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Projecting Outcomes with a Series of Demographic and Health Surveys

Thomas W. Pullum

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Projecting Outcomes with a Series of Demographic and Health Surveys

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ABSTRACT

A series of Demographic and Health Surveys (DHS) in the same country is often used to describe trajectories of continuity and change in many types of outcomes. Successive surveys are also compared to monitor short-term changes and to identify inconsistencies that may be related to data quality. In this paper, earlier surveys in a specific country are used to generate expected levels of outcomes in the most recent survey. Because projections are generally based on an assumption of continuity in underlying processes, deviations from projected values can suggest changes in those underlying processes. The procedure is applied to six major outcomes that are measured by DHS. Some outcomes are simplified slightly, so they can be described as binary, or counts, or rates. Virtually all DHS outcomes fall into one or another of these types. In six countries, models are applied that use one or two earlier surveys to produce expected values in the most recent survey. The single-survey model assumes that change in an outcome is only due to multivariate change in composition on the standard DHS background variables, plus some additional covariates. The two-survey model adds a linear time effect and an assumption that the rate of change between the two previous surveys has continued to the current survey. In addition to national estimates for each country, the model produces estimates for strata (combinations of region and urban/rural residence) and the age interval of the woman/mother. The observed values in the most recent survey may be very close to the projected values. However, the suggested utility of the procedure is not to forecast current values, but to help analysts see how countries, strata, or age groups may have deviated from the underlying assumptions. Researchers can then attempt to understand why a time trend has not continued, or has accelerated, and why some strata differ from the national trend. Such efforts would focus on a specific outcome in a specific country and lie outside the methods described here.

Key words: DHS surveys, projection, out-of-sample estimation

ACRONYMS AND ABBREVIATIONS

ARI	acute respiratory infection
cmc	century month code, starting with January, 1900, as cmc=1
DHS	Demographic and Health Surveys
EMW	ever-married women
GFR	general fertility rate
glm	generalized linear model
IMR	infant mortality rate
IR file	data file of individual respondents in the survey of women
KR file	data file of children born in the past 5 years to women in the IR file
mCPR	modern contraceptive prevalence rate
MIS	Malaria Indicator Survey
PR file	data file of individual household members in the household survey
SPA	Service Provision Assessment
U5MR	under-5 mortality rate

1 INTRODUCTION

The Demographic and Health Surveys (DHS) Program has conducted nearly 300 standard DHS surveys since 1985. Many have been in the same country, and are typically spaced about 5 years apart. The data files from almost all DHS surveys are available on the DHS website, and many outcomes and indicators are also available on STATcompiler. Many researchers, within DHS or elsewhere, have analyzed a sequence of surveys from the same country.

Repeated surveys within the same country have been analyzed from different perspectives. Often, within the final report on a recently completed survey, or in further analyses conducted soon after the data are released, the latest survey is compared with the immediately preceding survey to identify any changes in outcomes. For example, a further analysis of the 2013 and 2019–20 surveys of Liberia (Pullum 2022) examined evidence that infant mortality had increased between the two surveys, despite the expectation that it was continuing to decline. After a new survey is completed, there is typically even more interest in whether the key outcomes showed statistically significant improvements, when compared with the preceding survey, than in the current levels.

A series of surveys can also be used to describe long-term trajectories of continuity and change. For example, several authors, including Pullum and Assaf (2016) and Pullum (2017), have examined DHS surveys to identify the onset of a demographic transition or fertility stalls in different countries.

Whether analyzing two successive surveys or a longer series, researchers can make a comparison between a recent estimate and an expectation based on earlier estimates. In the simplest situation with two surveys, the value in the earlier survey becomes the reference point or expectation for the later survey. This paper formalizes and extends the use of earlier surveys to obtain expected or projected values for a new survey.

One impetus for developing these projection methods was a desire to assess the potential impact of the COVID-19 pandemic on access to health services and other outcomes. For example, it was proposed that if there was a difference between (a) the level of facility births in a post-COVID survey and (b) what would have been expected, together with other information about the pandemic, that could be attributed to the pandemic.

Here are two examples in which differences between two successive surveys were connected with interventions within that time interval. In Langston et al. (2014), improved care-seeking for sick children in Rwanda was found to be positively associated with a program in a specific region of Rwanda by comparing the 2005 and 2010 DHS surveys in that country. A difference-in-differences approach was used in which change in the intervention area was compared with change in the rest of Rwanda. Care-seeking increased in the intervention area, between the two surveys, by a greater amount than in the rest of Rwanda. Mallick, et al. (2019) used a similar strategy to assess the impact of a major intervention to improve maternal care and survival in Uganda by comparing the 2011 and 2016 DHS surveys.

Our goal is to improve the calculation of expected values for the outcomes in a new survey, without reference to specific interventions. This perspective can be described with a hypothetical example. Suppose that the infant mortality rate (IMR) in a new survey, for exposure and deaths in the 5-year window of time before the survey, is 50 deaths per 1,000 births. Although in an absolute sense this number is too high, the analytical question is how 50 per 1,000 compares with what would have been expected.

If the rate was also 50 deaths per 1,000 in the previous survey, we would be disappointed, but at least there would be consistency between the two surveys. However, suppose that "two surveys back," the rate was 70, so that the sequence for deaths per 1,000 births was 70 to 50 to 50 in the series of three surveys. We might then question the accuracy of the estimates or search for another explanation for why the downward trend did not continue. If in the same setting we also know that antenatal care and facility births, which are associated with better child survival, have become more common, such information would also affect the interpretation of the most recent estimate.

The approach described here assesses whether the rate observed in a new survey is consistent with an expected value based on earlier surveys in the same country. It goes beyond a simple extrapolation of the rates in earlier surveys and a comparison with the rate in the new survey. We use micro-level data that takes account of changes in the composition of covariates that are associated with the outcome, as well as time-related trends.

We illustrate the procedure with six outcomes in six countries with at least three DHS surveys. Within each series, we examine the correspondence between the observed values in the current survey and the values projected from the previous surveys. Observed and projected percentages or means are compared for the current survey as a whole and for strata, defined as combinations of urban/rural residence and region, the country's first administrative level. They are also compared for disaggregations based on the age of the woman or mother. The strategy is to simulate potential applications to new surveys, using sequences of previous surveys, so that the observed level of the outcome can be assessed for being lower or higher than expected.

2 DATA AND METHODS

2.1 Some General Terminology

A “projection” is essentially an extrapolation that uses earlier data and models drawn from demography and statistics, and an assumption that past levels or trends will continue. Observed values can deviate from projected values for many reasons. For example, because of limitations in the data that can be collected, a model never includes all the covariates that may affect the outcome. In a dynamic process, the time effect may not be linear. There may be differences in the data quality of the surveys.

In the context of statistical models, the terms “predict” and “predicted” are synonymous with “fit” and “fitted.” In our context, such estimates could be described as “projected values.”

The model projects to a “current” survey using one or two “previous” surveys. When only one previous survey is used, the expected values incorporate compositional change, but do not include a time trend. A time trend is included when two previous surveys are used. The model does not include all the surveys previously conducted in a country—only the one or two most recent previous surveys, which usually provide information about the interval 5 to 15 years before the current survey.

A projection will be “first order” when it uses the data from just one previous survey to develop a projection to the current survey. A first-order projection is essentially a multivariate direct standardization of the current survey on the composition of the most recent survey. In a first-order projection, it is assumed that composition on the covariates is the only source of change. The projection is “second order” if it uses the data from two previous surveys. Thus, the “order” is the number of earlier surveys used in the projection.

A “deviation” is an observed value minus an expected or projected value. The subtraction is always done in this sequence. If the deviation is positive, then the observed value is greater than the projected value. If it is negative, the observed value is less than the projected value. A “relative deviation” is a deviation divided by the projected value, and then multiplied by 100 so it can be interpreted as a percentage. The focus is on how or why an observed value differs from a projected value.

2.2 Countries and Surveys

Many countries have had three or more DHS surveys. The six countries selected for this report, listed in alphabetical order, are Bangladesh, Jordan, Kenya, Malawi, Philippines, and Rwanda. Three countries (Kenya, Malawi, and Rwanda) are in Sub-Saharan Africa, the region with the greatest concentration of DHS surveys. The other three surveys are in different regions: South Asia (Bangladesh), Middle East (Jordan), and Southeast Asia (Philippines). The countries were selected before the methods were applied and are not intended to illustrate any particular results. The methods were applied to the three most recent DHS surveys in each country. The selected countries have the experience of conducting DHS surveys that extends considerably further back than the three used here, and could be used to illustrate higher-order projections, although that is not attempted here. Malaria Indicator Surveys are not included. The intervals between most surveys were close to 5 years, although the approach does not require the spacing to be so regular. The calendar years of the surveys are:

- *Bangladesh:* 2011, 2014, 2017–18
- *Jordan:* 2007, 2012, 2017–18
- *Kenya:* 2003, 2008–09, 2014
- *Malawi:* 2004, 2010, 2015–16
- *Philippines:* 2008, 2013, 2017
- *Rwanda:* 2010, 2014–15, 2019–20

All the DHS surveys from Bangladesh and Jordan were limited to ever-married women (EMW). Those countries were included partly to illustrate the modifications needed for some outcomes in EMW surveys. Rather than using the so-called all-women factors described in the *Guide to DHS Statistics* (Croft, Marshall, and Allen 2018), we constructed a "pseudo-IR file." Women in the IR file were supplemented by including women in the household (PR) file who are eligible for inclusion in the IR file on every characteristic *other than* marital status. That is, women in the PR file who are age 15–49 and *de facto* residents of the household but are never-married are added to the IR file. For the women who are added, relevant outcomes are explicitly constructed and set at the values that are implicitly assumed for an EMW survey. Never-married women are assumed not to be sexually active, not to be using contraception, and never to have given birth. Then, for example, when the mean number of births in the past 5 years *for all women* is used as an outcome, and the number of births for never-married women has been set at zero, the mean can be calculated in exactly the same way as in an all-women survey.

For easier use in statistical software, a variable "survey" was constructed that takes the values 1, 2, and 3 for the successive surveys, in chronological order.

2.3 Outcome Variables

We include six outcomes or dependent variables. Four relate to women as the units of analysis, and two to children. All were calculated from the file of women (the IR file). Some outcomes are commonly used indicators, and others are strongly associated with commonly used indicators, but are easier to fit into the framework of a statistical model. They are:

Recent fertility: The mean number of children born in in the past 5 years, per 1,000 women. These births are used in the numerators of the standard 5-year fertility rates; the mean is approximately equivalent to the General Fertility Rate (GFR) for the past 5 years.

Current use of modern contraception: The percentage of women currently in a union who are using a modern method of contraception; equivalent to the modern contraceptive prevalence rate (mCPR).

Unmet need for family planning: The percentage of women currently in a union, and not pregnant, who say they want to delay or prevent their next birth but are not using contraception; equivalent to the usual indicator of unmet need.

Facility birth: For the most recent birth in the past 5 years, the percentage delivered in a facility.

Child mortality: The number of deaths per 1,000 births in the past 5 years. The denominator is the number of births in the past 5 years. This rate is not equal to the Under-5 Mortality Rate (U5MR) but is usually only slightly lower than the U5MR.

Treatment for child illness: Of the children born in the past 5 years who had diarrhea, fever, or cough in the past 2 weeks, the percentage who are reported to have received medical treatment. ("Cough" is not restricted to potential symptoms of Acute Respiratory Infection (ARI), because some earlier surveys do not include the follow-up question for that determination.)

2.4 Covariates

The variables included on the right-hand side of the model are described as covariates and could also be described as controls. These variables are available within the DHS standard recode files, and generally are statistically associated with the selected outcomes. In the DHS final reports, the standard tabulations for major indicators are given within categories of "background" variables, most of which are included here, although the model is multivariate rather than univariate. It would be possible to extend to other data, such as spatial covariates that can be attached to the sample clusters.

Date of interview: Time is built into the model with the date of interview, which is given in the survey(s) by the respondent's month of interview (as a century month code, cmc). Date of interview is not included as a covariate in the first-order models. In the second-order model, time is included as a linear covariate on the scale of the link function.

