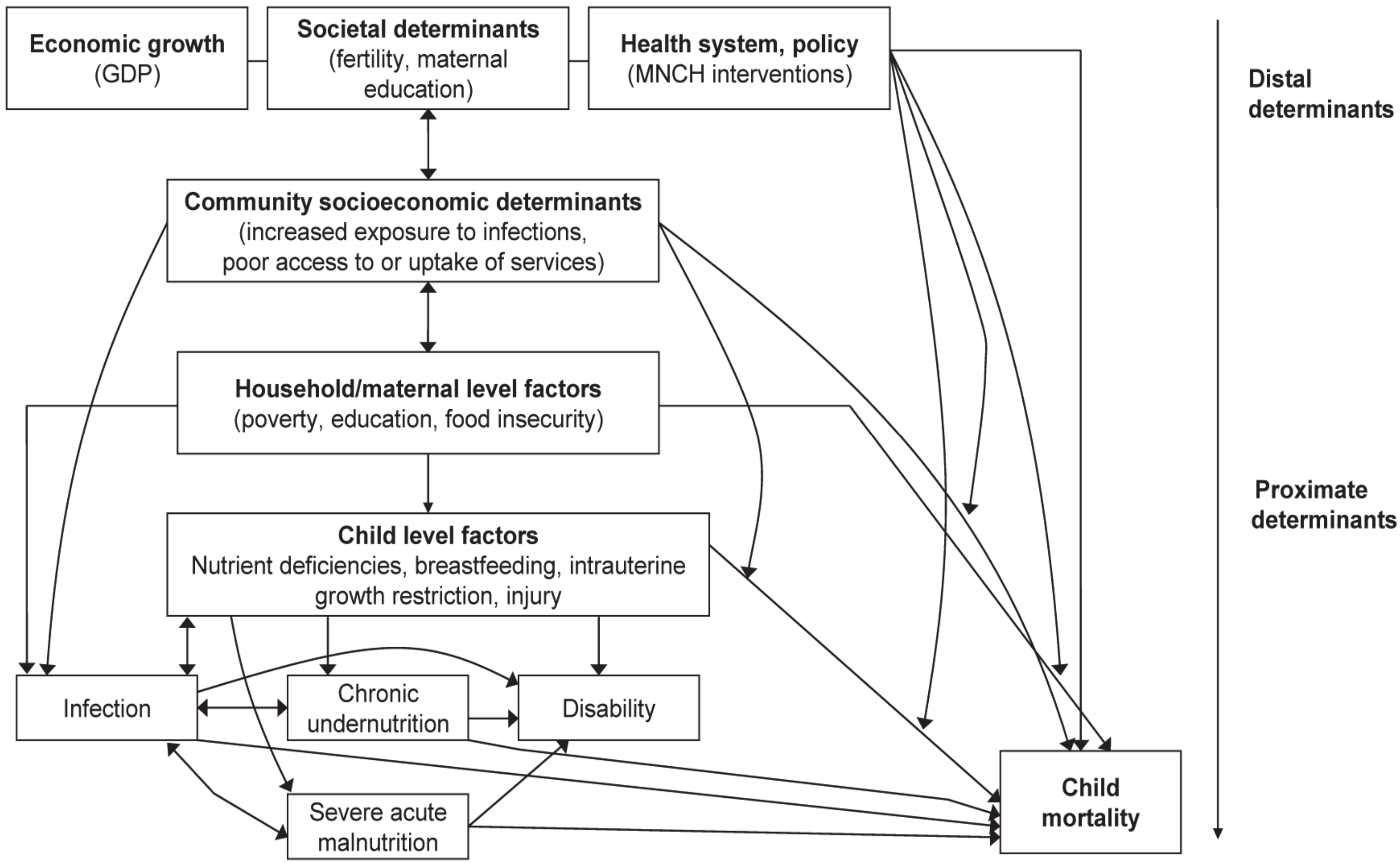
The overall directionality of country-level factors on child health is downward, from distal to proximate (Figure 1). Country-level factors may: (1) exert direct, cross-level effects on child mortality, (2) exert indirect, cross-level effects mediated through more proximal variables, such as community or household socioeconomic factors, and (3) modify the associations between independent and dependent variables operating within or across levels (e.g., country gross domestic product (GDP) modifying the effects of household-level disadvantage on child mortality). Of course, this conceptualization is complex and many interactions may produce bidirectional effects such that family-level and child-level factors may influence the community and country-level variables. Using this framework, we examine the effects of both economic growth and coverage of MNCH interventions on reducing child mortality in sub-Saharan Africa. We use both an *ecological time series* (country-level) approach and a *multilevel* (children nested within countries) approach.

Since September 2008, the governments of 147 countries have agreed to accelerate efforts to achieve a series of development goals,[7] which are referred to as the Millennium Development Goals (MDGs).[8] Of the eight goals established, the fourth (MDG-4) is "to reduce by two thirds, between 1990 and 2015, the under-five mortality rate".[8] Considerable resources and efforts have gone into assessing the progress toward achieving MDG-4, including determining what interventions are needed to accomplish this goal.[9, 10] With less than 1,000 days remaining until the 2015 deadline for accomplishing the goals of MDG-4, there has been renewed attention to the success (or not) of meeting these targets.[11] The UN Inter-agency Group on Child Mortality Estimation (UN-IGME) was established to track progress toward MDG-4 and assess whether countries will achieve it.[12]

According to the most recent UN-IGME estimates in 2010, sub-Saharan Africa as a whole has the highest rate of child mortality (121 deaths per 1,000 live births), with one in every eight children dying before their fifth birthday. This is nearly double the average in developing/low-income regions (62.7 deaths per 1,000 live births), and nearly 18 times the average for developed/high-income regions (6.8 per 1,000). Sub-Saharan Africa and South Asia together accounted for 82 percent of global under-five deaths in 2010, although these regions account for less than half of the global population under age 5.[12]

The U5MR for sub-Saharan African declined from 174 per 1,000 in 1990 to 121 per 1,000 in 2010.[12] This corresponds to a 30 percent reduction in U5MR since 1990, well short of the target of a two-thirds reduction.[9] The annual rate of reduction in U5MR has been 1.8 percent over the period 1990-2010, although the region experienced a more rapid rate of reduction from 2000-2010, at an annual rate of 2.4 percent, double the 1.2 percent rate between 1990 and 2000. Compared with other developing regions, however, sub-Saharan Africa has experienced slower rates of decline in U5MR and continues to have higher fertility rates.

Figure 1. Hypothesized relational structure among child mortality; child, household/maternal, and community determinants; and country-level economic growth, social determinants, and health system and policy variables



Note: Adapted from Bronfrenbrenner[4], Mosley & Chen[3], Boyle[5], and Bhutta.[6]

It has been argued that poor economic performance and poverty are key drivers of poor health and nutrition in developing countries.[13] It has also been argued, however, that economic growth and prosperity do not automatically imply improved health and that other factors, such as greater equality in the distribution of wealth, seem to be important in improving health.[14] Economic growth continues to be promoted as a policy instrument in low-income countries, under the premise that such growth will improve average incomes, lift people out of poverty, and improve health by encouraging greater consumption of health-promoting goods and services.[15]

An alternative policy approach to improving health has been to encourage the strengthening of health systems in low-income countries,[16] and in particular improving the coverage of key maternal, newborn, and child health interventions.[17, 18] Coverage of interventions such as measles and diphtheria, pertussis, and tetanus (DPT) vaccinations, and skilled birth attendance are widely accepted indicators of progress toward improving health systems and achieving the MDGs.[19, 20] Further, the coverage and equity distribution of a set of core MNCH interventions are being tracked across a range of low- and middle-income countries as we approach the 2015 MDG deadline.[21] To date, however, there has been limited evidence on how the coverage of these interventions is related to declines in U5MR, as these measures are considered long-term indicators of health systems performance and are insensitive to shorter-term changes in coverage.[22]

In this report, we investigate factors that have contributed to the recent declines in U5MR in sub-Saharan Africa since 1990, using data from the Demographic and Health Surveys (DHS). Specifically, we focus on the contributions of economic growth and MNCH interventions in reducing child mortality in sub-Saharan Africa. We examine those MNCH interventions that can be estimated from the DHS data and that have reliable evidence for reducing child mortality in low-income countries: contraceptive prevalence; antenatal care; skilled birth attendance; immunization; treatment of childhood illnesses; and improved water and sanitation facilities.[6, 17, 23-38]

Methods

Data Sources

We used data from DHS surveys[39] conducted since 1990. We selected surveys for each country that included birth histories ('BR' files), MNCH coverage indicators, assessments of household wealth, and the standard DHS wealth index included with the survey datasets.[40, 41] The sample included all DHS or related surveys with a 'BR' file from which child mortality rates could be calculated. Related surveys include the AIDS Indicator Surveys (AIS) and the Malaria Indicator Surveys (MIS).

In total, 99 surveys are included in this report, covering 36 countries and 93 percent of the population of sub-Saharan Africa.[42] Thirty-eight surveys were conducted before 2000, 20 between 2000 and 2004, 24 between 2005 and 2008, and 19 since 2009. Twenty-five of the 36 countries conducted at least two surveys during this period, and 20 conducted three or more.

Sampling Plan

The DHS household surveys use nationally representative sampling plans and have special emphasis on fertility, child mortality, and indicators of maternal and child health.[39] The target population in DHS surveys considered in this report is women age 15-49 and their children. A complete birth and death history was collected for each eligible woman survey respondent and included the date of birth, and if applicable the date of death, of all children ever born. Due to the coverage, comparability, and data quality of DHS,[43] it is possible to conduct pooled and cross-country comparative analyses.[39]

Study Population, Data Designs, and Sample Sizes

In this report the study population was structured as two distinct data designs. First, we examined the study population as an ecological time series design, where the lowest level of analysis was the survey period, which was nested within countries as a hierarchical structure. This can be shown graphically, with rectangles representing units of analysis and arrows representing classification hierarchies. **Figure 2** presents a graphical classification diagram for the ecological time series data structure.

Second, we used a multilevel repeated cross-sectional design, where children at the lowest unit of analysis were nested within primary sampling units (PSU), within survey periods, and within countries (**Figure 3**). A key substantive advantage of the second approach is the ability to account for within-country between-child factors that can influence both child mortality and the country-level economic development and coverage indicators. Further, the ecological time series data structure assumes that the probability of dying (or U5MR) is the same for all children within a country period. This assumption is relaxed in the multilevel data structure, although in doing so we are modeling the probability of a child dying before the fifth birthday, and not U5MR.

Figure 2. Classification diagram for the ecological time series data structure with survey periods nested within countries

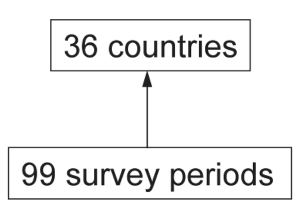
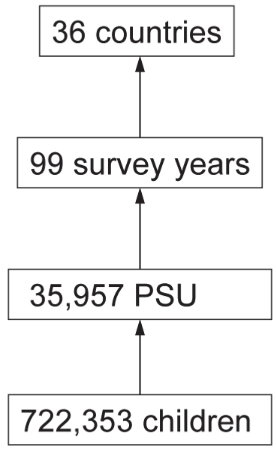


Figure 3. Classification diagram for the multilevel data structure with children nested within primary sample units (PSU), within survey periods, and within countries



Ecological time series data structure

For the ecological time series design, the lowest unit of analysis was the survey period, nested within country. In total, 99 surveys were included in this analysis, covering 36 countries, with between one and five survey periods per country. In total, 25 countries had at least two survey periods, and the average number of survey periods across all countries was 2.8. The ecological time series design accounts for the nested structure of survey periods within countries (**Figure 2**). On the subset of countries (n = 25) where more than one survey was available, we used a change-on-change approach to examine changes in U5MR occurring between the first and last survey periods, corresponding to changes in the explanatory variables over the same period. In both approaches the U5MR corresponds to a five-year reference period immediately preceding the survey.