Birth cohort: Cohorts, defined by calendar year of birth, are represented by different women in a sequence of surveys, because DHS does not re-interview the same women. We use 5-year birth cohorts, identified by midpoint years that are multiples of five. For example, the "1980 cohort" includes women born in 1980 +/- 2, the calendar years 1978–82, inclusive. Each survey with respondents age 15–49 includes eight birth cohorts. The inclusion of birth cohort provides continuity across surveys. With a 5-year spacing between surveys, each new survey includes one new (younger) cohort and one (older) cohort ages out of eligibility.

Age: Current age is included in standard 5-year age intervals 15–19, 20–24,…, 45–49. In a single survey, cohort and age are collinear. In a series of two surveys, they are nearly collinear. If both are included, the model may be unstable. If there is evidence of instability, age is retained and cohort is dropped.

Parity 5 years before the interview: The number of children at the beginning of the past 5 years has a likely association with some outcomes, especially recent fertility, current use of modern contraception, and unmet need. Parity is calculated as the number of children ever born minus the number born in the past 5 years.

Socioeconomic characteristics: Level of education (none, primary, secondary, and higher) is included as a categorical covariate. Wealth quintile, a household-level categorical covariate, is also included.

Strata. We also include combinations of region (specific to each survey) and urban/rural residence as a categorical covariate. In many surveys, these combinations comprise the strata in the sampling design, but those combinations are used regardless of whether they are the sampling strata. In general, regions are the first administrative level in the country and the sampling strata are the units for which the sample is designed to give statistically stable estimates. Some countries experienced changes across surveys in the definition of regions and the codes for the regions. An important part of pre-processing the data is to make the coding of region in earlier surveys as consistent as possible with the coding in the current survey.

2.5 Statistical Model[1]

Outcomes are defined at the level of the individual woman or her children and are modeled with generalized linear models (glm). We can distinguish the following three setups.

The outcome is binary (0/1). For current use of modern contraception, unmet need, and facility birth, the glm model has a binomial error and logit link function. If the outcome is Y and “X” is a list of all predictors in the model, then the Stata command is “glm Y X, family(binomial) link(logit)”.

The outcome is a count. For children born in the past 5 years, the outcome is usually 0 or 1, but it can be a larger number. In some surveys (typically because of multiple births) the number can range up to 6. The generic glm model for a count has Poisson error and log link. The Stata command is “glm Y X, family(poisson) link(log)”. An alternative of a negative binomial was considered but gave identical results.

The outcome requires an adjustment for exposure. For child mortality and treatment for child illness, the units are children born in the past 5 years. Normally, these outcomes would be analyzed with the child (KR) file. However, it is easy to analyze them with the mother’s data (in the IR file), if the number of children in the denominator of each rate is taken into account. Say that Y is a count of the number of children with the outcome and d (for denominator) is the number of children at risk; logd is the natural logarithm of d (NA if d=0). Then with a Poisson framework, which we use, the Stata command is “glm Y X, offset(logd) family(poisson) link(log)”. The same result, on a logit rather than log scale, could be obtained with a binomial model, “glm Y X, family(binomial d) link(logit)”.

All analysis was done with Stata, using svyset and svy to adjust for three components of the sampling design—the weights, clusters, and sampling strata.

Two other variables are crucial to the projections. A variable “pop1” is defined to be 1 for cases in survey 2, and NA otherwise. The command is “gen pop1=1 if survey==2”. The number “1” in the label “pop1” indicates that pop1 is used in the first-order model, in which only survey 2 is used to fit survey 3.

A variable “pop2” is defined to be 1 for cases in either survey 1 or survey 2, and NA otherwise. The command is “gen pop2=1 if survey==1 | survey==2”. The number “2” in the label “pop2” indicates that pop2 is used in the second-order model, in which both surveys 1 and 2 are used to fit survey 3. To apply these restrictions, the glm command is preceded by “svy, subpop(pop1):” or “svy, subpop(pop2):”. The projections are accomplished by three steps:

1. Estimate a model described above in a file that includes the pooled surveys from a specific country but omitting survey 3 from the estimation.

2. Fit or “predict” the values for survey 3, which was excluded from the estimation because of “subpop”. The Stata command is “predict hat if survey==3, xb”, where “hat” is a fitted value on the logit or log scale.

[1] This section is relatively technical and includes Stata commands to facilitate replication. Some readers may wish to skip over it.

3. Transform the out-of-sample fitted values by using the anti-logit or anti-log transformation; restrict to the relevant cases, such as women currently in union or children who experienced an illness; and calculate means for the entire sample or subgroups, in survey 3.

The estimates thus produced are "out-of-sample" estimates, because survey 3 was not included in the data used to fit the models.

2.6 Goodness-of-Fit

The model involves two stages at which the correspondences between data and estimates must be assessed. The first is an evaluation of how close the in-sample estimates for surveys 1 and 2 are to the data observed in those surveys. The second is the comparison of the out-of-sample estimates for survey 3 and with the observed values in that survey.

The in-sample fit reflects the quality of the model, given the variables available in the first two surveys. There is no consensus on fully satisfactory measures of fit for generalized linear models. We will use two approaches to measuring goodness-of-fit. The first, which can only be applied to the logit model, is Tjur's coefficient of determination (Tjur 2009). That coefficient is M1-M0, where M1 is the mean of the fitted probability of 1 for cases in which the observed outcome is 1, and M0 is the mean of the fitted probability of 1 for cases in which the observed outcome is 0. The second measure is the proportionate reduction in the residual deviance when the model is compared with a null model (which has no covariates), which can be described as a pseudo-R^2 (McFadden 1974).

Specification error is problematic at the level of the individual case, which is the level at which both measures are calculated. However, for strata or age groups, which are included as categorical covariates, the marginal fit should be exact in a first-order model and nearly exact in a second-order model.

We also describe the out-of-sample differences and relative differences between the observed and expected values of an outcome, at the national level and within subpopulations (strata or age groups). These differences can arise from many sources, including the quality of the in-sample estimates, possible data-quality issues in any of the surveys, and real changes on the ground such as programmatic interventions and economic shocks, as well as legal and cultural changes, etc. We will describe but will not attempt to analyze the out-of-sample differences. Such an analysis would be limited to one country and outcome at a time and the types of information available for that country.

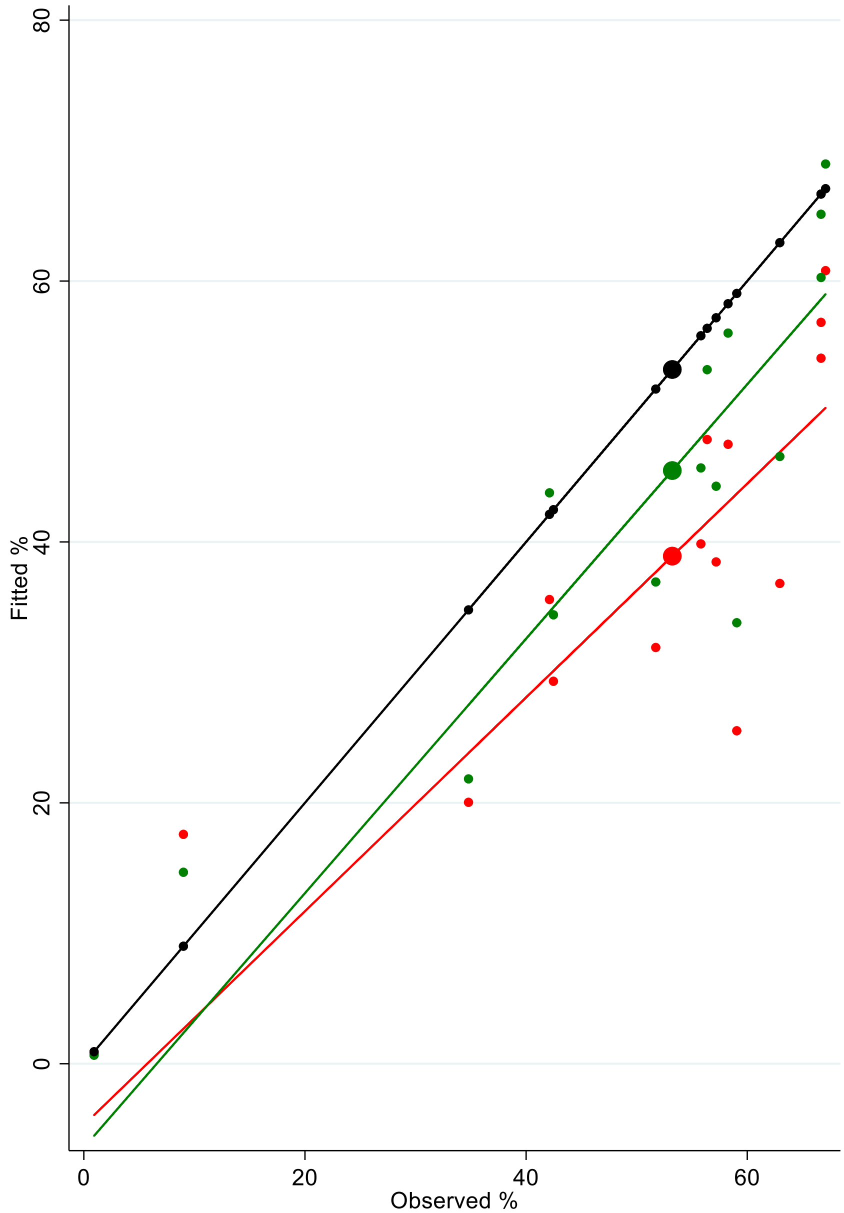
3 RESULTS

3.1 Illustrative Results for Kenya

As described, the model is applied to six countries, six outcomes, and two orders of projection. For each of these 72 applications, the national-level results are supplemented with breakdowns by strata and age groups. Most of the presentation of results is in the form of figures.

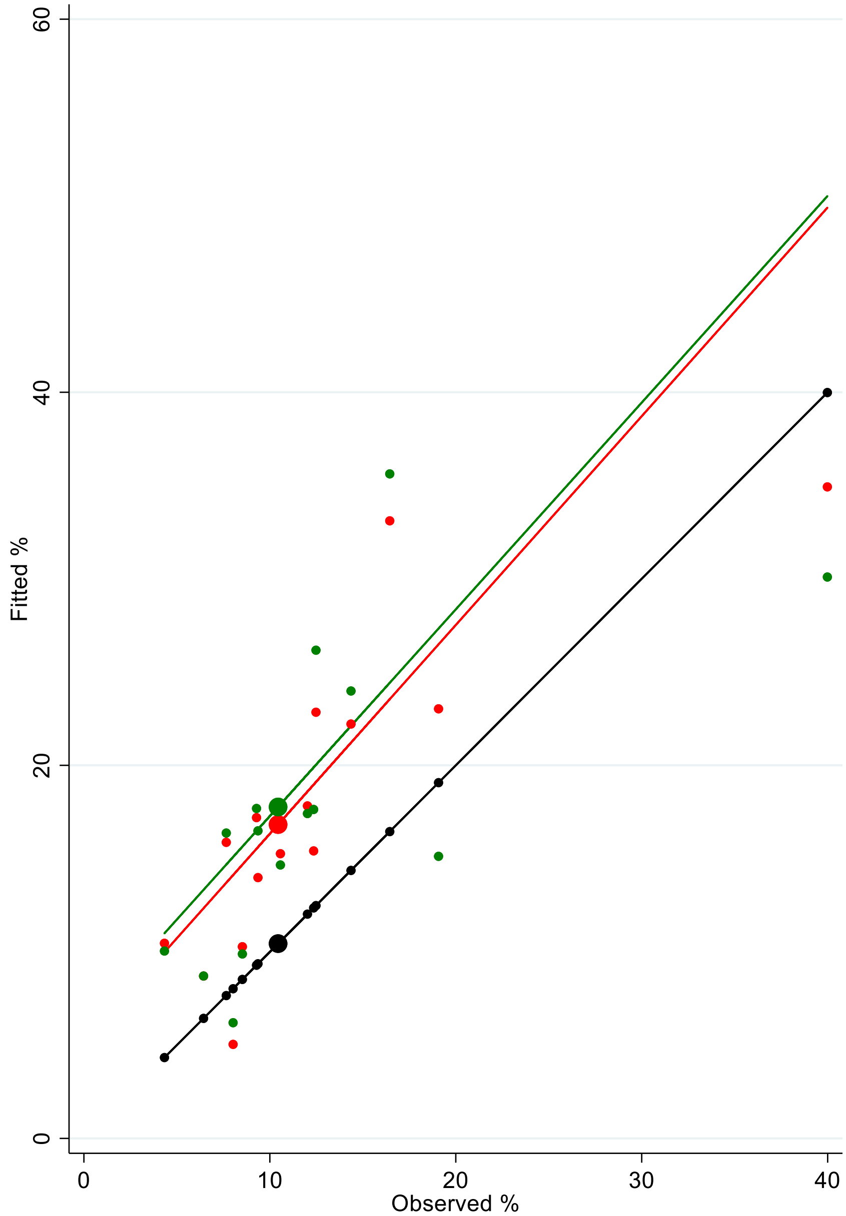
Kenya will illustrate the format of the figures and how to interpret them. The text will include six figures for Kenya, one for each of the six outcomes, showing the disaggregation by strata.

Figure 1 Kenya: projection of use of modern contraception, nationally and disaggregated by strata



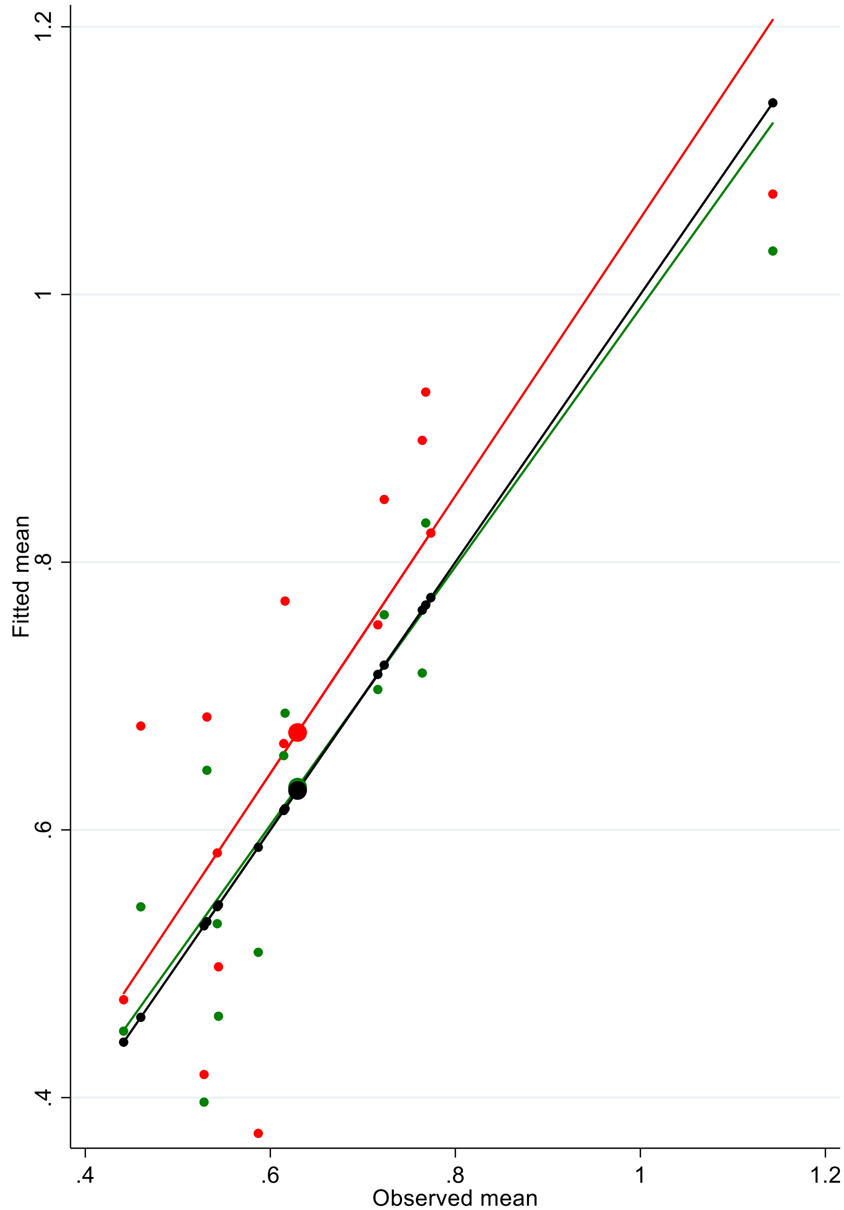
Black: observed; red: first order projection; green: second order projection.

Figure 2 Kenya: projection of unmet need for family planning, nationally and disaggregated by strata



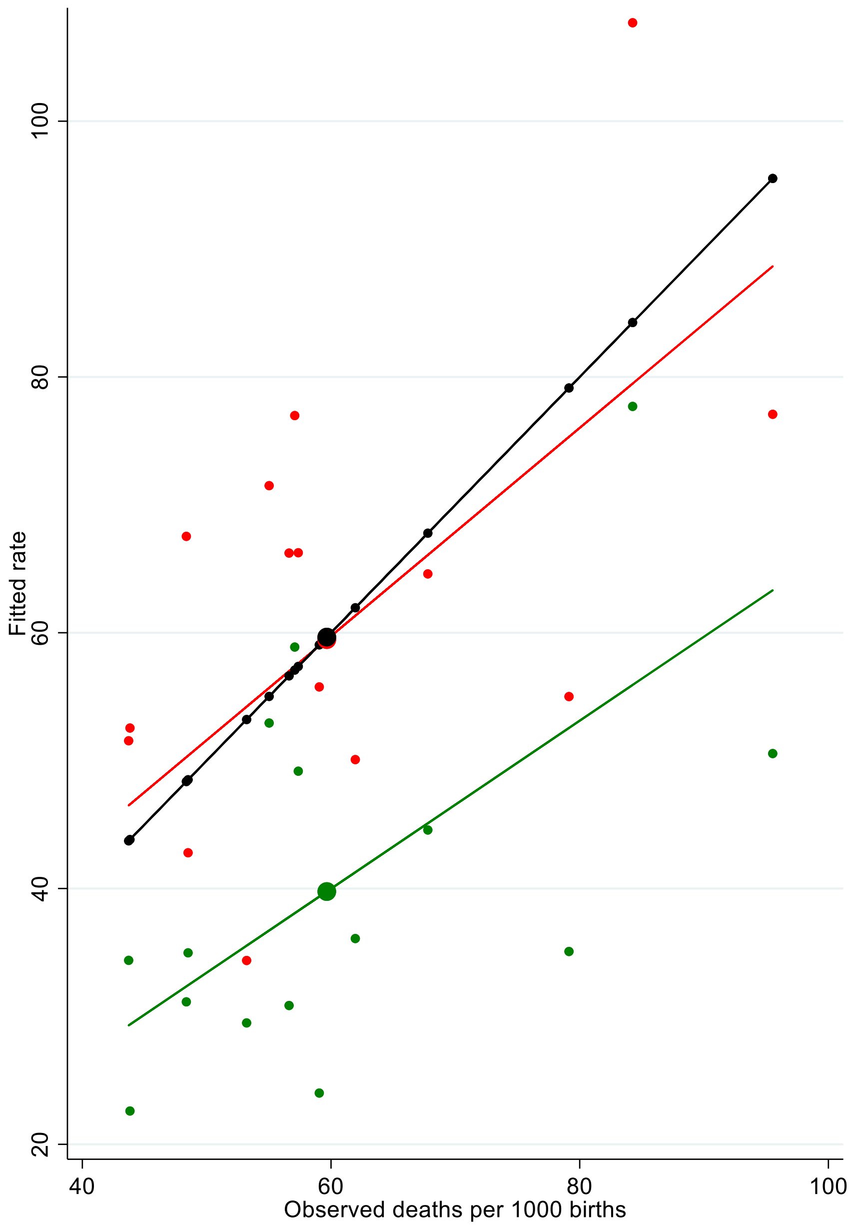
Black: observed; red: first order projection; green: second order projection.

Figure 3 **Kenya: projection of children born in past 5 years, nationally and disaggregated by strata**



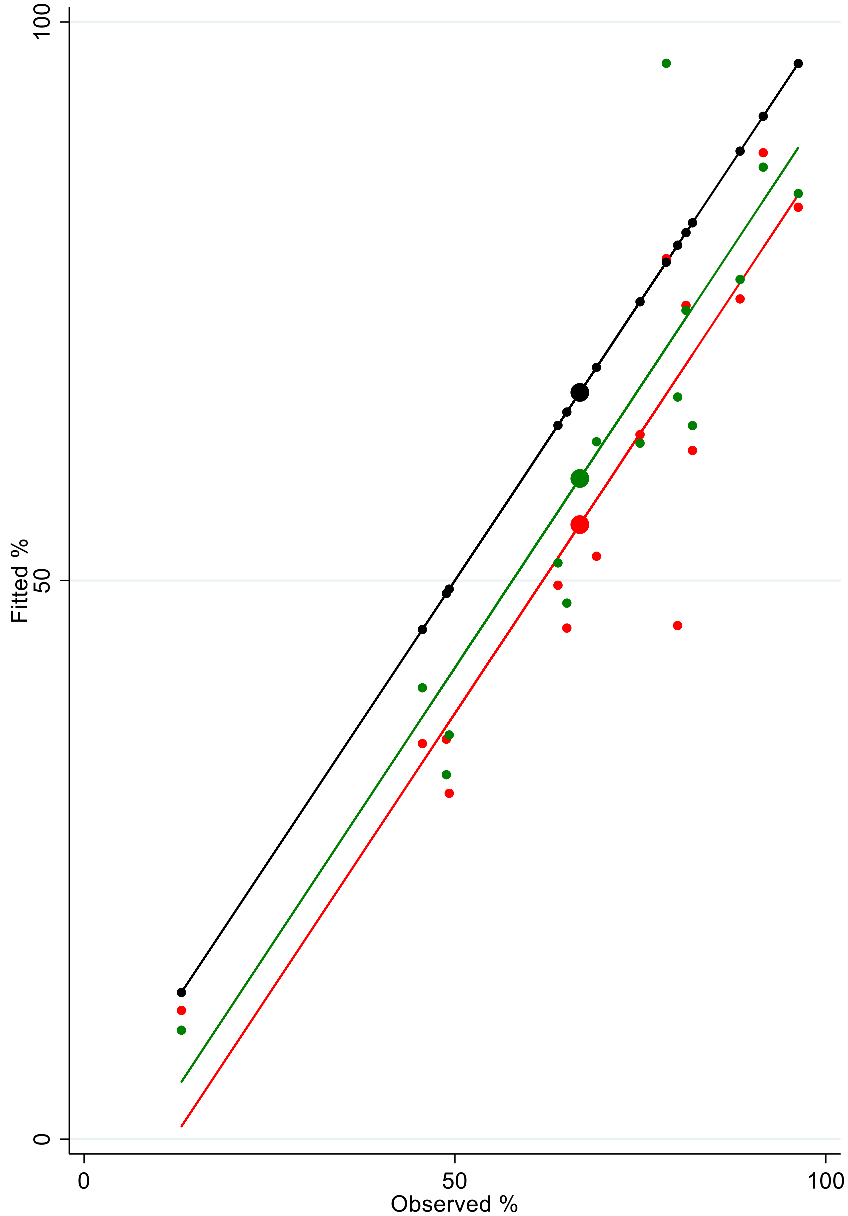
Black: observed; red: first order projection; green: second order projection.