Multilevel repeated cross-sectional data structure

For the multilevel design, the lowest unit of analysis was at the child level. In this approach, a nested hierarchy was defined which included children at level one, nested in primary sample units (PSUs) at level two, nested in countries at level three (**Figure 3**). Children across all surveys were pooled, and we defined a reference period from which to examine the probability of child death as the five-year period immediately preceding the survey. In total, there were 748,363 birth histories of children born within the reference period. After making exclusions for missing data, the final analytical sample size was 722,353. Maternal height was included as a potential confounder. In models where maternal height was included, the sample size was 509,432, because anthropometric measurements for women were not available in all 99 surveys.

Outcomes

This report uses two distinct outcomes, corresponding to the two data designs employed. In the ecologic time series design, the outcome is the calculated U5MR in each of the 99 surveys. In the multilevel design, the outcome is the probability of child death occurring within five years prior to the survey (reference period).

Ecological time series data structure

Levels of child mortality are typically expressed as probabilities of dying between exact ages (x and x+n), which are derived from life tables and denoted by ${}_nq_x$.[44] The U5MR, also denoted ${}_5q_0$, is formally defined as the probability of a child death occurring between birth and a child's fifth birthday.[12] Further, the U5MR is a composite measure of mortality occurring during the first five years, which can be further defined as the probability of dying within 1 month (neonatal mortality), 0-11 months (infant mortality, including neonatal deaths, or ${}_1q_0$), and 12-59 months (child mortality, conditional on having reached the first birthday, or ${}_4q_1$).[45] The U5MR is expressed as deaths per 1,000 live births.[12, 44]

Under-five mortality rates were calculated using the DHS synthetic cohort life table methodology.[46] This approach uses age segments 0, 1–2, 3–5, 6–11, 12–23, 24–35, 36–47, 48–59 months (completed ages) for the calculation of the individual probabilities of dying, without adjustment for heaping at age of death of 12 months.[46] Imputation procedures were used for children with missing ages at death. The calculation of the U5MR was based on the number of deaths to live-born children in the five-year reference period preceding the survey. Death probabilities were calculated for each of the age segments defined above and then combined into the mortality rate as the product of the component survival probabilities, and expressed as a rate per 1,000 live births.

Multilevel repeated cross-sectional data structure

In the multilevel design, the outcome was defined at the child level as a child death occurring within the reference period. This was expressed as a binary outcome: 1 for a death occurring in the child's first five years; 0 for survival through 59 months of age. This outcome is interpreted as the probability of a child death occurring within the first five years of life.

Exposures

Per capita gross domestic product (pcGDP) was used as the primary measure of a country's economic growth and development. Per capita GDP is the value of all goods and services produced within a country in a given period of time, divided by the total population of that country in the same period. These data were obtained from the World Bank[47] and corresponded to the five-year reference period preceding the survey. Since pcGDP was measured multiple times for 25 countries with repeated DHS, the inclusion of pcGDP in regression models allows for the estimation of the effect of within-country change in pcGDP, interpreted as economic growth. Analysis of pcGDP was included in regression models as the logarithm of pcGDP.

The second key exposure of interest was coverage of maternal and child health interventions. We selected a subset of maternal, newborn, and child health interventions that have sufficient evidence in the literature of an effect on reducing child mortality from the major causes of under-five deaths.[17, 23-38, 48] These interventions, classified by the timing of coverage include:

Pre-pregnancy: Contraceptive prevalence, demand for family planning satisfied (pre-pregnancy), 1+ ANC visits with a skilled provider/4+ visits with any provider, neonatal tetanus protection.

Pregnancy/birth: Skilled attendant at birth, early initiation of breastfeeding (within 24 hours), BCG, DTP3, measles, and full vacation coverage, Vitamin A supplementation, oral rehydration therapy (ORT), care-seeking for pneumonia (CPNM), children sleeping under insecticide-treated mosquito nets.

Infancy/childhood: Improved water and sanitary facilities at last antenatal care visit by a skilled provider, skilled birth attendant, measles and DPT3 vaccination coverage, care seeking for pneumonia, tetanus vaccination of mother, access to improved sanitary facilities, early initiation of breastfeeding, insecticide-treated bed net use by children, contraceptive prevalence (modern and traditional methods), and access to an improved drinking water source.

Finally, we used a composite variable (the composite coverage index, or CCI) based on a weighed average of coverage of a set of eight interventions, giving equal weight to family planning, maternal and newborn care, immunization, and case management of sick children, as a way to effectively summarize and compare coverage of MNCH interventions across countries and over time.[17]

Child, maternal, and household-level covariates used with multilevel data structure

We used a variety of theoretically important maternal and child characteristics as covariates in the multilevel regression models.[49] Age, sex, multiple/single birth, birth order, and preceding birth interval were included as child characteristics, along with age of the mother at birth, maternal education, household wealth quintile, area of residence, and maternal height, as maternal characteristics. Child age was categorized as 0-1 years, 2-3 years, and 4 years. Sex and twin status were binary variables that indicate whether the child was a boy or a girl, and whether a single or multiple birth. Birth order was categorized into five groups to indicate first, second, third, fourth, or fifth/higher born. Preceding birth interval was recorded in months and categorized as <24 months, 24-47 months, and 48 or more months between births. Mother's age at birth was calculated and categorized as under age 17, 17-19, 20-24, 25-29, and 30-49. Maternal education was categorized in four groups: no education, any primary, incomplete secondary, and complete secondary/higher.

Household wealth was defined according to an index developed from indicators of household asset ownership and housing characteristics (e.g. whether the household had a flush toilet, refrigerator, car, moped/motorcycle, television, washing machine, or telephone). Country-specific and weighted linear combinations of these items were constructed with weights for each item obtained from a principal component analysis.[41] The index was then standardized with a mean 0 and standard deviation 1 and, using the quintiles of this distribution, the survey population in each country was divided into fifths from poorest to richest. Similar measures have been developed in India and other settings and shown to be a consistent proxy for household income and expenditure.[40]

Whether the household was located in an urban or rural area was included according to country-specific definitions. Where available, maternal height in centimeters was included in regression models and categorized as: <145 cm, 145-149 cm, 150-154 cm, 155-159 cm, and 160+ cm. The relationship between child mortality and these covariates was examined (see Table 8).

Analysis

Our analysis uses two approaches that correspond to the two data structures described previously. We first describe the ecological time series analyses conducted at the level of surveys within countries, followed by the multilevel analyses conducted at the level of children within surveys and countries.

Ecological time series data structure

In the ecological time series models, where the survey is the unit of analysis, we fit regression models of the form (illustrated with the example of pcGDP as a single covariate),

$$y_{ij} = \beta_0 + BC_j + BS_{ij} + \beta_1 pcGDP_{ij} + e_{0ij}, \qquad (1)$$

where y_{ij} represents the U5MR for survey time *i* in country *j*; β_0 represents the intercept or the average U5MR holding pcGDP constant ($\beta_1 pcGDP_{ij}$), and after accounting for country differences (BC_j); BC_j represents the country-specific dummy variables estimating differences in U5MR between countries; BS_{ij} represents the effects associated with dummies for survey years; $\beta_1 pcGDP_{ij}$ represents the change in U5MR for a unit change in pcGDP; and e_{0ij} represents the residuals at the survey-year level i in country j. β_1 is the effect of a one-unit increase in pcGDP on U5MR.

We first ran a series of ecological regressions that included survey period and one exposure of interest per model. We then fit a multivariable model that included pcGDP and the composite coverage indicator (CCI). The CCI is used as a summary for all of the other coverage variables to increase model parsimony and reduce potential multicollinearity, given the small size of the dataset.

While these models were also fitted using the 'random effects' approach, we focus on the fixed effects approach because of the additional assumptions required by the random effects approach, even though random effects models are more efficient. Since we want to err on the conservative side with regard to the strength of the association between the independent variables and the dependent variable, we use the fixed effects approach as the basis for interpretation. It should be noted that, while we control for all country-level confounders that do not vary over time, the model also ends up controlling for any country-level "mediators" that could potentially underestimate the strength of association.

This modeling approach used in our analyses is able to account for imbalance in the number of survey periods available for each country. In our dataset, several countries have only one survey, whereas others have three or more. In a traditional 'change on change' regression model, information is lost because countries without at least two surveys cannot be included in the model. Further, the fixed effects model can readily handle situations where multiple periods are available per country, whereas the 'change on change' model essentially removes the intervening periods and only examines the first and last.

Multilevel repeated cross-sectional data structure

We also conducted multilevel analyses on the dataset where children are the lowest unit of analysis. In these analyses the basic model is a two-level multilevel logistic regression model with a binary response (*y*, child death, or not) for child *i* in PSU *j*. [50] Countries are treated as fixed effects using country indicator variables in the fixed part of the model (BC_k). The outcome of child mortality, Pr(y_{ijk} = 1), is assumed to be binomially distributed $y_{ijk} \sim Binomial(1, \pi_{ijk})$ with probability π_{ij} related to the set of independent variables X and a random effect for each level by a logit link function:

$$Logit(\pi_{ij}) = \beta_0 + BC_k + BS_{jk} + \beta_1 pcGDP_k + BX_{ij} + (u_{0j}) \qquad (2)$$

The right-hand side of the equation consists of the fixed part linear predictor ($\beta_0 + BC_k + BS_{ij} + \beta_1 pcGDP_{jk} + BX_{ijk}$) and random intercepts for PSU (u_{0jk}). The intercept, β_0 represents the log odds of child mortality for the reference group, BS_{ij} is a vector of coefficients for dummy variables for survey years, $\beta_1 pcGDP_{jk}$ represents the log odds of child mortality for a one-unit increase in pcGDP, and the BX represents a vector of coefficients for the log odds of child mortality for a one-unit increase for each independent variable. Coefficients are exponentiated and presented as odds ratios for interpretation. The random intercepts are assumed to be independently and identically distributed and have variances estimated for PSU (σ_u^2).[51]

We fitted a sequence of models where the child- and maternal-level covariates were first entered in to the model, followed by one country-level exposure at a time. A final multivariable multilevel model was then fitted that included all child and maternal covariates plus important economic and coverage indicators from the previous models.

In both the ecological time series analyses and the multilevel analyses, the country-level economic and coverage indicators are defined in standard deviation units. This is to allow comparability of the coefficients across different models. **Table 1** presents the mean, standard deviation, minimum, maximum, and a correlation matrix for all of the economic and coverage indicators at the first survey period.