Figure 4 Kenya: projection of child deaths in past 5 years, nationally and disaggregated by strata



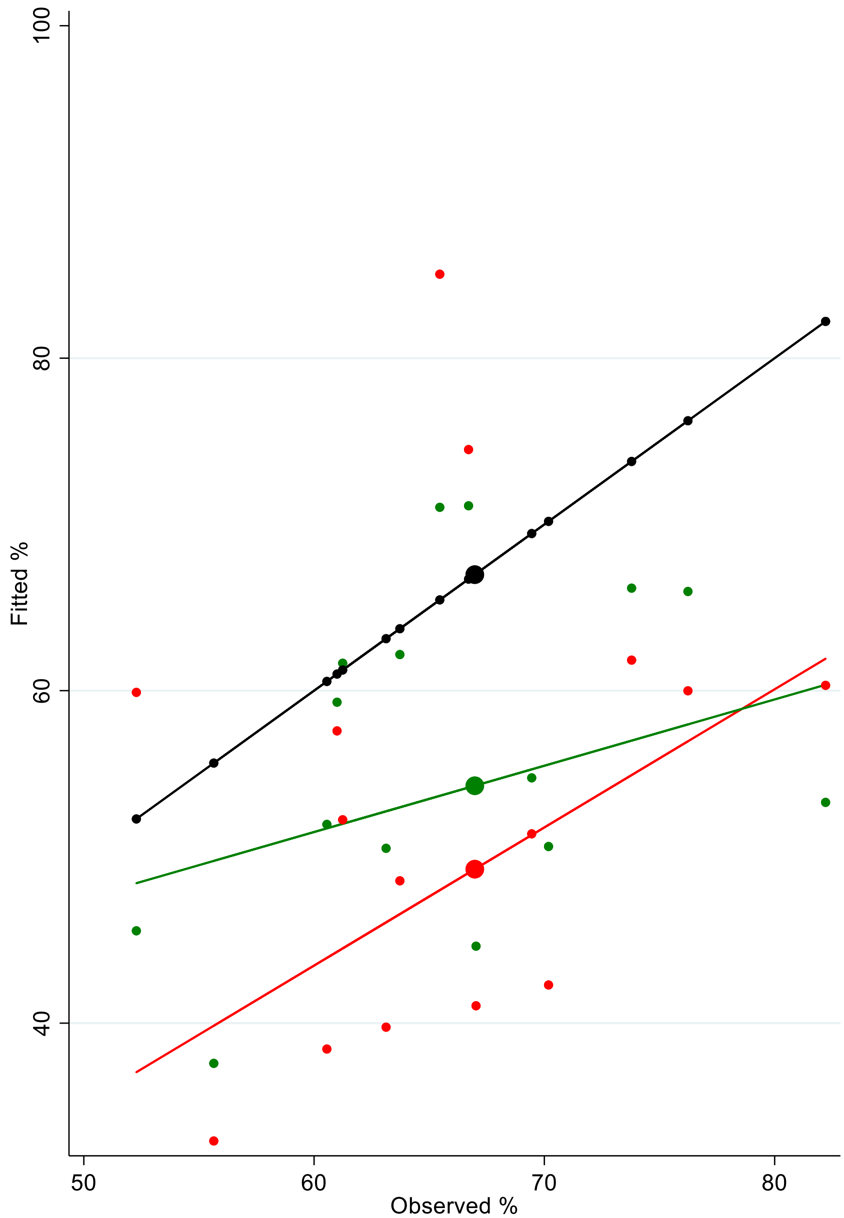
Black: observed; red: first order projection; green: second order projection.

Figure 5 **Kenya: projection of last birth was in a facility, nationally and disaggregated by strata**



Black: observed; red: first order projection; green: second order projection.

Figure 6 Kenya: projection of treatment for child illness, nationally and disaggregated by strata



Black: observed; red: first order projection; green: second order projection.

Figure 1 shows the pattern for use of modern methods of contraception in Kenya. The observed values in the most recent DHS survey, in 2014,[2] are shown with dots on the black line. The values are the same on both the vertical and horizontal axes (if both axes had the same scale, the black line would be at a 45-degree angle). This line is constructed simply by sorting the values of the outcome, nationally and by strata. The large dot on the black line is the national value, and the smaller dots show the observed values for the strata.

The projected values are shown with red and green dots. Red is used for the first-order projection, which simply adjusts for the changes in distributions of covariates from the 2008–09 survey to the 2014 survey.

[2] Kenya had an MIS in 2020, but most of the outcomes used in this report are not included in MIS surveys.

Green is used for the second-order projection, which adjusts for composition, but also extrapolates to 2014, with a term for time based on the rate of change from the 2003 survey to the 2008–09 survey. Because logit regression is appropriate for this binary outcome, the time effect is linear on the logit scale. The large red and green dots show the national projections and the small dots show the stratum-level projections. Nationally, or for a given stratum, the black, red, and green dots are directly above or below one another.

A red line is fitted through the red dots for strata, weighted by the number of cases in each stratum, and a green line is fitted through the green dots for strata.[3] The red and green lines are included to make it easier to see the general pattern of displacement of the red and green dots relative to the black dots.

The most important interpretation comes from the position of the national observed value, relative to the two national estimates. In Figure 1, the national observed value is above both projections. Current use of modern contraception was higher in the 2014 survey than would have been expected, but was closer to the estimate that used two previous surveys than to the estimate using just one. The implication is that the use of modern contraception had increased between the 2003 and 2008–09 surveys, and the pattern of increase extended to the 2014 survey. Because the observed value in 2014 was higher than the two-survey projection, there was a greater rate of increase from 2008–09 to 2014 than there had been from 2003 to 2008–09.

In many contexts, a deviation between an observed value and an expected value is interpreted as error. That interpretation does not apply here. The differences between the observed and projected values, taken at face value, simply mean that the extrapolation of past levels and trends did not capture the dynamics of changes in the outcome between the 2008–09 and 2014 surveys. If an objective of the reproductive health program in Kenya is to promote the use of contraception, and to help women implement preferences for the number and spacing of births, then the pattern in Figure 1 would be welcome. Indeed, an accelerated increase in the outcome would probably be the ideal.

Comparing the small black dots for strata with the corresponding red and green dots (vertically aligned), the national pattern appears to have largely carried over to the strata. Most strata had an observed value that was higher than either projection or was closer to the two-survey projection than to the single-survey projection. The greatest negative deviation was for a stratum that had particularly low use of family planning. (Specific strata are not identified by name.)

We next consider the pattern in Figure 2, which describes the percentage of women who have an unmet need for contraception. Here the deviations of observed values are negative, the reverse of what was seen in Figure 1. This is to be expected, because contraceptive prevalence and unmet need tend to be negatively associated. There is very little difference between the two orders of projection, nationally and for most strata. The red and green dots are very close to each other, implying that unmet need changed little between the 2003 and 2008–09 surveys. Another implication is that the two-survey projection added little value to the single-survey projection. The difference is small, but the single-survey projection is slightly more consistent with the observed values.

[3] Because the underlying model is not linear, fitted lines through the projections for subgroups may not go through the national projection. For the figures, in order to simplify the presentation, the red and green lines were forced to go through the national projection. All analysis of residuals is based on the projected values, not on the fitted line.

Figure 3 describes the mean number of births in the past 5 years. The differences between the observed and projected values are small. The national observed mean agrees almost exactly with the two-survey projection. In virtually all strata, the observed means are closer to the two-survey projection than to the single-survey projection.

The pattern in Figure 4, which describes child deaths (per 1,000 births) during the past 5 years, is very different. Observed under-5 mortality in the 2014 survey agrees almost exactly with the single-survey projection. In every stratum, the observed rate corresponds more closely to the single-survey projection. A decline in under-5 mortality would have been expected, based on an extrapolation of the decline from 2003 to 2008–09, but did not materialize.

The fifth figure, with the percentage of births that take place in a facility rather than at home, shows the same pattern as contraceptive use in Figure 1. In Figure 5, the black dots tend to be above both the red and green dots but are closer to the green dots. This pattern implies an accelerated improvement over the course of the three surveys. There was only one stratum in which the observed percentage of facility births was less than what would have been expected, and this was a stratum in which prevalence was already among the highest levels. Although the observed values were closer to the two-survey projections, there was little difference between the single-survey and two-survey projections.

Figure 6 describes the percentage of children who received some kind of medical treatment for diarrhea, fever, or cough in the past 2 weeks. The results are similar to those seen in Figures 1 and 5 and are welcome from a program perspective. Nationally, the observed percentage is higher than both projections, but is closer to the two-survey projection.

There is considerable scatter in the stratum-level projections in Figure 6. For three strata, the displacement was the opposite of the national-level pattern, with the observed percentage below the single-survey projection.

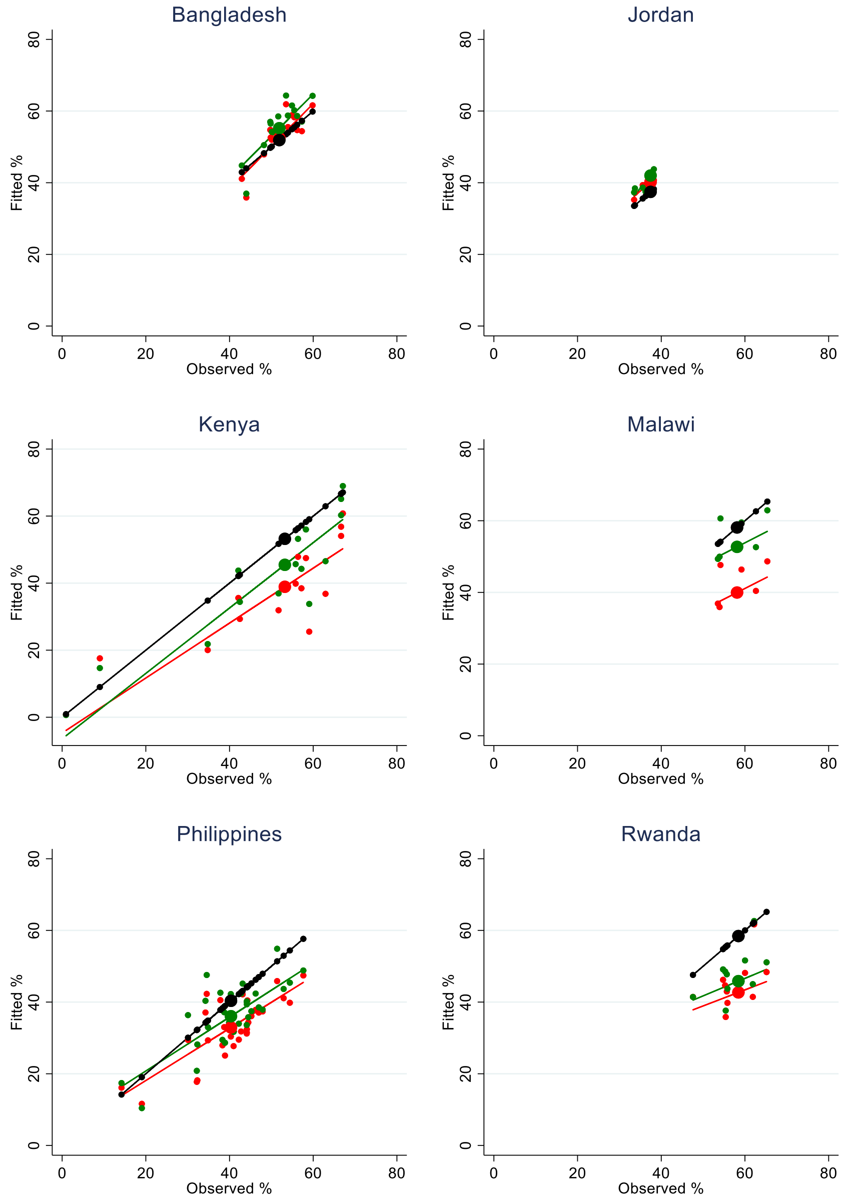
Summarizing Figures 1–6, the national observed values tended to match the first-order projection (Figure 4), to match the second-order projection (Figure 3), or to show improvement over both projections, but be closer to the second-order projection (Figures 1, 5, and 6). In one case, the national estimate was an improvement over both projections, but was slightly closer to the first-order projection (Figure 2).

These projections could not have been made in the absence of the latest survey, because they require controls for composition. We use the term “projection,” but repeat that the values are out-of-sample estimates that include the same covariates for all two or three surveys, except for the inclusion of a coefficient for time in the two-sample estimates.

3.2 Results for All Countries

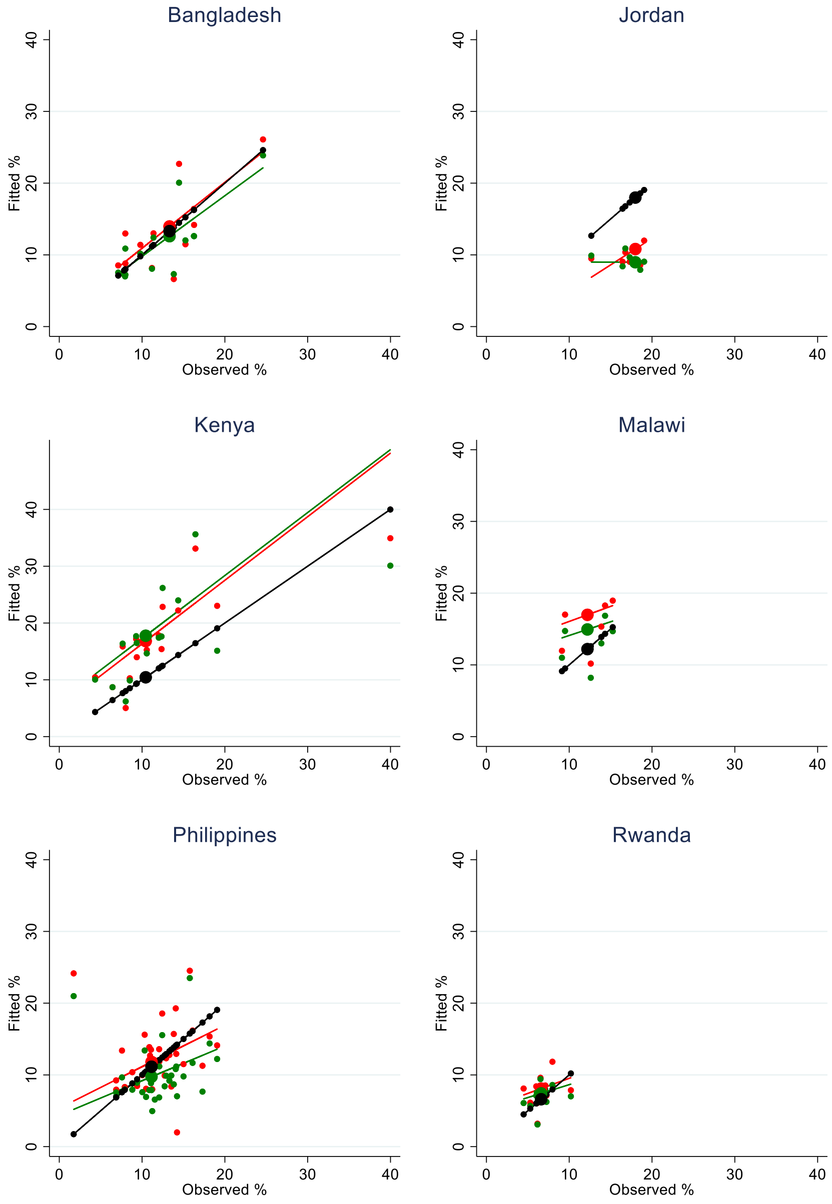
We now review the results for the six outcomes in all six countries. Figures 7–12 correspond to Figures 1–6, respectively, but have subfigures for each country. The figures for Kenya are repeated on a smaller scale. Again, the breakdown for subpopulations uses strata, which are defined as combinations of region and urban/rural residence.

Figure 7 **Use of modern contraception: projections in each country, nationally and disaggregated by strata**



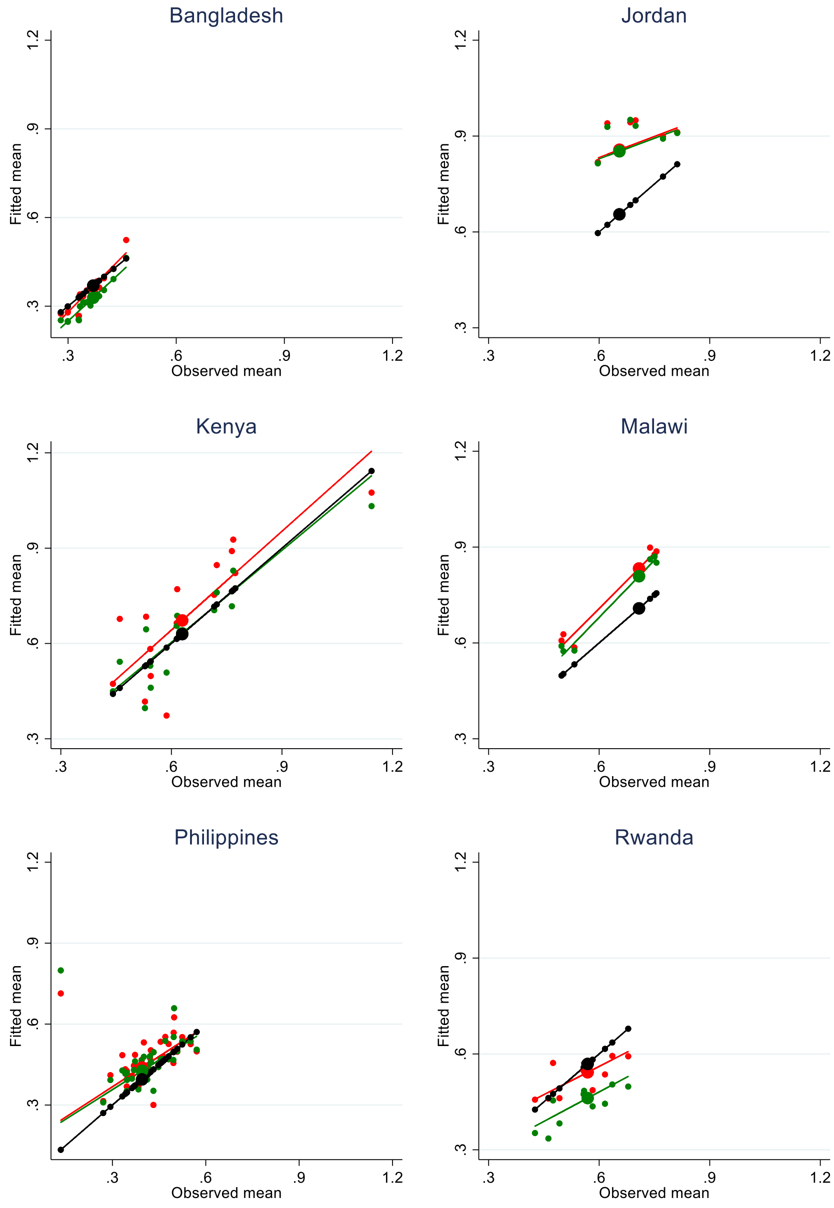
Black: observed; red: first order projection; green: second order projection.

Figure 8 **Unmet need for family planning: projections in each country, nationally and disaggregated by strata**



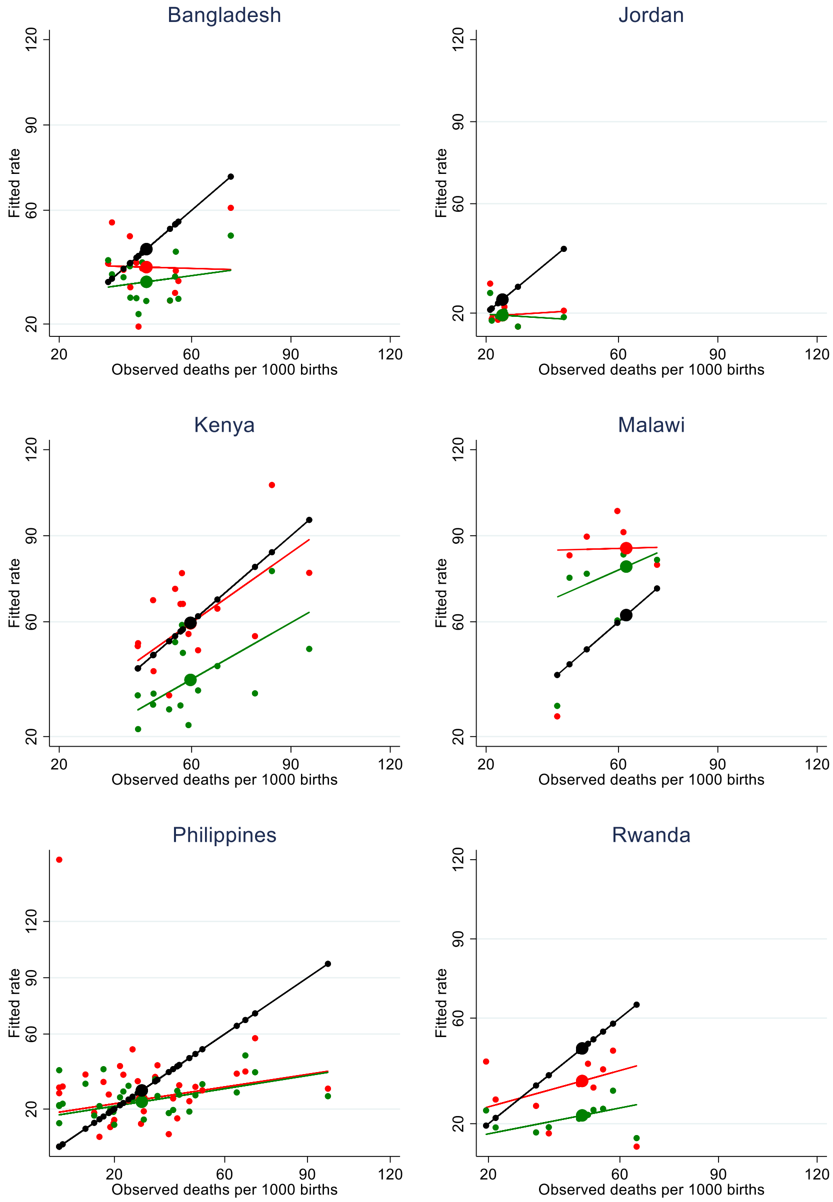
Black: observed; red: first order projection; green: second order projection.

Figure 9 Children born in past 5 years: projections in each country, nationally and disaggregated by strata



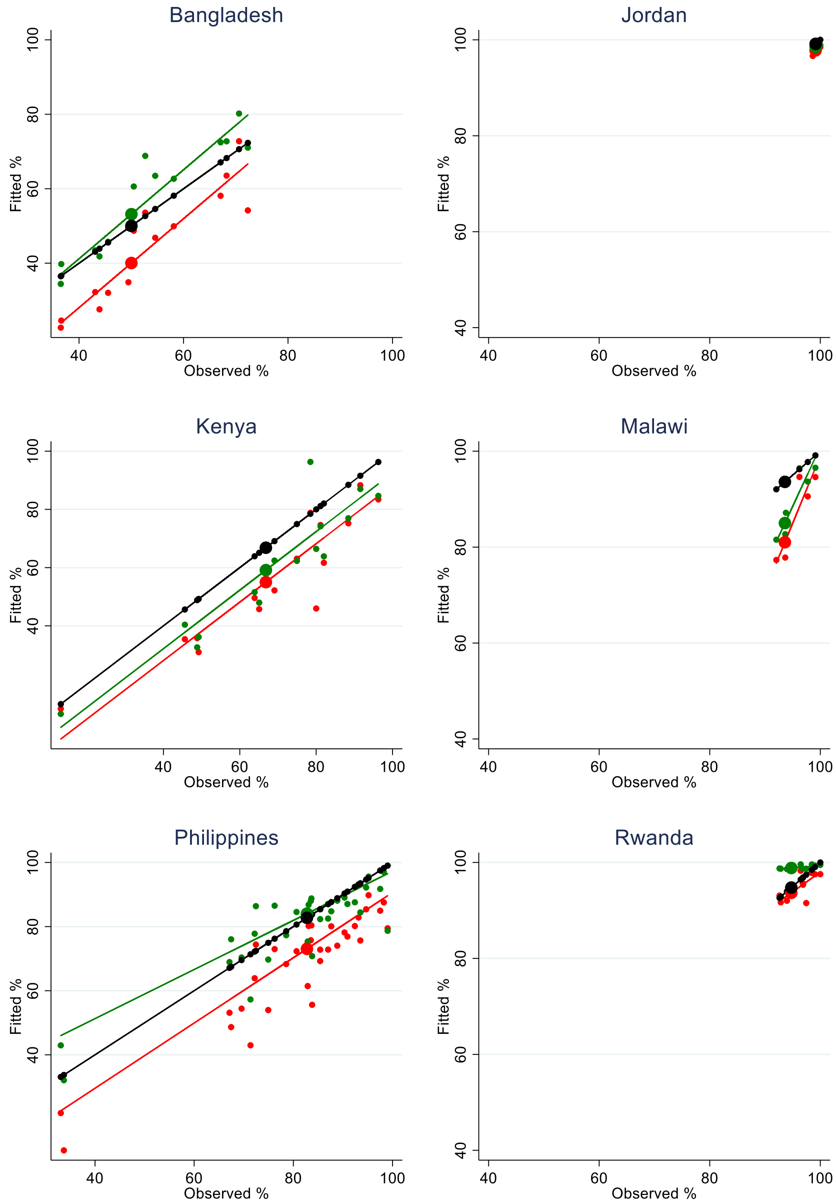
Black: observed; red: first order projection; green: second order projection.