Table 1. Descriptive statistics and correlation matrix of all of the economic and coverage indicators measured in the first survey period, from Demographic and Health Surveys conducted in 36 sub-Saharan African countries

Variable	Mean	S.D.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Log GDP	6.1	0.9	4.7	8.4	1.000																	
2. CCI	51.9	16.3	20.5	77.1	0.525	1.000																
3. ANC1	78.9	19.0	26.7	98.9	0.281	0.912	1.000															
4. ANC4	48.5	20.9	8.6	79.3	0.362	0.879	0.707	1.000														
5. SBA	42.7	20.9	4.0	85.5	0.508	0.852	0.702	0.632	1.000													
6. MSLV	63.8	18.5	22.8	94.3	0.167	0.933	0.842	0.607	0.638	1.000												
7. DPT3	60.4	21.8	20.0	95.7	0.107	0.886	0.820	0.572	0.526	0.959	1.000											
8. CPNM	45.7	16.2	13.5	75.3	0.385	0.843	0.767	0.814	0.766	0.694	0.643	1.000										
9. Tetan	35.8	17.5	0.0	72.6	-0.158	0.184	0.343	0.200	0.254	0.347	0.321	0.235	1.000									
10. Sanit	25.8	16.6	4.8	67.6	0.514	0.798	0.475	0.365	0.625	0.576	0.503	0.529	0.042	1.000								
11. Bednet	23.8	21.2	0.6	56.2	-0.144	0.296	0.337	-0.308	0.439	0.370	0.461	0.650	-0.357	0.061	1.000							
12. Contra	20.6	14.2	4.1	56.3	0.615	0.849	0.581	0.630	0.610	0.618	0.559	0.521	-0.135	0.542	-0.279	1.000						
13. Water	58.6	16.7	28.9	92.1	0.571	0.790	0.605	0.497	0.516	0.508	0.474	0.598	-0.101	0.375	0.641	0.606	1.000					
14. BCG	80.9	16.7	38.8	98.9	0.149	0.913	0.844	0.638	0.648	0.920	0.887	0.703	0.328	0.314	0.160	0.609	0.557	1.000				
15. Full vacc	48.4	23.0	0.0	86.5	-0.068	0.832	0.698	0.498	0.452	0.941	0.981	0.558	0.326	0.313	0.238	0.519	0.386	0.855	1.000			
16. VITA	57.6	17.8	25.9	80.7	0.245	0.315	0.120	-0.052	0.138	0.405	0.402	-0.032	-0.446	0.706	-0.240	0.565	0.080	0.286	0.486	1.000		
17. ORT	35.2	13.0	11.9	62.8	0.155	0.643	0.550	0.652	0.647	0.605	0.565	0.655	0.348	0.444	0.563	0.465	0.450	0.495	0.488	-0.503	1.000	
18. FPS	39.4	16.8	18.7	79.0	0.630	0.797	0.513	0.573	0.554	0.527	0.453	0.453	-0.186	0.497	-0.448	0.951	0.568	0.530	0.413	0.605	0.336	1.000

CCI, composite coverage index; ANC1, 1 ANC visit with skilled provider; ANC4, 4+ ANC visits with any provider; SBA, skilled birth assistance; MSLV, measles vaccination; DPT3, 3 doses of DPT vaccine; CPNM, care seeking for pneumonia; Tetan, tetanus vaccination; Sanit, improved sanitation facilities; Bednet, use of insecticide treated bednets; Contra, contraceptive prevalence; Water, improved water; BCG, BCG vaccination coverage; Full vacc, full vaccination coverage; VITA, vitamin A supplementation; ORT, oral rehydration therapy; FPS, family planning needs satisfied

Results

Trends in U5MR, Economic Growth, and MNCH Intervention Coverage

Between 1990 and 2012, the U5MR declined in a majority (22 of 25) of sub-Saharan African countries where repeated DHS surveys were available, although the rate of change varied across countries (Table 2). The U5MR ranged from 59.4 deaths per 1,000 live births in South Africa to 317.3 per 1,000 in Niger in the initial round of surveys (median year: 1996), corresponding to a five-fold difference across countries. In the most recent round of DHS surveys (median year: 2009), the U5MR ranged from 64.6 deaths per 1,000 live births in Gabon to 197.2 per 1,000 in Niger, indicating a three-fold difference across countries.

Table 2 also shows that for the countries included in this analysis, GDP per capita increased on average by US$165 during the study period, although ten countries saw declines in pcGDP between repeated surveys. The coverage of maternal, neonatal, and child health interventions generally increased between 1990 and 2012. For example, the coverage of at least one antenatal care (ANC) visit with a skilled provider increased from 60 percent in Burkina Faso in 1993 to nearly 95 percent in 2010. There were modest declines (from 2 percent to 7 percent) observed in measles vaccination coverage in a number of countries during the study period.

The rate of decline in U5MR was faster in urban than rural areas and in the richest groups compared with the poorest groups for two-thirds (16 of 25) of countries. In 40 percent of the ountries (10 of 25), the rate of mortality decline was faster in the highest education groups compared with those with no education (Table 3).

Table 2. Year of survey, under-five mortality rates, and country-level economic and coverage indicators of maternal and child health interventions in 36 sub-Saharan African countries for first and repeated surveys

	First survey								Repeated survey							
Country	**Year**	**N**	**U5MR**	**pcGDP**	**ANC**	**SBA**	**MSLV**	**Water**	**Year**	**N**	**U5MR**	**pcGDP**	**ANC**	**SBA**	**MSLV**	**Water**
Angola	2011	8,354	90.5	2,441	75.7	.	.	53.4			.	.		.	.	.
Burundi	2010	7,883	96.1	144	98.9	60.3	94.3	74.2			.	.		.	.	.
Benin	1996	5,274	166.4	383	80.5	37.1	64.3	62.6	2006	16,403	124.8	348	88.0	77.7	61.1	71.5
Burkina Faso	1993	5,923	187.0	313	60.0	41.4	59.6	47.2	2010	15,356	128.4	407	94.9	67.1	87.3	78.2
Central African Republic	1994	4,857	157.4	445	66.4	27.3	52.4	59.6			.	.				.
Cote d'Ivoire	1994	6,990	149.4	833	83.2	26.5	53.1	76.6	2005	3,703	124.7	646	87.3	54.9		78.6
Cameroon	1991	3,400	125.2	992	78.2	58.1	56.0	50.3	2011	12,018	121.8	965	84.7	63.6	70.6	74.4
Congo, Dem. Rep.	2007	9,,181	147.7	112	85.3	52.8	62.9	45.3			.	.				.
Congo, Rep.	2005	4,932	116.5	1,030	86.9	31.2	66.2	71.6			.	.				.
Comoros	1996	2,062	103.9	584	83.9	29.7	63.4	90.0			.	.				.
Ethiopia	2000	11,120	166.1	133	26.7	5.6	26.6	28.9	2011	11,969	88.0	194	42.6	10.0	55.7	49.0
Gabon	2000	4,463	88.6	4,589	95.1	85.5	54.8	85.3	2012	6,173	64.6	7,994	95.0	89.3	74.3	92.2
Ghana	1993	3,849	119.4	375	85.7	25.5	64.4	58.9	2008	3,047	80.0	376	95.4	58.7	90.2	83.4
Guinea	1999	6,050	176.6	450	73.5	34.8	52.1	62.0	2005	6,573	163.0	342	82.1	32.4	50.2	68.9
Kenya	1993	6,271	96.0	382	94.8	45.1	83.8	45.5	2008	6,173	73.6	440	91.7	44.3	85.0	58.5
Liberia	2007	5,890	109.5	175	79.3	46.3	63.0	69.4	2009	4,296	114.4	147				71.9
Lesotho	2004	3,784	112.8	436	90.4	55.4	84.9	78.8	2009	4,072	116.7	645	91.8	72.6	80.3	78.0
Madagascar	1992	6,473	162.6	243	78.8	56.7	54.0	30.7	2008	12,740	71.7	317	86.3	43.9	69.6	45.2
Mali	1995	10,506	237.2	304	47.5	13.9	50.8	36.7	2006	14,526	190.3	249	37.2	26.8	68.4	56.3
Mozambique	1997	7,320	200.8	137	72.0	25.3	57.5	39.4	2011	11,356	96.9	329	90.6	54.3	81.5	47.2
Malawi	1992	4,587	233.3	145	90.6	54.9	85.9	45.9	2010	20,437	112.1	213	97.5	71.3	93.0	81.8
Namibia	1992	4,000	83.8	1,551	87.7	68.2	75.6	67.6	2006	5,281	69.3	1,836	94.6	81.4	83.8	89.3
Niger	1992	7,029	317.3	315	31.0	14.9	27.8	36.2	2006	9,353	197.2	171	46.1	17.6	47.0	46.8
Nigeria	1990	8,091	192.5	339	58.9	32.0	45.6	47.2	2010	6,111	142.8	804	57.5			60.6

(Continued...)

Table 2. – *Continued*

	First survey								Repeated survey							
Country	**Year**	**N**	**U5MR**	**pcGDP**	**ANC**	**SBA**	**MSLV**	**Water**	**Year**	**N**	**U5MR**	**pcGDP**	**ANC**	**SBA**	**MSLV**	**Water**
Rwanda	1992	5,663	150.7	320	94.3	25.9	89.8	62.3	2010	9,237	75.7	274	98.0	69.0	95.0	68.7
Senegal	1992	5,765	131.7	736	74.2	47.2	57.2	60.9	2010	12,542	71.6	772	93.3	65.0	82.1	72.7
Sierra Leone	2008	5,785	139.6	291	86.9	42.4	59.7	54.5			.	.				.
Sao Tome and Principe	2008	1,972	62.5	665	97.9	81.7	84.0	92.1			.	.				.
Swaziland	2006	2,866	119.8	1,255	97.1	74.3	91.5	62.9			.	.				.
Chad	1996	5,785	194.0	306	32.6	4.0	22.8	42.8	2004	5,785	190.5	192	42.6	14.5	22.8	46.7
Togo	1998	7,188	146.1	302	82.8	29.7	42.6	52.3			.	.				.
Tanzania	1991	8,310	140.8	219	92.0	53.1	81.2	54.9	2010	8,148	81.1	375	87.7	48.9	84.5	53.4
Uganda	1995	7,344	147.3	245	91.5	30.5	59.6	48.7	2011	8,057	90.0	336	94.9	59.2	75.8	74.8
South Africa	1998	5,167	59.4	3,480	95.0	84.4	82.2	85.5			.	.				.
Zambia	1992	6,411	190.9	313	92.2	50.4	77.0	49.4	2001	6,499	168.0	360	93.4	43.4	84.4	54.5
Zimbabwe	1994	4,187	77.1	815	93.1	41.2	86.3	79.4	2010	5,630	84.1	453	89.8	66.2	79.1	79.9

U5MR, under-five mortality rate

pcGDP, per capita gross domestic product

ANC, 1+ antenatal care visit with skilled provider

SBA, skilled birth attendant; MSLV, measles vaccination coverage; Water, coverage of improved drinking water sources

Table 3. U5MR in 36 sub-Saharan African countries and rates of change according to urban/rural, household wealth, and education population subgroups