Figure 10 Child deaths in past 5 years: projections in each country, nationally and disaggregated by strata



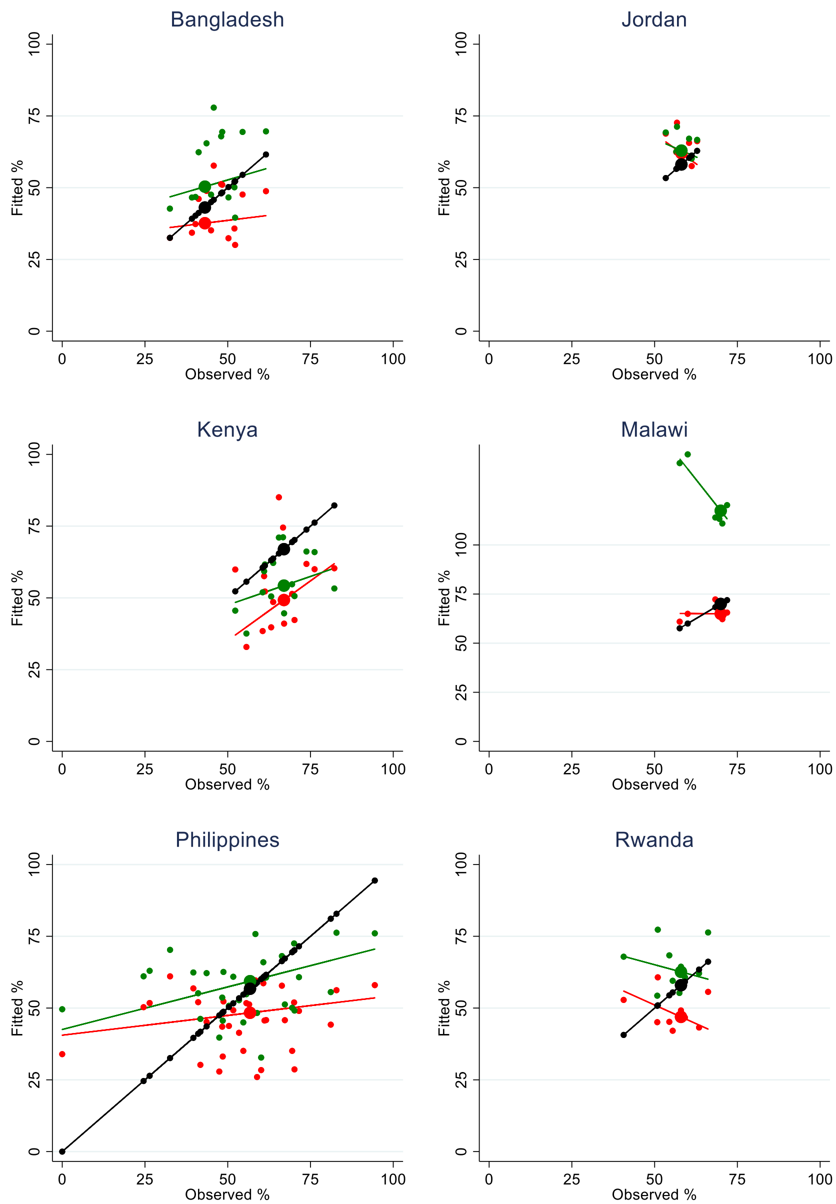
Black: observed; red: first order projection; green: second order projection.

Figure 11 Last birth was in a facility: projections in each country, nationally and disaggregated by strata



Black: observed; red: first order projection; green: second order projection.

Figure 12 **Treatment for child illness: projections in each country, nationally and disaggregated by strata**



Black: observed; red: first order projection; green: second order projection.

Within each figure, all the subfigures have the same vertical and horizontal scales, in order to provide a better sense of the differences between countries in both the levels and the dispersion across strata. An unfortunate disadvantage of uniform scaling is that some differences are difficult to display visually. Jordan, for example, has relative homogeneity across strata, which tends to reduce the horizontal variation in the subfigure. The surveys in Bangladesh were closely spaced, only about three years apart, which tends to reduce the vertical variation in the subfigure.

In Figure 7, for the use of modern contraception, the horizontal and vertical scales range widely from 0% to 80%. Kenya and the Philippines have strata in which the prevalence is below 20%, while some other countries have strata with prevalence above 60%. Focusing on the national level estimates, there are two general observations. First, without exception, the two-survey projection is higher than the single-survey projection. Sometimes the difference is small, but it is consistent. Second, the observed prevalence is either above both projections—in Kenya, Malawi, Philippines, and Rwanda—or below both projections—in Bangladesh and Jordan. In the first pattern, the observed value is closer to the two-sample projection. In the second pattern, the observed value is closer to the single-sample projection. These generalizations largely carry over to the strata.

Figure 8 shows the results for unmet need for family planning, which generally moves in a direction opposite to contraceptive use. In Kenya and Malawi, the national observed value is distinctly below both projections. In Jordan, the national observed projection is substantially higher than both projections. The directions of the deviations in these three countries are opposite to those in Figure 7, as expected. For the other three countries, the national observed values are barely distinguishable from the projected values. In all countries, the difference between the two-survey and single-survey projections is small.

The next figure in the series, Figure 9, describes the mean number of children born per woman in the past 5 years. In Bangladesh, the values are low and clustered in a narrow range near .4. Kenya shows the most dispersion across strata, with an observed mean above one child in one stratum. In Jordan, the single-sample and two-sample projections are almost identical and the observed means (nationally and in all strata) are well below both projections. Normally, contraceptive use and fertility are inversely related, but both declined between the two most recent surveys in Jordan. The DHS staff and others attempted to reconcile this apparent discrepancy in terms of potential data quality issues, changes in population composition, the asynchronous measurement of the two outcomes, etc. The most complete analysis of the pattern was done by Bietsch and colleagues (Bietsch et al. 2021) but the pattern is still not fully understood.

Malawi is similar to Jordan in terms of fertility decline, with the observed levels below both projected values, but in a context of increased contraceptive use. In the other four countries, the observed values coincide almost exactly with one projection or the other. In Bangladesh and Rwanda, the observed values coincide with the single-survey projection. In Rwanda, the observed values coincide with the two-survey projection. In the Philippines, the two projections agree with each other almost exactly, and the observed values are only slightly less.

Figure 10 describes under-5 mortality. Malawi again stands out with lower-than-projected levels in the latest survey. In one stratum, the observed level was above the projections, but this was already the stratum with the lowest mortality. In Bangladesh, Jordan, the Philippines, and Rwanda, the national observed levels were somewhat above both projections, but the deviation was very small in the Philippines. In Kenya, as noted earlier, the observed value agreed with the single-survey projection but was considerably above the two-survey projection.

Figure 11 shows the percentage of births (the most recent birth in the past 5 years) in a facility. In Jordan, Malawi, and Rwanda (and especially Jordan), facility births have become the norm. In Malawi, the observed levels in the latest survey were above both projections. In Rwanda, the national observed value was between the two projections, but closer to the single-sample projection. In Bangladesh, Kenya, and the Philippines, levels were below 40% in one or two strata, but are generally well above that level, especially in the Philippines. In Bangladesh and the Philippines, the observed values were very close to the two-sample projection. In Kenya, as seen earlier, the observed values were above both projections, but closer to the two-sample projections.

This report includes three other sets of six figures, in which each figure has six sub-figures. The figures in Appendix 1 are analogous to those just described but are disaggregated by the age of the woman or mother. Appendices 2 and 3 are structured with a separate country for each figure, with sub-figures for the indicators. Appendix 2 is broken down by strata, and Appendix 3 is broken down by age groups. In Appendices 2 and 3, the subfigures refer to different indicators, and there is no need for fixed vertical and horizontal scales in the subfigures. Although the figures are repeated, there is better resolution for visual interpretations, but further discussion would be repetitive.

3.3 Model Fit and Deviations

The figures in the body of the report and in Appendices 1–3 show differences across outcomes and countries visually. The national results are described numerically in a set of tables, one for each outcome, in Appendix 4. In the Appendix 4 tables, the first three columns give the country, the observed value of the outcome in the most recent survey, and the order of the projection, either 1 or 2. The observed value is the same for both order 1 and order 2, but the remaining columns are different for the two projections. The projected values for orders 1 and 2 are followed by measures of fit. For the three binary outcomes, Tjur's coefficient of determination is given, but it is not defined for the other three outcomes. McFadden's pseudo-R^2 is given for all models. The last two columns give the deviations (observed minus projected) and the relative deviations, expressed as percentages.

Some of the national deviations are very small, but there is a lack of consistency. Within the same country or outcome or model there is a mix of good matches and poor matches. The second-order model, which includes a trend, is not necessarily any more accurate than the corresponding first-order model, which does not include a trend.

For the logit models, Tjur's coefficient of determination and the Pseudo-R^2 are close in magnitude. Most values are in a respectable range for logit models. It is likely that with additional covariates, the fit could be increased somewhat. However, as with most applications of logit regression, unexplained variation far outweighs systematic variation. For the Poisson models, only the pseudo-R^2 is defined and its values are larger. Again, with additional covariates, the fit to the previous surveys could probably be improved somewhat. It is likely that in the second-order model, the fit is better if the two surveys are closer to each other in time (as with the Bangladesh surveys), but there are not enough replications of the model, or variations in the interval, to be able to demonstrate this.

We have examined but do not include summary measures of the deviations for strata and age groups. The strata are different for every country because region is a country-specific variable. It is clear from the figures that those deviations can be large in either direction.

4 DISCUSSION AND CONCLUSIONS

The absence of firm conclusions about the direction and magnitude of deviations from the projections should not be surprising, because of several issues.

First, it is reasonable that the two alternative projections differ from each other. The first-order projection simply takes into account the multivariate change in composition between the most recent survey and the immediately preceding survey. It does not allow for potential change in the coefficients between the surveys. A serious decomposition of change between two surveys would allow for change in coefficients, as well as interactions or nonadditive components. The two-survey projection uses more data, but adding a coefficient for temporal change is a qualitative difference from the single-survey projection. We have examined the coefficient for time, and in many cases, it is not significantly different from zero. Even if the coefficient for time is not different from zero, the two-sample projection will differ from the single-sample projection because it includes the composition of two surveys, not just one.

Second, the results raise a question about the value of using more of the prior history. All of the selected countries have had at least five usable surveys. It would be possible, in a mechanical manner, to include the earlier surveys, essentially fitting a line through data points long before the current survey. This would be meaningful if there were strong evidence of a continuous pattern of change. There is abundant evidence, however, that changes in the selected outcomes have not been continuous over a long interval of time.

A third issue is the representation of the time effect. The effect is assumed to be linear on the scale of the link function, which is the logit for binary outcomes and the logarithm for counts and rates. An assumption of linearity on a nonlinear scale could be questioned. There is also a question about how to allow for accelerations or retardations in the nature of the trend. The model for change need not require an assumption that change is uniform across subpopulation. About half of the strata, for example, are urban and half are rural. Some strata have much more of a health infrastructure than others. It would be possible to elaborate the two-sample model by allowing for different trajectories of change in the different strata, with Bayesian adjustments for the different sizes of the strata.

Fourth, more covariates could be included. Spatial covariates could be added with geospatial data files that are already available and can be readily linked with sample clusters. Establishing continuity across successive surveys is complicated, however, by the fact that each survey has completely different clusters. The cluster-level data would need to be converted to interpolated surfaces. Links with measures of the service environment, for example, as described with Service Provision Assessment (SPA) surveys, would also strengthen the models. Unfortunately, contemporaneous DHS and SPA data for three (or more) successive surveys in the same country are not available.