		U5MR							Annualized % Change						
Country	Year	Overall	Urban	Rural	Poorest 20%	Richest 20%	No education	Second-ary+	Overall	Urban	Rural	Poorest 20%	Richest 20%	No education	Second-ary+
Angola	2011	90.5	74.4	98.6	85.8	77.1	90.1	56.9	.	.	.	.	.	.	.
Burundi	2010	96.1	66.5	98.7	116.4	66.7	110.7	42.8	.	.	.	.	.	.	.
Benin	1996	166.4	142.5	177.6	188.6	114.4	175.1	75.0	.	.	.	.	.	.	.
	2006	124.8	105.9	134.3	138.1	75.3	131.1	66.8	-2.5	-2.6	-2.4	-2.7	-3.4	-2.5	-1.1
Burkina Faso	1993	187.0	132.1	196.4	179.7	137.1	192.5	88.2	.	.	.	.	.	.	.
	2010	128.4	81.7	137.5	149.0	78.3	136.8	55.8	-1.8	-2.2	-1.8	-1.0	-2.5	-1.7	-2.2
CAR	1994	157.4	133.8	173.2	167.5	108.5	174.2	86.9	.	.	.	.	.	.	.
Cote d'Ivoire	1994	149.4	126.5	161.2	186.9	105.2	158.5	107.4	.	.	.	.	.	.	.
	2005	124.7	105.4	137.2	151.4	105.5	128.7	97.0	-1.5	-1.5	-1.4	-1.7	0.0	-1.7	-0.9
Cameroon	1991	125.2	107.0	136.7	186.8	80.0	180.3	73.6	.	.	.	.	.	.	.
	2011	121.8	89.6	144.8	178.3	69.1	166.0	73.6	-0.1	-0.8	0.3	-0.2	-0.7	-0.4	0.0
Congo, Dem. Rep.	2007	147.7	114.9	168.3	174.6	83.0	199.1	107.2	.	.	.	.	.	.	.
Congo, Rep.	2005	116.5	91.9	137.1	123.5	80.7	166.0	92.1	.	.	.	.	.	.	.
Comoros	1996	103.9	67.1	115.4	122.5	82.6	117.7	53.0	.	.	.	.	.	.	.
Ethiopia	2000	166.1	134.9	169.7	137.6	140.7	174.7	93.0	.	.	.	.	.	.	.
	2011	88.0	68.7	90.9	112.1	73.7	95.5	34.4	-4.3	-4.5	-4.2	-1.7	-4.3	-4.1	-5.7
Gabon	2000	88.6	83.6	102.6	93.5	40.3	112.1	81.4	.	.	.	.	.	.	.
	2012	64.6	62.0	78.0	68.1	50.1	104.1	60.4	-2.3	-2.2	-2.0	-2.3	2.0	-0.6	-2.2
Ghana	1993	119.4	96.7	127.9	147.2	78.0	149.1	39.0	.	.	.	.	.	.	.
	2008	80.0	72.1	84.7	97.2	62.3	89.2	65.6	-2.2	-1.7	-2.3	-2.3	-1.3	-2.7	4.5
Guinea	1999	176.6	135.3	190.1	206.4	127.8	184.5	83.5	.	.	.	.	.	.	.
	2005	163.0	124.3	174.6	190.5	106.4	167.1	78.4	-1.3	-1.4	-1.4	-1.3	-2.8	-1.6	-1.0
Kenya	1993	96.0	85.2	97.6	126.7	70.5	98.7	56.3	.	.	.	.	.	.	.
	2008	73.6	64.6	75.5	88.7	68.4	83.1	60.1	-1.6	-1.6	-1.5	-2.0	-0.2	-1.1	0.5

(Continued...)

Table 3. – *Continued*

		U5MR							Annualized % Change						
Country	**Year**	**Overall**	**Urban**	**Rural**	**Poorest 20%**	**Richest 20%**	**No education**	**Second-ary+**	**Overall**	**Urban**	**Rural**	**Poorest 20%**	**Richest 20%**	**No education**	**Second-ary+**
Liberia	2007	109.5	110.1	109.3	112.5	103.3	105.1	105.7	.	.	.	.	.	.	.
	2009	114.4	102.2	121.7	121.5	109.1	121.5	103.6	2.2	-3.6	5.7	4.0	2.8	7.8	-1.0
Lesotho	2004	112.8	118.3	111.3	109.5	103.6	201.7	100.2	.	.	.	.	.	.	.
	2009	116.7	94.7	123.6	118.0	84.9	77.3	97.4	0.7	-4.0	2.2	1.6	-3.6	-12.3	-0.6
Madagascar	1992	162.6	124.5	168.4	146.3	217.5	199.5	100.8	.	.	.	.	.	.	.
	2008	71.7	56.9	73.5	88.2	47.9	82.8	55.2	-3.5	-3.4	-3.5	-2.5	-4.9	-3.7	-2.8
Mali	1995	237.2	180.3	256.3	275.3	164.2	250.2	81.3	.	.	.	.	.	.	.
	2006	190.3	133.3	210.8	211.3	107.7	198.0	81.9	-1.8	-2.4	-1.6	-2.1	-3.1	-1.9	0.1
Mozambique	1997	200.8	174.2	208.4	236.7	156.4	210.1	108.8	.	.	.	.	.	.	.
	2011	96.9	90.6	99.3	110.2	87.5	95.3	73.5	-3.7	-3.4	-3.7	-3.8	-3.1	-3.9	-2.3
Malawi	1992	233.3	216.6	235.6	242.0	189.9	233.6	143.4	.	.	.	.	.	.	.
	2010	112.1	117.3	111.2	109.7	95.3	112.1	88.8	-2.9	-2.5	-2.9	-3.0	-2.8	-2.9	-2.1
Namibia	1992	83.8	73.9	88.7	90.5	73.1	91.5	73.3	.	.	.	.	.	.	.
	2006	69.3	60.6	75.7	90.8	36.2	60.5	60.1	-1.2	-1.3	-1.0	0.0	-3.6	-2.4	-1.3
Niger	1992	317.3	203.1	337.8	310.6	237.7	326.7	104.3	.	.	.	.	.	.	.
	2006	197.2	126.3	209.5	182.5	146.2	202.5	76.9	-2.7	-2.7	-2.7	-2.9	-2.7	-2.7	-1.9
Nigeria	1990	192.5	132.8	208.6	225.2	125.8	216.4	115.5	.	.	.	.	.	.	.
	2010	142.8	107.8	152.9	166.1	76.3	172.5	90.0	-1.3	-0.9	-1.3	-1.3	-2.0	-1.0	-1.1
Rwanda	1992	150.7	150.9	150.7	128.3	141.6	160.6	104.5	.	.	.	.	.	.	.
	2010	75.7	66.1	76.9	85.3	54.9	93.6	58.3	-2.8	-3.1	-2.7	-1.9	-3.4	-2.3	-2.5
Senegal	1992	131.7	88.5	153.3	172.6	64.6	143.3	49.0	.	.	.	.	.	.	.
	2010	71.6	51.2	84.2	96.2	43.2	81.7	26.3	-2.5	-2.3	-2.5	-2.5	-1.8	-2.4	-2.6
Sierra Leone	2008	139.6	153.9	134.4	171.1	140.6	139.6	126.8	.	.	.	.	.	.	.
Sao Tome and Principe	2008	62.5	76.1	49.2	91.2	27.4	146.3	47.0	.	.	.	.	.	.	.
Swaziland	2006	119.8	137.8	114.4	129.0	116.1	175.5	108.9	.	.	.	.	.	.	.

(Continued...)

Table 3. – *Continued*

		U5MR							Annualized % Change						
Country	Year	Overall	Urban	Rural	Poorest 20%	Richest 20%	No education	Second-ary+	Overall	Urban	Rural	Poorest 20%	Richest 20%	No education	Second-ary+
Chad	1996	194.0	197.3	193.0	159.4	183.1	195.5	171.2	.	.	.	.	.	.	.
	2004	190.5	167.3	195.8	161.4	177.1	186.0	154.6	-0.2	-1.9	0.2	0.2	-0.4	-0.6	-1.2
Togo	1998	146.1	104.7	158.9	172.3	94.3	159.8	83.8	.	.	.	.	.	.	.
Tanzania	1991	140.8	156.4	136.7	135.8	111.9	142.1	90.8	.	.	.	.	.	.	.
	2010	81.1	100.6	76.2	88.8	87.3	77.1	76.2	-2.2	-1.9	-2.3	-1.8	-1.2	-2.4	-0.8
Uganda	1995	147.3	129.2	149.7	170.2	105.9	161.1	100.8	.	.	.	.	.	.	.
	2011	90.0	63.7	94.1	105.6	56.5	101.3	67.6	-2.4	-3.2	-2.3	-2.4	-2.9	-2.3	-2.1
South Africa	1998	59.4	47.3	71.7	92.3	24.9	98.4	45.3	.	.	.	.	.	.	.
Zambia	1992	190.9	173.0	206.5	221.6	133.6	204.0	159.4	.	.	.	.	.	.	.
	2001	168.0	151.5	175.8	173.9	98.3	189.2	127.5	-1.3	-1.4	-1.7	-2.4	-2.9	-0.8	-2.2
Zimbabwe	1994	77.1	66.1	81.0	82.4	66.6	79.5	65.0	.	.	.	.	.	.	.
	2010	84.1	86.7	83.0	85.8	58.1	72.6	80.1	0.6	2.0	0.2	0.3	-0.8	-0.5	1.5

Annualized % change is change in U5MR divided by number of years between first and last repeated survey, expressed as a percentage

Change in U5MR against Change in Pcgdp and Change in MNCH Intervention Coverage

Figures 4-6 plot the association between *changes* in U5MR and *changes* in pcGDP or coverage of MNCH interventions over the study period, along with the fitted linear regression line for a subset of 25 sub-Saharan African countries with at least two DHS surveys conducted during the study period. The regression equation including the intercept and slope from these models is also displayed in the figures. Many of these plots demonstrate a negative association, indicating that increases in pcGDP or coverage of MNCH interventions are associated with decreases in U5MR.

Table 4 presents the results of the regression from the ecological time series data of U5MR on country pcGDP and coverage of MNCH interventions. These models were fitted with one economic/coverage indicator at a time and included an indicator for survey period. We fitted models using fixed effects specifications, as described in the methods section, and coefficients represent the change in U5MR per one standard deviation increase in each of the economic/coverage indicators. Due to the more conservative approach and relatively small sample size (99 survey period units), there is less precision in the effect sizes from the fixed effects model compared with random effects models because between-unit effects are modeled as variables in the fixed part. Although less efficient (compared with a random effects approach), this approach is less biased if the causal model is one where between-unit effects are entirely confounders.

In the fixed effects analyses, per capita GDP has a negative but not statistically significant effect (β = -11.6, 95% CI: -29.1 to 5.9). The fixed effects specification indicates that the largest effects are observed for the composite coverage index (CCI) (β = -31.9, 95% CI: -48.6 to -15.3), 1+ ANC visit with a skilled provider (β = -21.9, 95% CI: -40.6 to -3.2), 4+ ANC visits with any provider (β = -17.9, 95% CI: -32.1 to -3.8), and skilled attendance at birth (β = -16.5, 95% CI: -28.2 to -4.8).

We also fitted a series of multivariable regressions to the ecological time series data, which included an indicator for survey period, pcGDP, and CCI (Table 5). In models with both pcGDP and CCI, the CCI is the stronger predictor of reduction in U5MR. For example, in the fixed effects model the coefficient for CCI is -31.8 (95% CI: -48.4 to -15.1) compared with a coefficient of -9.2 (95% CI: -27.9 to 9.4) for pcGDP, which is negative but not statistically significant. Further, the coefficient for CCI is essentially unchanged even after the inclusion of pcGDP to the model; the coefficient for pcGDP remained statistically non-significant in both models (p>0.05).

Table 4. Results of linear regression analyses of U5MR on country-level economic and health coverage indicators from the ecological time series data structure treating countries as fixed and random effects

	Fixed effects			
Economic and coverage indicators	**β**	**SE**	**95% CI**	**p-value**
GDP (log)	-11.6	8.9	-29.1 , 5.9	0.195
Composite coverage index	-31.9	8.5	-48.6 , -15.3	0.000
Antenatal care (1+ visits with skilled provider)	-21.9	9.5	-40.6 , -3.2	0.021
Antenatal care (4+ visits with any provider)	-0.4	6.4	-13.0 , 12.2	0.948
Skilled birth attendant	-7.0	6.6	-19.8 , 5.9	0.289
Early breastfeeding	-6.6	4.7	-15.8 , 2.5	0.154
BCG vaccination coverage	-5.8	4.6	-14.8 , 3.1	0.200
DPT 3 vaccination coverage	-3.9	4.5	-12.8 , 4.9	0.386
Measles vaccination coverage	-10.4	5.2	-20.6 , -0.2	0.047
Full vaccination coverage	-4.8	4.4	-13.5 , 3.8	0.274
Vitamin A supplementation	-1.0	4.5	-9.8 , 7.9	0.832
ORT for diarrhea	-5.7	5.4	-16.2 , 4.9	0.290
Care seeking for pneumonia	-14.3	5.3	-24.7 , -4.0	0.006
Insecticide-treated bednets for children	-14.3	5.0	-24.1 , -4.5	0.004
Contraceptive prevalence	-17.9	7.2	-32.1 , -3.8	0.013
Family planning need satisfied	-16.5	6.0	-28.2 , -4.8	0.006
Tetanus vaccination coverage	-5.6	4.0	-13.3 , 2.2	0.159
Improved sanitary facilities	-36.5	15.2	-66.2 , -6.8	0.016
Safe water	-14.7	9.0	-32.3 , 2.8	0.100

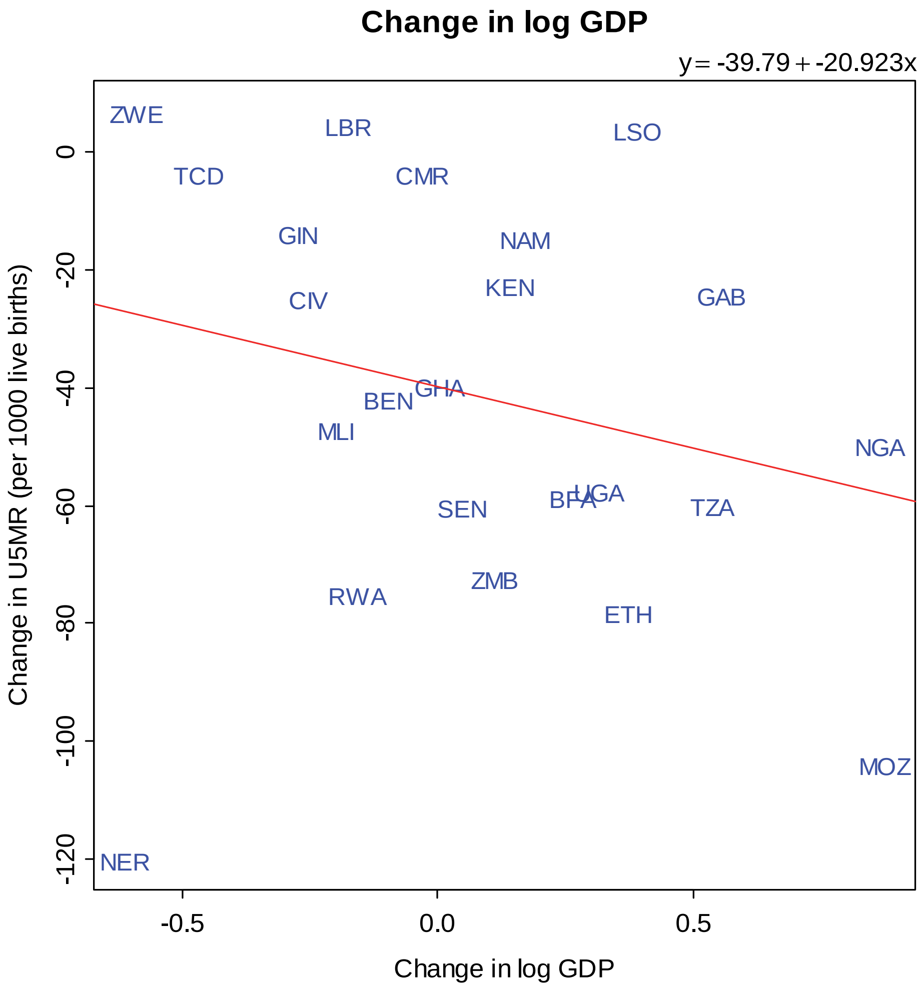
Table 5. Results of the multivariable ecological time series regressions of U5MR on country-level covariates

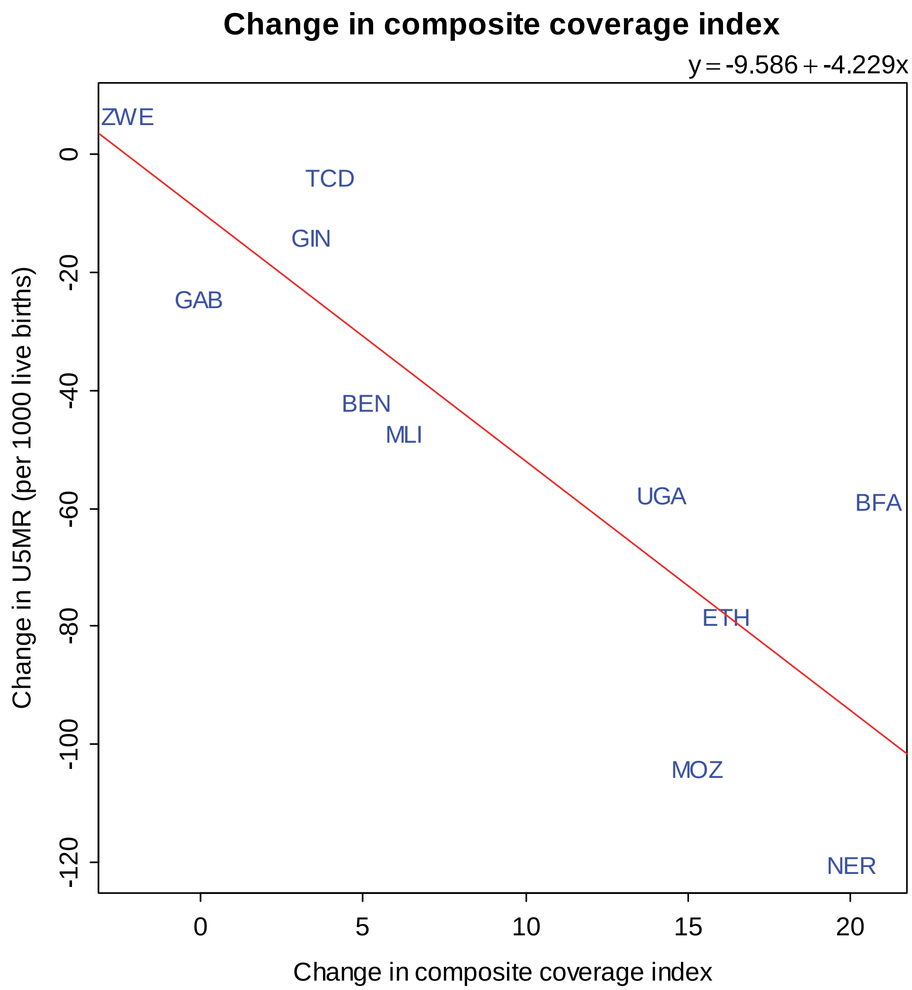
Economic and coverage indicators	**β***	**SE**	**95% CI**
Period	-12.2	3.7	-19.5 , -5.0
GDP	-9.2	9.5	-27.9 , 9.4
CCI	-31.8	8.5	-48.4 , -15.1

*Country as fixed effects

Models include an indicator for period, pcGDP, and CCI

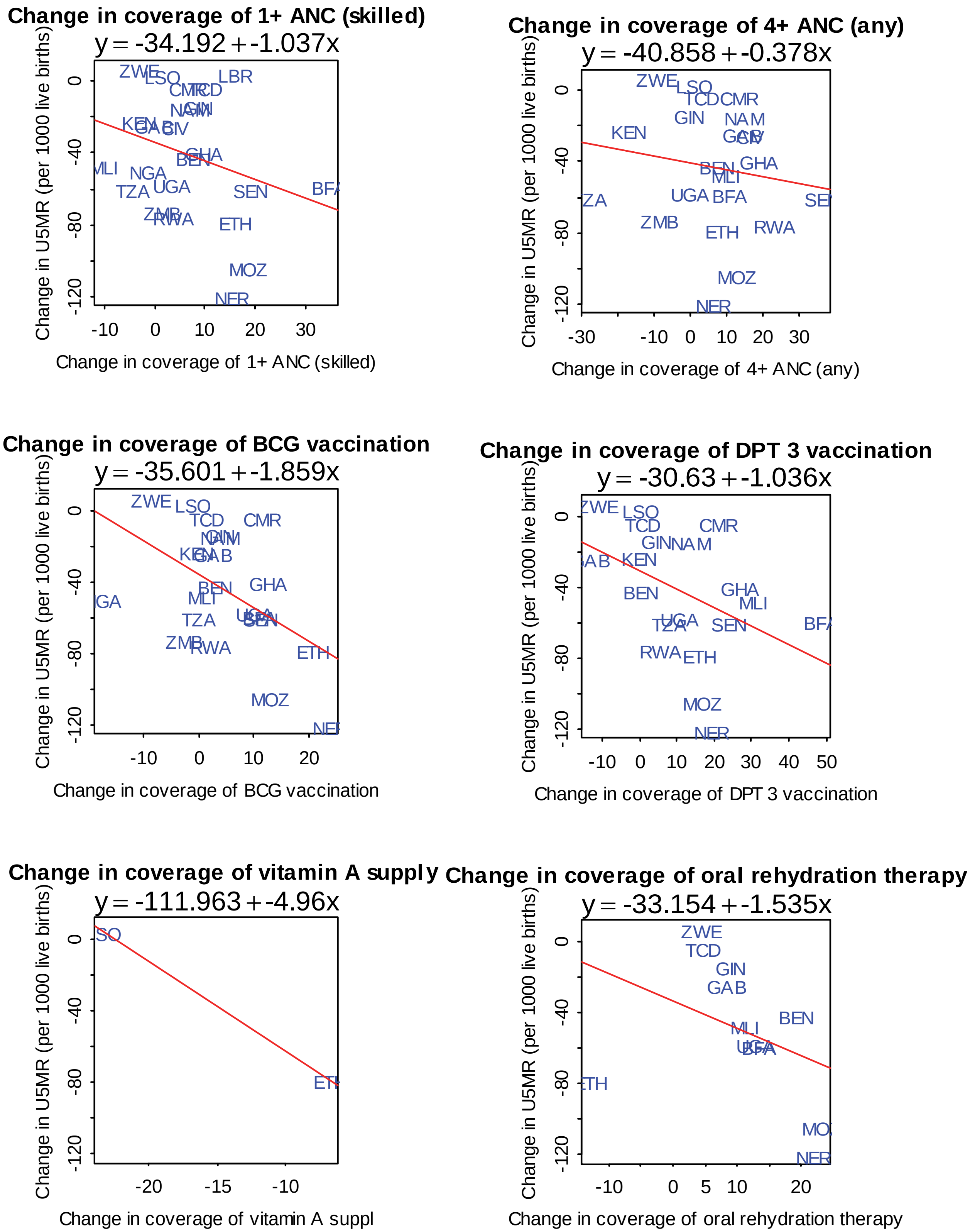
Figure 4. Change in U5MR and against change in log of pcGDP (left panel); change in U5MR against change in the composite coverage index, 25 sub-Saharan African countries