Finally, and most importantly, the objective is not primarily to predict the levels of the outcomes in the most recent survey. Instead, the goal is to generate hypothetical values that are consistent with previous data and relatively simple assumptions about patterns of change. The hypothetical values are implied by an assumption of continuity from the past. The single-survey model assumes no change, except in composition. The two-survey model assumes continued linear change. If the observed levels agree with projected levels, the assumptions have been at least partially validated. If there are deviations, then the underlying assumptions behind the projection must be re-examined. An earlier pattern of change may have ended, reversed, or accelerated. Deviations at a subnational level, such as a stratum, which differ from those at the national level, indicate that a national time trend did not extend to all subpopulations. Some subpopulations may experience more change, or less change, than the country as a whole. The potential value of these methods is in their application to multiple outcomes in a new survey in a specific country, as a way to identify recent changes in national trajectories and internal variations. The next step in a more focused analysis would be to try to understand and interpret such changes.

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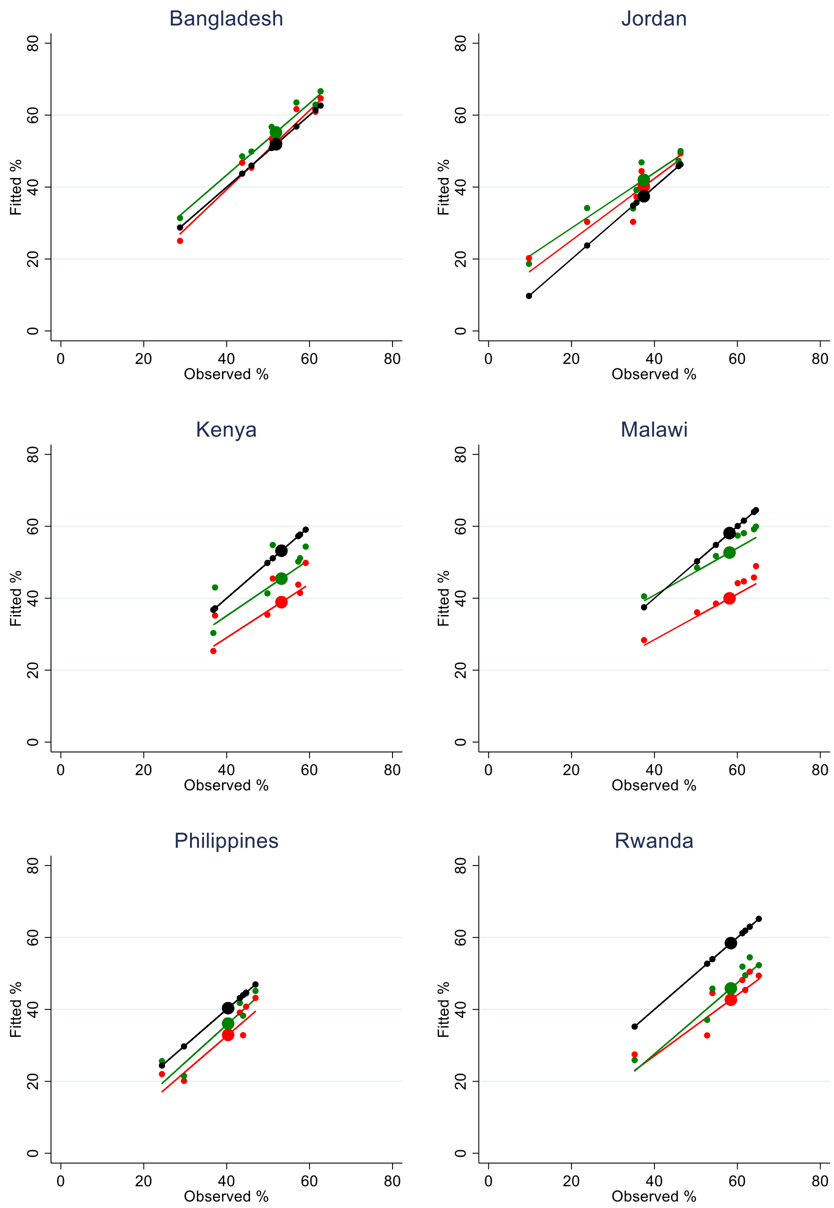
APPENDICES

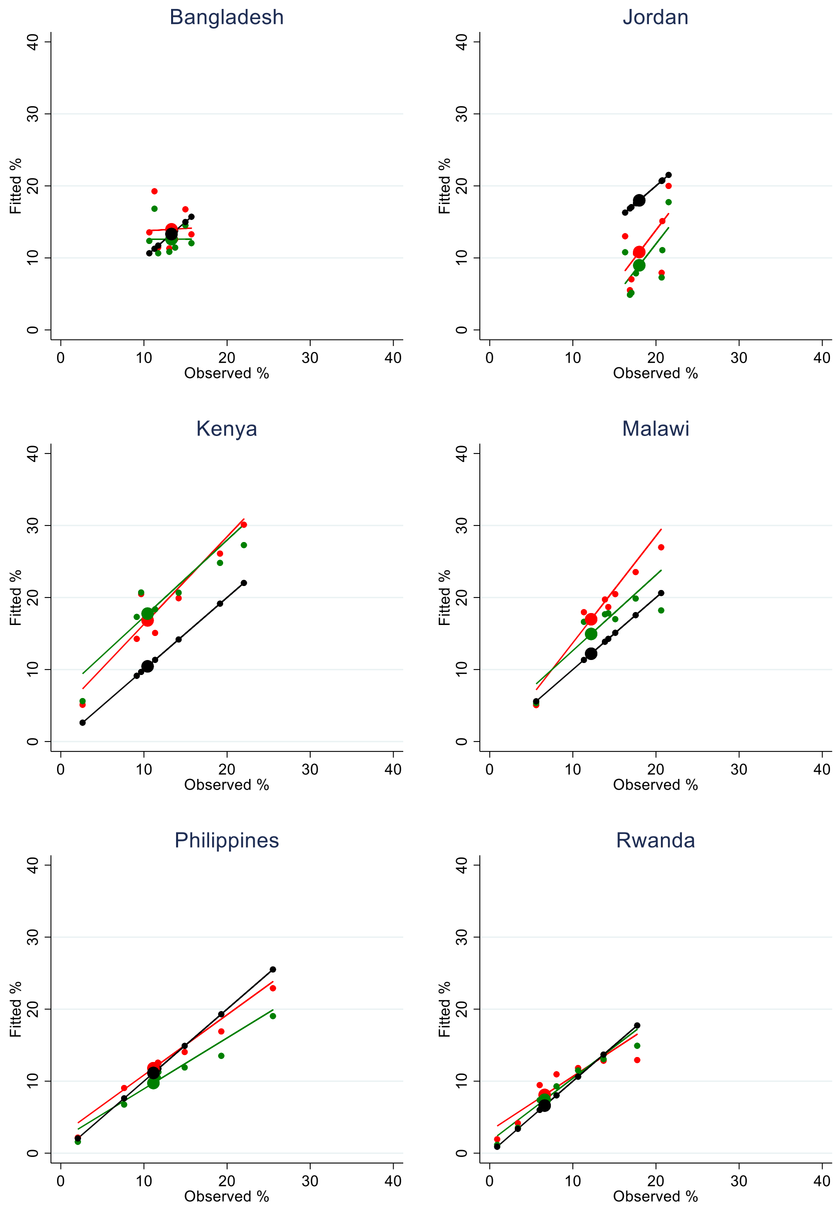
Appendix A1 Figures for Outcomes, by Country and Age Groups

Figure A1.1 Use of modern contraception: projections in each country, nationally and disaggregated by age



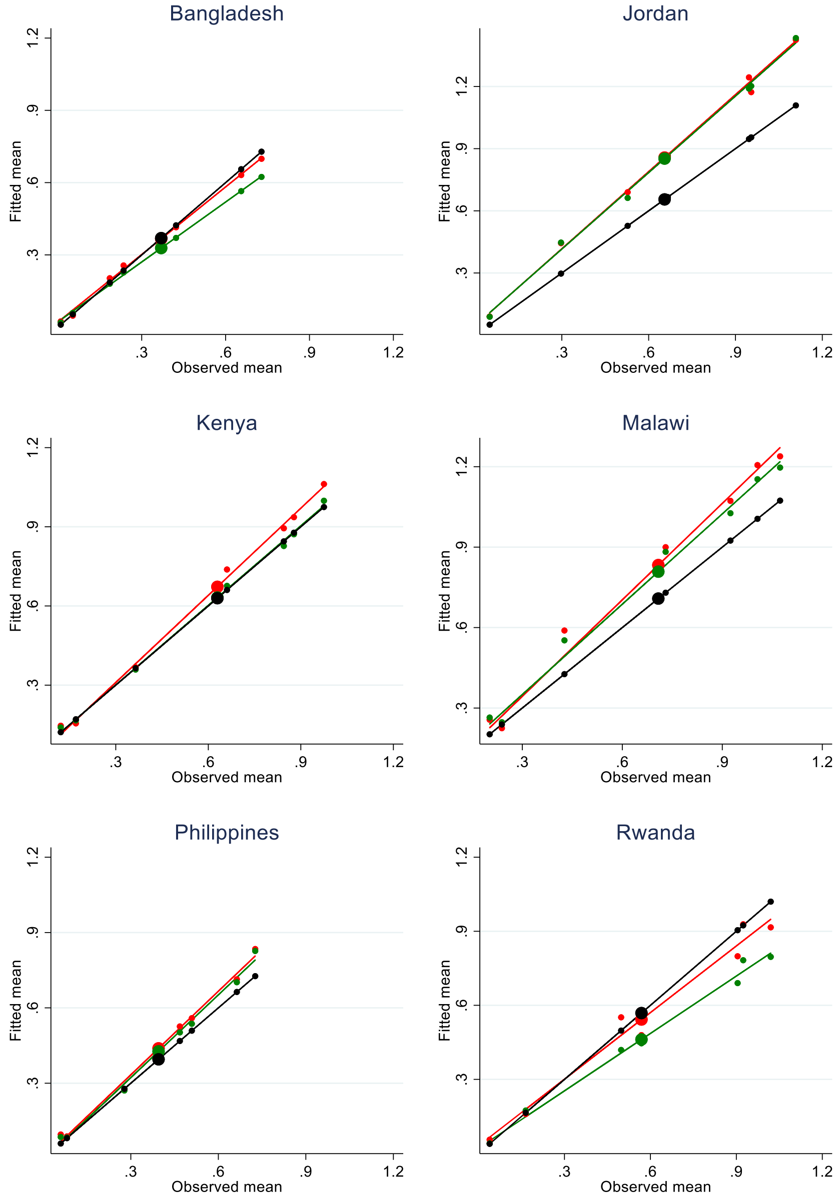
Black: observed; red: first order projection; green: second order projection.