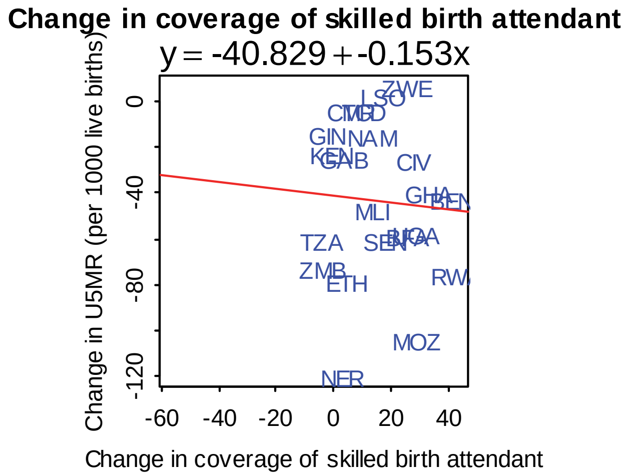


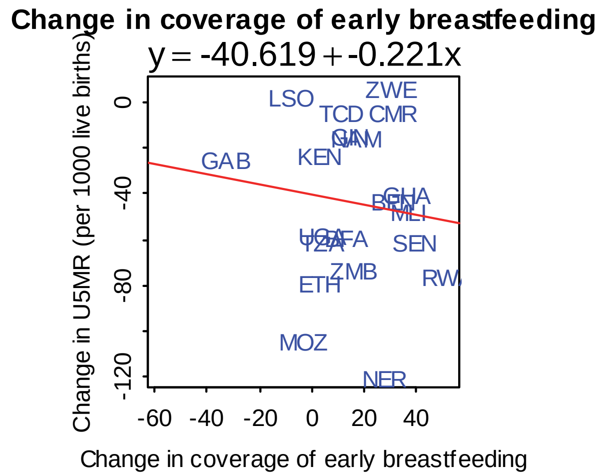


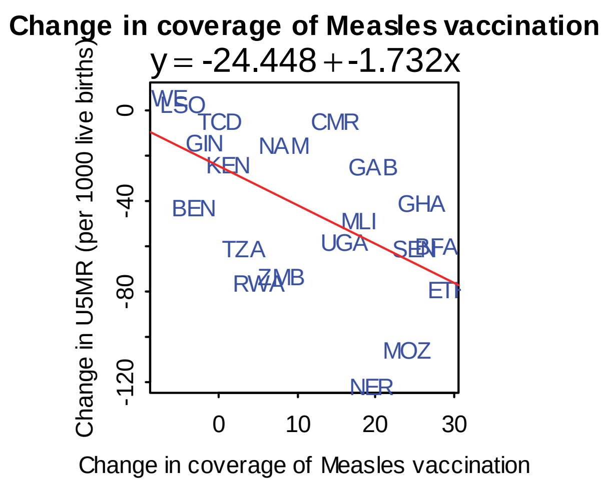
Change in composite coverage index
y = -9.586 + -4.229x
ZWE
TCD
GIN
GAB
BEN
MLI
UGA
BFA
ETH
MOZ
NER
0
-20
-40
-60
-80
-100
-120
0
5
10
15
20
Change in U5MR (per 1000 live births)
Change in composite coverage index

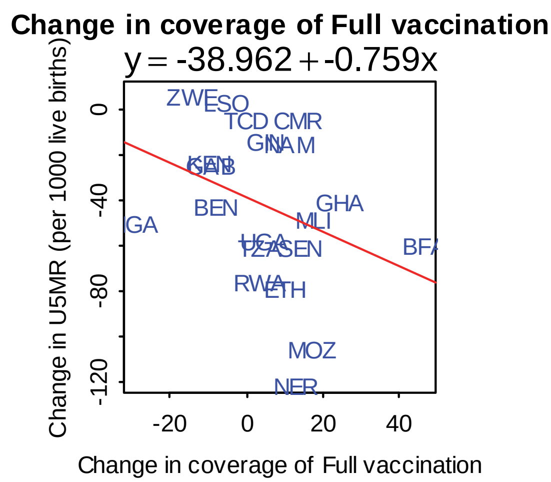
Figure 5. Change in U5MR and against change in coverage of MNCH interventions delivered during the infancy and childhood period




Change in coverage of skilled birth attendant
y = -40.829 + -0.153x
Change in U5MR (per 1000 live births)
Change in coverage of skilled birth attendant
-60 -40 -20 0 20 40
0 -40 -80 -120
ZWE LSO NAM CIV GHA MLI TZA ZMB ETH RW MOZ NER


Change in coverage of early breastfeeding
y = -40.619 + -0.221x
Change in U5MR (per 1000 live births)
Change in coverage of early breastfeeding
-60 -40 -20 0 20 40
0 -40 -80 -120
LSO ZWE TCD CMR GAB KEN GHA MLI SEN ZMB ETH RW MOZ NER


Change in coverage of Measles vaccination
y = -24.448 + -1.732x
Change in U5MR (per 1000 live births)
Change in coverage of Measles vaccination
0 10 20 30
0 -40 -80 -120
LSO TCD CMR GIN NAM KEN GAB BEN GHA MLI TZA UGA ZMB MOZ NER


Change in coverage of Full vaccination
y = -38.962 + -0.759x
Change in U5MR (per 1000 live births)
Change in coverage of Full vaccination
-20 0 20 40
0 -40 -80 -120
TCD CMR NAM BEN GHA MLI SEN ETH MOZ NER

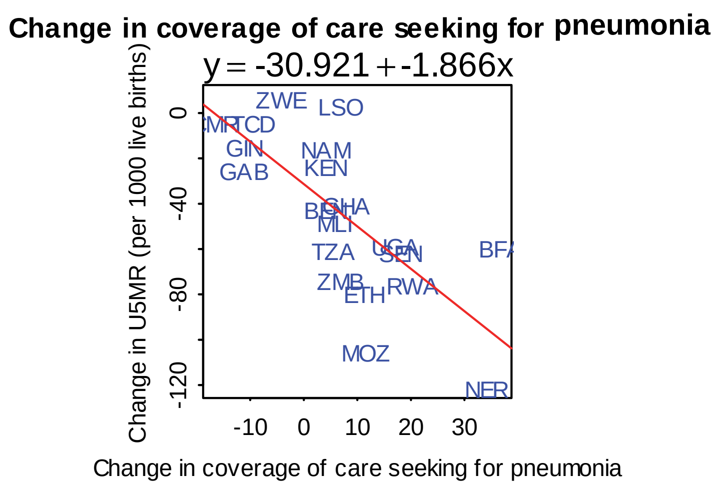
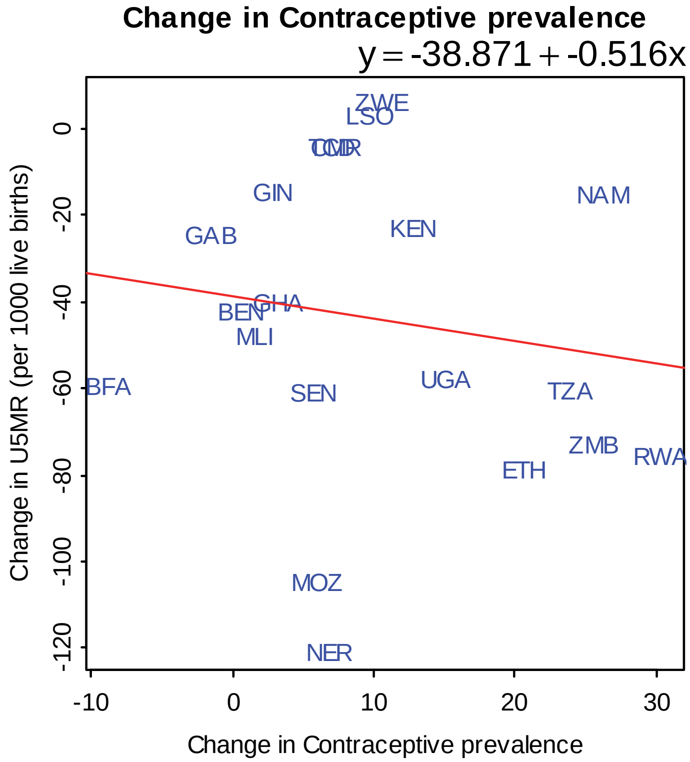
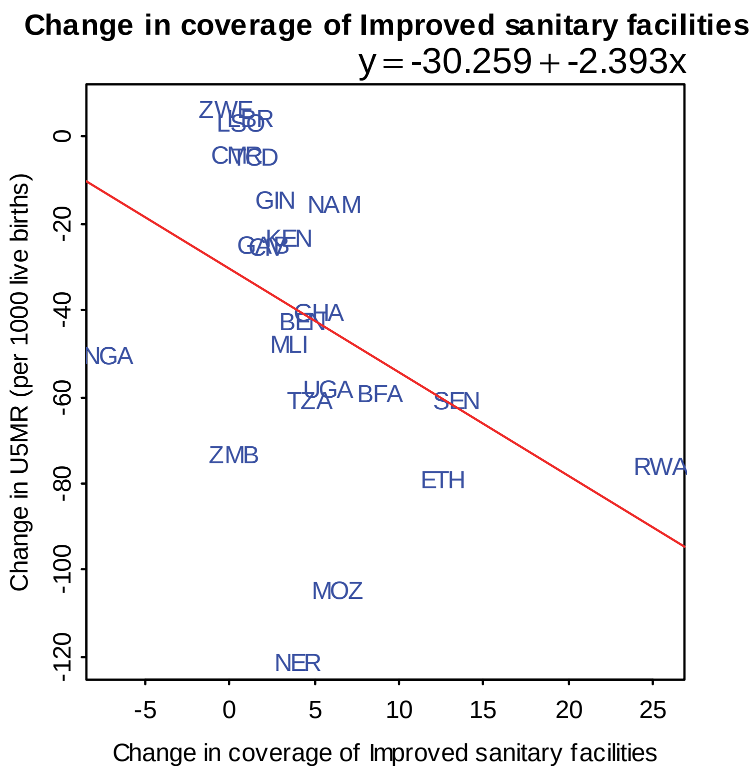

Change in coverage of care seeking for pneumonia
y = -30.921 + -1.866x
Change in U5MR (per 1000 live births)
Change in coverage of care seeking for pneumonia
-10 0 10 20 30
0 -40 -80 -120
ZWE LSO TCD GIN NAM GAB KEN MLI TZA SEN ZMB ETH RWA MOZ NER

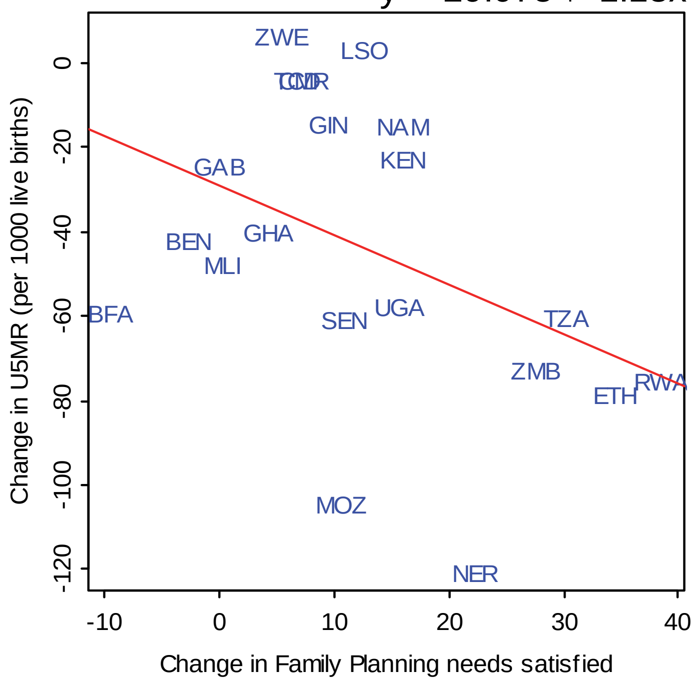
Figure 6. Change in U5MR and against change in coverage of MNCH interventions delivered during the pre-pregnancy period and improved sanitary facilities and drinking water source





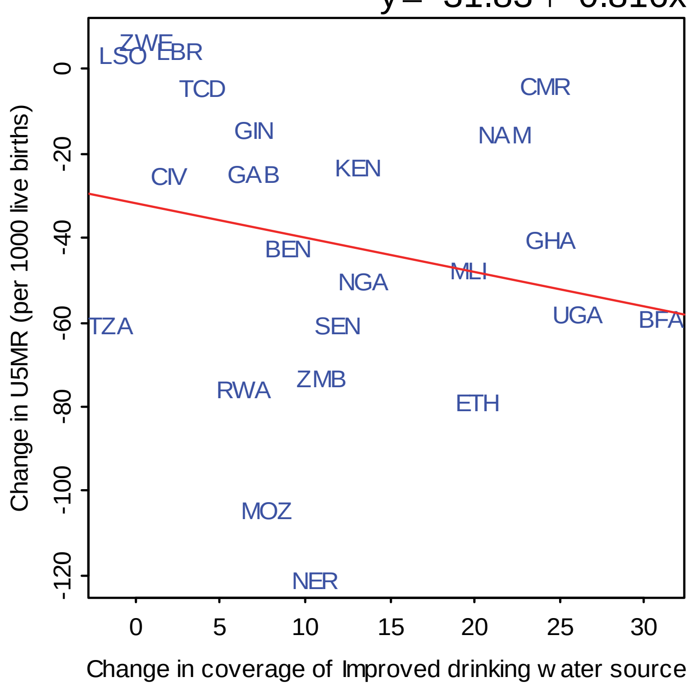
Change in Family Planning needs satisfied

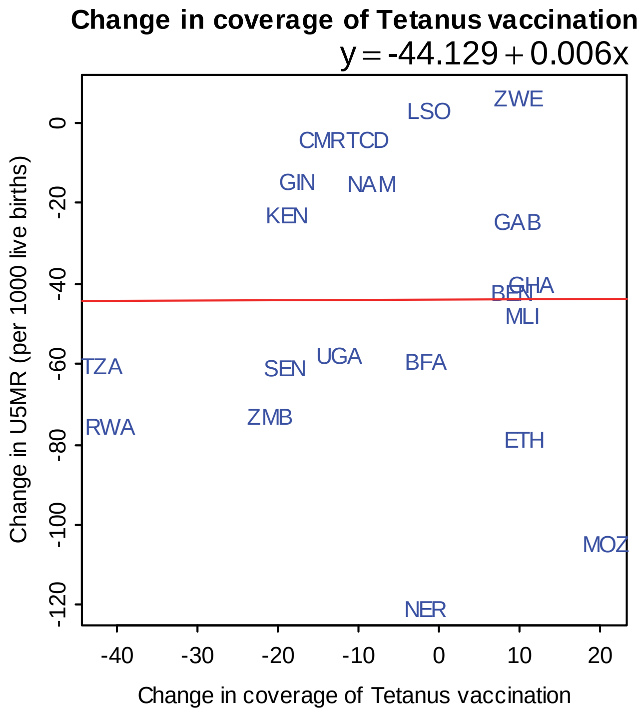
y= -29.075 + -1.18x



Change in coverage of Improved drinking water source

y= -31.83 + -0.816x





Multilevel Analyses Examining the Probability of Child-Level Mortality against Indicators of Economic Growth and MNCH Intervention Coverage

Our second major set of analyses examined factors associated with the probability of a child dying at age 0-59 months within a period of five years preceding each survey. We first examined the association between child and maternal covariates and child mortality at an individual level. These analyses used three-level logistic multilevel models with children (level one) nested in PSU (level two), nested within countries (level three). The full equation was given previously in equation 2. The primary motivation was to examine the probability of mortality at the child level so as to further control for child, maternal, and household-level factors that may be associated with child mortality and pcGDP and CCI/MNCH, which is not possible to do using ecological analysis.

Table 6 presents results of the multilevel logistic regression analyses of individual-level child mortality on the economic and MNCH indicators, with adjustment for all child, maternal, and household-level covariates. The first set of models includes one economic and MNCH indicator, along with all child, maternal, and household-level covariates, and countries are treated as a fixed effect. These models show that pcGDP is associated with a reduced probability of child death, with an odds ratio of 0.92 (95% CI: 0.88-0.95). The CCI is also associated with an even greater reduction in the probability of child mortality, with an odds ratio of 0.84 (95% CI: 0.81-0.87). Further, ANC with a skilled provider, care seeking for pneumonia, use of insecticide-treated bednets for children, contraceptive prevalence, family planning need satisfied, tetanus vaccination of mothers, and access to safe water and improved sanitation facilities are associated with reduced odds of child mortality, independent of the child and maternal factors.

Table 6. Odds ratios for child mortality for country-level economic and maternal/child intervention coverage indicators, adjusted for child, maternal, and household-level covariates across 36 sub-Saharan African countries from a three-level random intercepts logistic regression model

	Fixed effects	
Economic and coverage indicators	**OR**	**95% CI**
GDP (log)	0.92	(0.88 - 0.95)
Composite coverage index	0.84	(0.81 - 0.87)
Antenatal care (1+ visits with skilled provider)	0.89	(0.86 - 0.92)
Antenatal care (4+ visits with any provider)	1.06	(1.04 - 1.09)
Skilled birth attendant	1.01	(0.99 - 1.03)
Early breastfeeding	1.01	(1.00 - 1.03)
BCG vaccination coverage	1.01	(1.00 - 1.03)
DPT 3 vaccination coverage	1.01	(1.00 - 1.03)
Measles vaccination coverage	1.00	(0.99 - 1.02)
Full vaccination coverage	0.99	(0.98 - 1.01)
Vitamin A supplementation	0.99	(0.97 - 1.02)
ORT for diarrhea	0.99	(0.97 - 1.01)
Care seeking for pneumonia	0.91	(0.90 - 0.93)
Insecticide-treated bednets for children	0.89	(0.85 - 0.93)
Contraceptive prevalence	0.89	(0.86 - 0.91)
Family planning need satisfied	0.92	(0.90 - 0.94)
Tetanus vaccination coverage	0.95	(0.93 - 0.96)
Improved sanitary facilities	0.72	(0.68 - 0.77)
Safe water	0.91	(0.88 - 0.95)

In these models a three-level structure is specified where children are nested in PSU, with countries as fixed effects. All models include an indicator of survey period, sex of child, multiple birth, birth order, birth interval, child's age, mother's age at birth, mother's education, household wealth quintile, and area of residence in addition to one country-level economic/coverage indicator per model. In fixed effects models, countries are modeled as a set of indicator variables entered into the fixed part of a two-level random intercepts logistic regression model. The second level is for PSU.

The second set of models, presented in Table 7, includes all child and maternal covariates in addition to three country-level variables shown to be important in predicting child mortality in the previous models: pcGDP, the CCI, and access to improved sanitary facilities. PcGDP, the CCI, and improved sanitary facilities remain strong predictors of reduced probability of mortality among children age 0-59 months.

We further examined child, maternal, and household-level factors without the inclusion of the country-level economic and coverage indicators. Table 8 presents the unadjusted and adjusted odds ratios for these associations. Boys, multiple births, higher order births, older children, children with shorter preceding birth intervals, children of mothers with lower levels of education, children in relatively poorer households, and children in rural areas have increased odds of death within the first five years of life. Women's education demonstrates a strong protective effect against child death (OR: 0.61, 95% CI: 0.57-0.66) for women with a secondary or higher level of education.

Table 7. Odds ratios for child mortality for multivariable models of country-level economic and maternal/child intervention coverage indicators adjusted for child, maternal, and household-level covariates across 36 sub-Saharan African countries from a three-level random intercepts logistic regression model

	Fixed effects	
Economic and coverage indicators	**OR**	**95% CI**
GDP	0.96	(0.92 - 1.00)
CCI	0.92	(0.88 - 0.96)
Improved sanitary facilities	0.57	(0.50 - 0.65)

In these models a three-level structure is specified where children are nested in PSU, nested in countries. PSU and countries are treated as random effects in the random effects models. All models include an indicator of survey period, sex of child, multiple birth, birth order, birth interval, child's age, mother's age at birth, mother's education, household wealth quintile, and area of residence, in addition to four country-level economic/coverage indicators per model. In fixed effects models, countries are modeled as a set of indicator variables entered into the fixed part of a three-level random intercepts logistic regression model.

Table 8. Risks of child mortality according to child, maternal, and household-level covariates across 36 sub-Saharan African countries

Maternal/child covariates	Children (n)	%	Deaths (n)	OR	95% CI	aOR1	95% CI	aOR2	95% CI
Total	748,363	100.0	75,302	0.97	(0.97 - 0.97)	0.97	(0.97 - 0.97)	0.97	(0.97 - 0.97)
Sex of the child									
Girl	370,220	49.5	35,166	0.88	(0.87 - 0.89)	0.88	(0.86 - 0.89)	0.88	(0.86 - 0.90)
Boy (reference)	378,143	50.5	40,136	1.00		1.00		1.00	
Multiple birth									
Singleton (reference)	722,481	96.5	68,219	1.00		1.00		1.00	
Multiple birth	25,882	3.5	7,083	3.69	(3.58 - 3.80)	4.03	(3.91 - 4.16)	4.21	(4.06 - 4.37)
Birth order									
1st (reference)	162,013	21.6	17,287	1.00		1.00		1.00	
2nd	136,874	18.3	12,514	0.82	(0.80 - 0.84)	1.32	(1.28 - 1.36)	1.32	(1.27 - 1.37)
3rd	111,471	14.9	10,133	0.80	(0.78 - 0.82)	1.31	(1.27 - 1.35)	1.28	(1.23 - 1.33)
4th	91,560	12.2	8,464	0.80	(0.78 - 0.82)	1.30	(1.25 - 1.35)	1.26	(1.21 - 1.32)
5th or higher	246,445	32.9	26,904	0.92	(0.90 - 0.94)	1.39	(1.34 - 1.44)	1.32	(1.27 - 1.38)
Birth interval									
<24 mo (reference)	280,326	37.5	35,510	1.00		1.00		1.00	
24-47 mo	345,177	46.2	30,975	0.65	(0.64 - 0.66)	0.56	(0.55 - 0.58)	0.56	(0.55 - 0.58)
48+ mo	121,311	16.2	8,368	0.53	(0.52 - 0.54)	0.47	(0.45 - 0.48)	0.46	(0.44 - 0.47)
Child's age									
0-1 y (reference)	293,348	39.2	20,909	1.00		1.00		1.00	
2-3 y	288,883	38.6	32,671	1.68	(1.65 - 1.71)	1.64	(1.61 - 1.67)	1.71	(1.67 - 1.75)
4 y	166,132	22.2	21,722	1.97	(1.93 - 2.01)	1.88	(1.84 - 1.92)	1.95	(1.90 - 2.00)

(Continued...)

Table 8. – *Continued*

Maternal/child covariates	Children (n)	%	Deaths (n)	OR	95% CI	aOR1	95% CI	aOR2	95% CI
Mother's age at birth									
<17 y	61,250	8.2	8,310	1.56	(1.51 - 1.61)	1.36	(1.31 - 1.42)	1.32	(1.26 - 1.38)
17-19 y	112,626	15.1	12,165	1.22	(1.19 - 1.25)	1.15	(1.11 - 1.18)	1.11	(1.07 - 1.16)
20-24 y	207,676	27.8	19,781	1.07	(1.04 - 1.09)	1.05	(1.02 - 1.08)	1.04	(1.01 - 1.07)
25-29 y (reference)	165,196	22.1	14,889	1.00		1.00		1.00	
30-49 y	200,854	26.9	20,125	1.12	(1.10 - 1.15)	1.09	(1.07 - 1.12)	1.08	(1.05 - 1.12)
Maternal education									
No education (reference)	347,674	46.5	40,692	1.00		1.00		1.00	
Any primary	280,612	37.5	26,790	0.88	(0.86 - 0.89)	0.92	(0.90 - 0.94)	0.93	(0.90 - 0.95)
Incomplete secondary	92,008	12.3	6,292	0.65	(0.63 - 0.67)	0.73	(0.71 - 0.76)	0.74	(0.71 - 0.77)
Complete secondary or higher	28,051	3.7	1,527	0.49	(0.47 - 0.52)	0.60	(0.56 - 0.64)	0.61	(0.57 - 0.66)
Household wealth quintile									
Poorest	174,536	23.3	19,019	1.00		1.00		1.00	
2nd	156,252	20.9	17,121	0.99	(0.97 - 1.01)	1.01	(0.98 - 1.03)	0.99	(0.97 - 1.02)
3rd	147,946	19.8	15,417	0.93	(0.91 - 0.96)	0.97	(0.95 - 0.99)	0.97	(0.94 - 1.00)
4th	139,045	18.6	13,681	0.87	(0.85 - 0.89)	0.94	(0.92 - 0.97)	0.94	(0.91 - 0.97)
Richest	130,513	17.4	10,055	0.65	(0.63 - 0.67)	0.78	(0.75 - 0.81)	0.77	(0.74 - 0.80)
Area of residence									
Urban	201,107	26.9	16,909	0.76	(0.75 - 0.78)	0.94	(0.91 - 0.96)	0.94	(0.91 - 0.97)
Rural (reference)	547,256	73.1	58,393	1.00		1.00		1.00	
Maternal height									
160+ cm	214,085	41.0	21,491	1.00				1.00	
155-159 cm	154,440	29.6	16,184	1.09	(1.06 - 1.11)			1.07	(1.05 - 1.10)
150-154 cm	105,154	20.2	11,271	1.14	(1.11 - 1.17)			1.12	(1.09 - 1.15)
145-149 cm	37,668	7.2	4,306	1.27	(1.22 - 1.31)			1.23	(1.19 - 1.28)
<145 cm (reference)	10,248	2.0	1,262	1.40	(1.31 - 1.49)			1.34	(1.25 - 1.43)

aOR1 adjusted for sex of child, multiple birth, birth order, birth interval, child age, mother's age at birth, mother's education, household wealth quintile, and area of residence

aOR2 includes maternal height

Summary of Fixed Effects Models at the Survey Period and Child Levels

Table 9 presents a summary of the associations between pcGDP and coverage of MNCH interventions on U5MR at the survey period/country level and the probability of child mortality before 60 months at the child level. In general, the effects are larger at the survey-period level compared with the child level; however, caution is urged when interpreting the child-level coefficients, which are presented in log odds and are not directly comparable to the beta coefficients from the linear models. Despite this limitation, the result fits our conceptual and analytical framework that these effects should be smaller because country-level factors are conceptualized as distal factors in the model and likely mediated through more proximal factors at the community, household, mother, or child levels.

Table 9. Summary of the associations between pcGDP and coverage of MNCH interventions on U5MR at the survey period/country level and the probability of child mortality at age 0-59 months at the child level from both the fixed effects and random effects model specifications

	Fixed effects			
	Survey period		Child	
Economic and coverage indicators	β	SE	β	SE
GDP (log)	-11.6	8.9	-0.04	0.007
Composite coverage index	-31.9	8.5	-0.08	0.008
Antenatal care (1+ visits with skilled provider)	-21.9	9.5	-0.05	0.007
Antenatal care (4+ visits with any provider)	-0.4	6.4	0.02	0.005
Skilled birth attendant	-7.0	6.6	0.00	0.005
Early breastfeeding	-6.6	4.7	0.01	0.004
BCG vaccination coverage	-5.8	4.6	0.01	0.003
DPT 3 vaccination coverage	-3.9	4.5	0.00	0.003
Measles vaccination coverage	-10.4	5.2	0.00	0.004
Full vaccination coverage	-4.8	4.4	0.00	0.004
Vitamin A supplementation	-1.0	4.5	0.00	0.006
ORT for diarrhea	-5.7	5.4	-0.01	0.004
Care seeking for pneumonia	-14.3	5.3	-0.04	0.004
Insecticide-treated bednets for children	-14.3	5.0	-0.07	0.008
Contraceptive prevalence	-17.9	7.2	-0.05	0.006
Family planning need satisfied	-16.5	6.0	-0.04	0.005
Tetanus vaccination coverage	-5.6	4.0	-0.02	0.003
Improved sanitary facilities	-36.5	15.2	-0.12	0.012
Safe water	-14.7	9.0	-0.05	0.007

Sensitivity Analyses Using Random Effects Models

In sensitivity analyses, we explored the use of random effects models at the country level. In general, the standard errors were considerably smaller in the random effects models at the country/survey period level due to improvements in efficiency in these models in treating countries as a distribution and thus reducing the effective number of parameters in the model. However, we prefer the fixed effects approach because it is less biased if the causal model is one that country-level factors are entirely confounders and if the model is used for the interpretation of ‘time trend’ effects. The choice of random or fixed specification of country has little substantive effect on the association between pcGDP and MNCH and the probability of child death before 60 months.

Discussion

In this report we explored the contribution of economic growth and health coverage indicators to the declines in U5MR across 36 sub-Saharan African countries from 1990-2012. The study has two salient findings:

First, improvements in MNCH coverage and interventions are strongly associated with reductions in child mortality; this association is universally consistent across the two types of data structures analyzed and regardless of the statistical specification.

Second, the contributions of increases in economic growth are not consistently associated with the reductions in child mortality In only three of eight model specifications are increases in economic growth associated with reductions in child mortality. Even when there is a statistically significant association, the strength of the association is substantially weaker compared with the health coverage predictors.

Although, as documented in this report, U5MR has been falling in sub-Saharan Africa in recent decades, the region continues to have the highest rates of child mortality in the world.[12] It has been suggested that continuing high fertility in sub-Saharan Africa compared with other regions is likely related to the Africa's slower declines in U5MR. The total fertility rate in sub-Saharan Africa remains twice as high as in the rest of the world, at 4.9 in 2011 compared with an average 2.4 elsewhere.[52] Although we did not examine fertility rates directly, our findings based on DHS data demonstrate that increases in contraceptive prevalence are associated with decreases in U5MR, in both the ecological and multilevel analyses. This finding suggests that continuing declines in fertility would likely be associated with further declines in U5MR, although there has been debate about the causal association between fertility reduction and child mortality reduction.

The analysis did not find the role of economic growth to be important in predicting declines in U5MR at the country level; the association is not consistent across different model specifications. The effect of coverage of selected maternal and child health interventions is generally greater than the effect of pcGDP, both at the ecologic and individual levels, underscoring that coverage of health interventions may have a particularly important role in sub-Saharan Africa, where U5MR remains high. Further, the effect of GDP is not consistent across different model specifications, whereas health care coverage is consistently associated with reductions in U5MR and child mortality. It has been suggested that in other situations and regions, such as China, where U5MR is already lower than in sub-Saharan Africa, economic growth may lead to further declines in U5MR.[53]

Limitations

This study has several limitations. First, given that DHS surveys are typically conducted only at intervals of three to six years[39], we were only able to study large changes in U5MR, and in some countries repeated surveys were not available, prohibiting a full time-series cross-sectional analysis. Second, due to sample size restrictions in the ecological analyses, we could only model about five to seven key indicators in the final multivariable adjusted model, and several other potentially relevant determinants of U5MR were not examined.

Third, we analyzed U5MR over the five-year period preceding each survey. This method provided greater precision in the estimates of U5MR but may have masked information on recent trends in U5MR that could potentially have been revealed with a shorter reference period. Fourth, the coverage of maternal, newborn, and child health interventions was also calculated from each of the surveys, and where possible we used a similar five-year period before each survey. In spite of these efforts, it is likely that some difficulty remains in establishing the timing of exposures and outcomes, as both were measured contemporaneously in the same survey. Further, although we chose a logistic regression analysis for the child-level models, a hazard model would have been another alternative. Regardless of model choice, there would be no additional information gained from the independent variables, given that the indicators were calculated using a five-year window.

Fifth, the analyses did not include indicators of the incidence (or prevalence) of childhood diseases. Given the method in which the prevalence of diseases are captured in DHS (i.e. any diarrhea within two weeks preceding the survey) we were not confident that these would be comparable across countries, especially since surveys may have been conducted at different times and in different seasons. Finally, a more general limitation is that this study was based on estimates of U5MR. Any estimate of U5MR from survey data is subjected to sampling errors and will always be inferior to complete vital registration data.[9] Countries where U5MR remains high and/or rates of mortality decline are slow typically lack comprehensive vital registration systems.[54] Strengthening such systems is likely to improve future assessments of factors associated with declines in U5MR in sub-Saharan African.

Concluding Remarks

The results presented in this report indicate a secular decline in U5MR in a majority of countries in sub-Saharan Africa over the past two decades. A large part of this decline can be explained by coverage of selected maternal, newborn, and child health interventions and other social improvements, such as improved access to clean drinking water and sanitation facilities. There remains a fair amount of unexplained variation in the outcomes, and it is likely that other factors related to health systems as well as economic, social, or political factors play a role in influencing U5MR in sub-Saharan Africa.

It has been suggested that effective implementation of available, cost-effective MNCH interventions can prevent much of the current burden of under-five mortality in low-income settings.[55] However, many countries in sub-Saharan Africa are not on track to reach MDG-4[12], which is likely related in part to the low levels of coverage of key interventions in the 1990s in many countries.[38, 56] In the 2000s, global health initiatives and resources for health increased, and along with such increases came improvements in coverage of life-saving child health interventions in several countries.[38, 56] We would therefore expect that progress toward MDG-4 in such settings, while lagging behind other areas, might likely continue into 2015 and beyond.[9, 12]

It appears that health system improvements, including scaling up of key MNCH interventions, are a key explanation for reductions in U5MR in sub-Saharan Africa. For example, in Tanzania between 1999 and 2004–05 the coverage of interventions relevant to child survival improved substantially.[57] In particular, Vitamin A supplementation increased from 14 percent in 1999 to 85 percent in 2005, and other improvements also were seen: children sleeping under insecticide-treated nets increased from 10 percent to 29 percent, oral rehydration therapy for children increased from 57 percent to 70 percent, and exclusive breastfeeding for those younger than age 2 months increased from 58 percent to 70 percent.[57]

Over this same period Tanzania's national wealth (in GDP per person) increased by 93 international dollars, from $819 to $912 per person (or US$256 to US$303). Improvements in the proportion of households living below the poverty line, in educational attainment, and in literacy rates improved only marginally during this time. Therefore, it is unlikely that growth in national wealth would account for much of the reduction in mortality, especially since poverty rates in Tanzania and other sub-Saharan African countries did not improve dramatically over the study period.

Based on our multilevel analyses, it appears that the coverage of health interventions has played a relatively more important role in reducing child mortality compared with the role of economic growth.

Although recent gains have been made in reducing under-five mortality in sub-Saharan Africa, the U5MR in this region continues to be the highest anywhere. While sub-Saharan Africa as a whole has reduced U5MR by 30 percent, this is less than half of the MDG-4 target. As the global health community considers both the strong likelihood that the MDG-4 targets are not going to be accomplished by 2015,[58, 59] and looks ahead to the post-MDG era,[60] it is important to sustain efforts to reduce child mortality. For sub-Saharan Africa, a continued focus on fertility declines, improved health coverage, greater equity in the coverage of proven life-saving interventions, and widespread access to clean water and sanitation, might be the key to reducing
mortality.

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