Figure A1.2 Unmet need for family planning: projections in each country, nationally and disaggregated by age



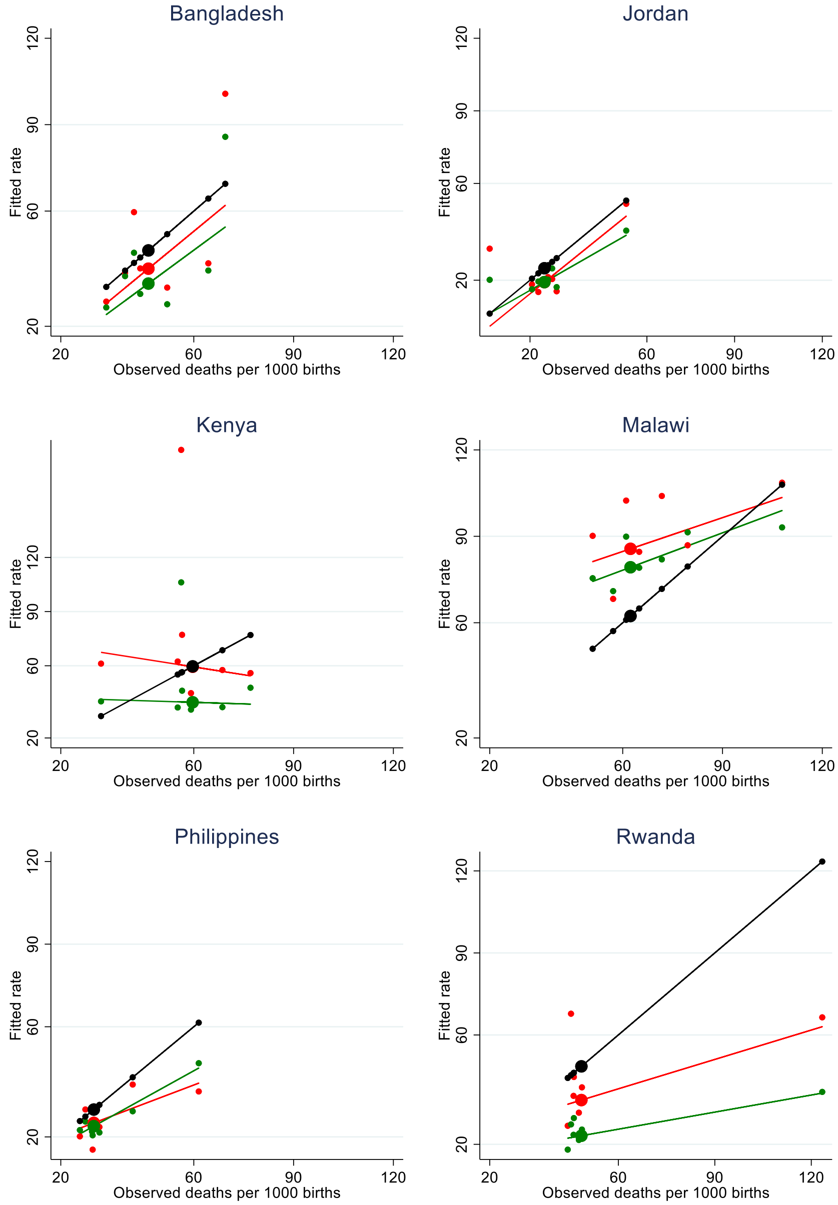
Black: observed; red: first order projection; green: second order projection.

Figure A1.3 Children born in past 5 years: projections in each country, nationally and disaggregated by age



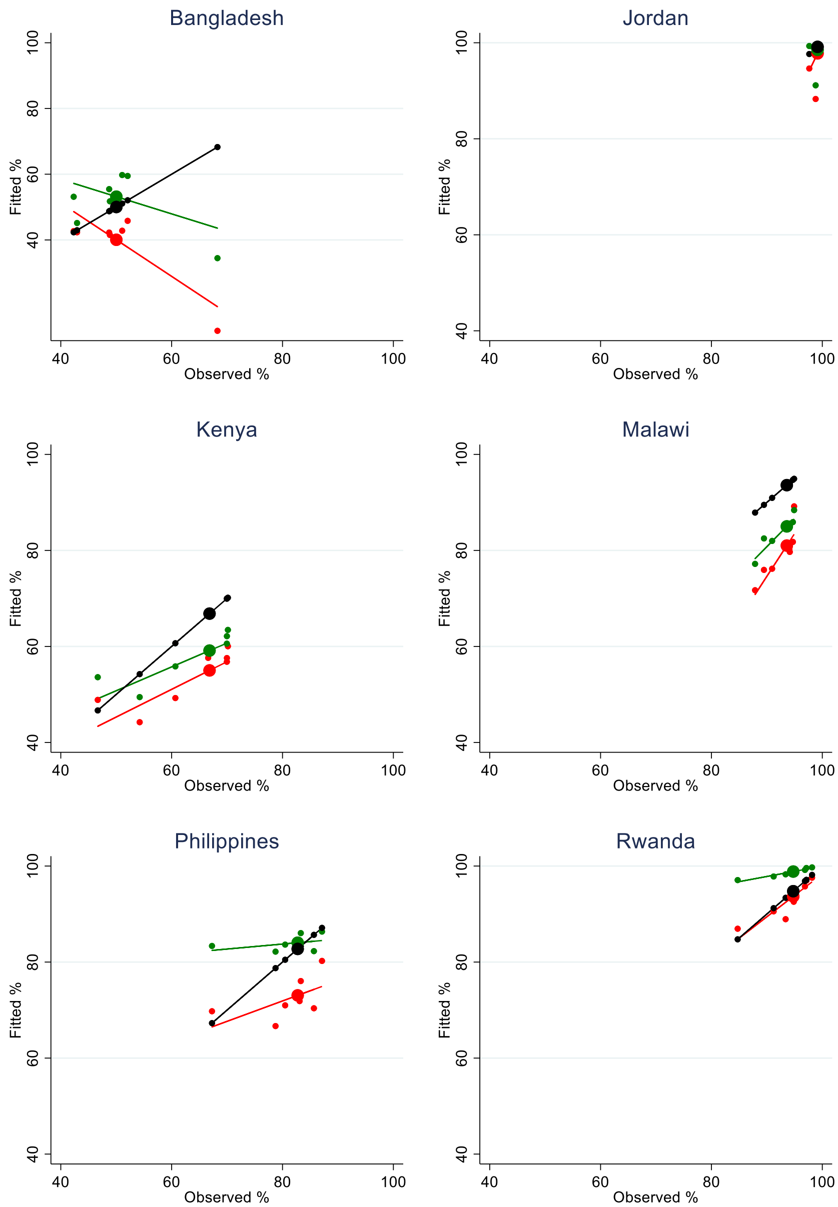
Black: observed; red: first order projection; green: second order projection.

Figure A1.4 Child deaths in past 5 years: projections in each country, nationally and disaggregated by age



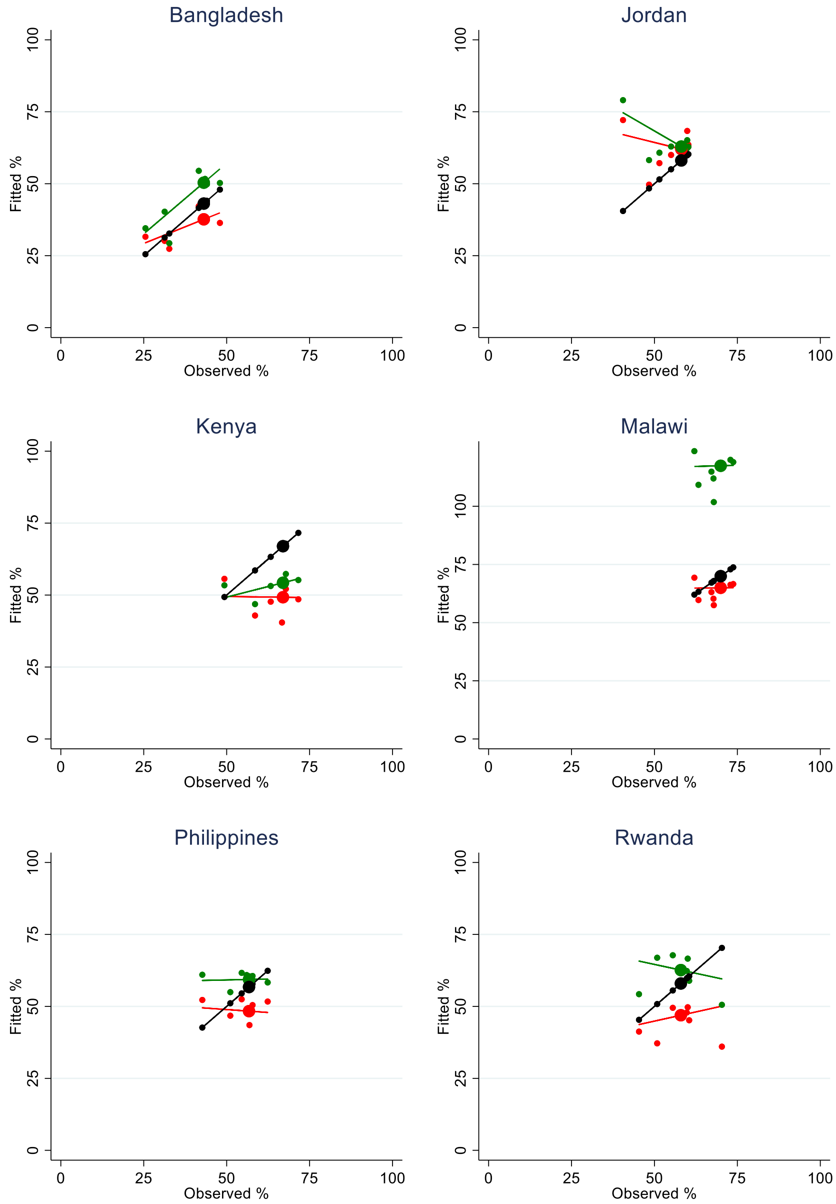
Black: observed; red: first order projection; green: second order projection.

Figure A1.5 Last birth was in a facility: projections in each country, nationally and disaggregated by age



Black: observed; red: first order projection; green: second order projection.

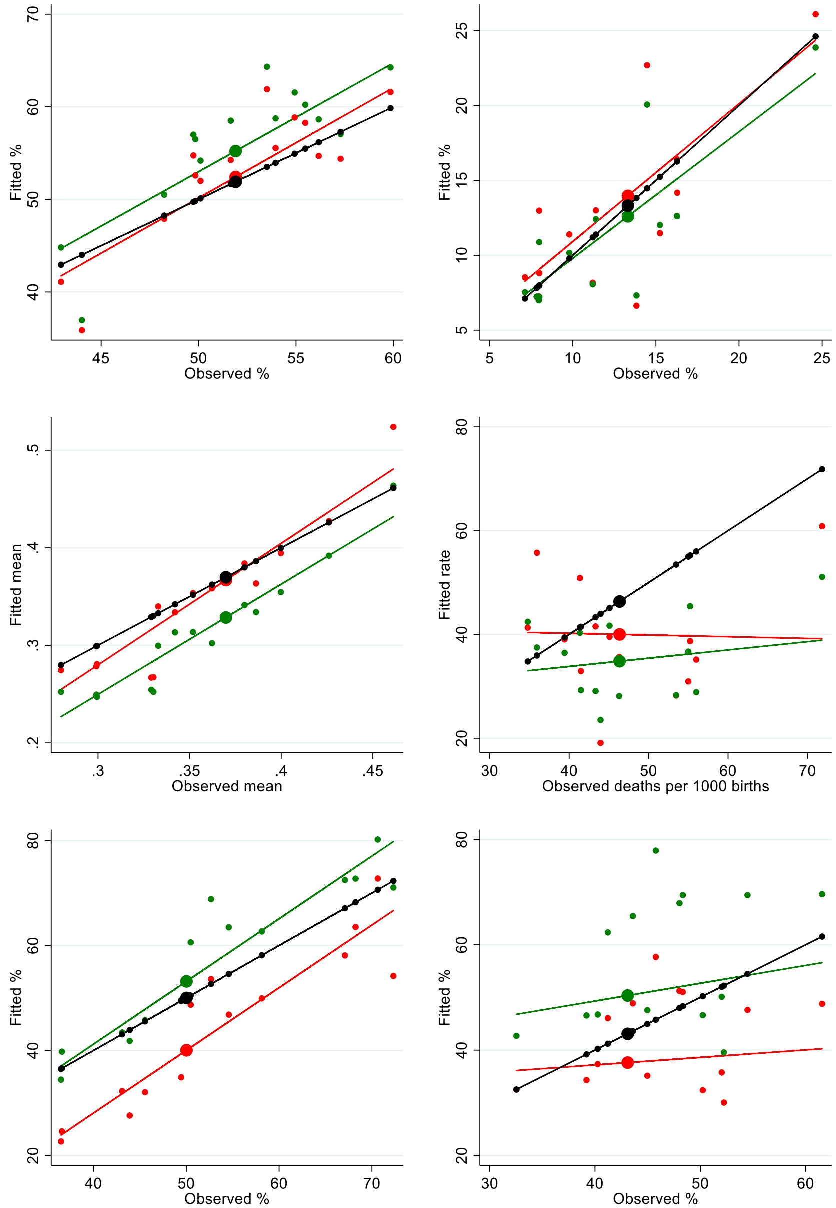
Figure A1.6 Treatment for child illness: projections in each country, nationally and disaggregated by age



Black: observed; red: first order projection; green: second order projection.

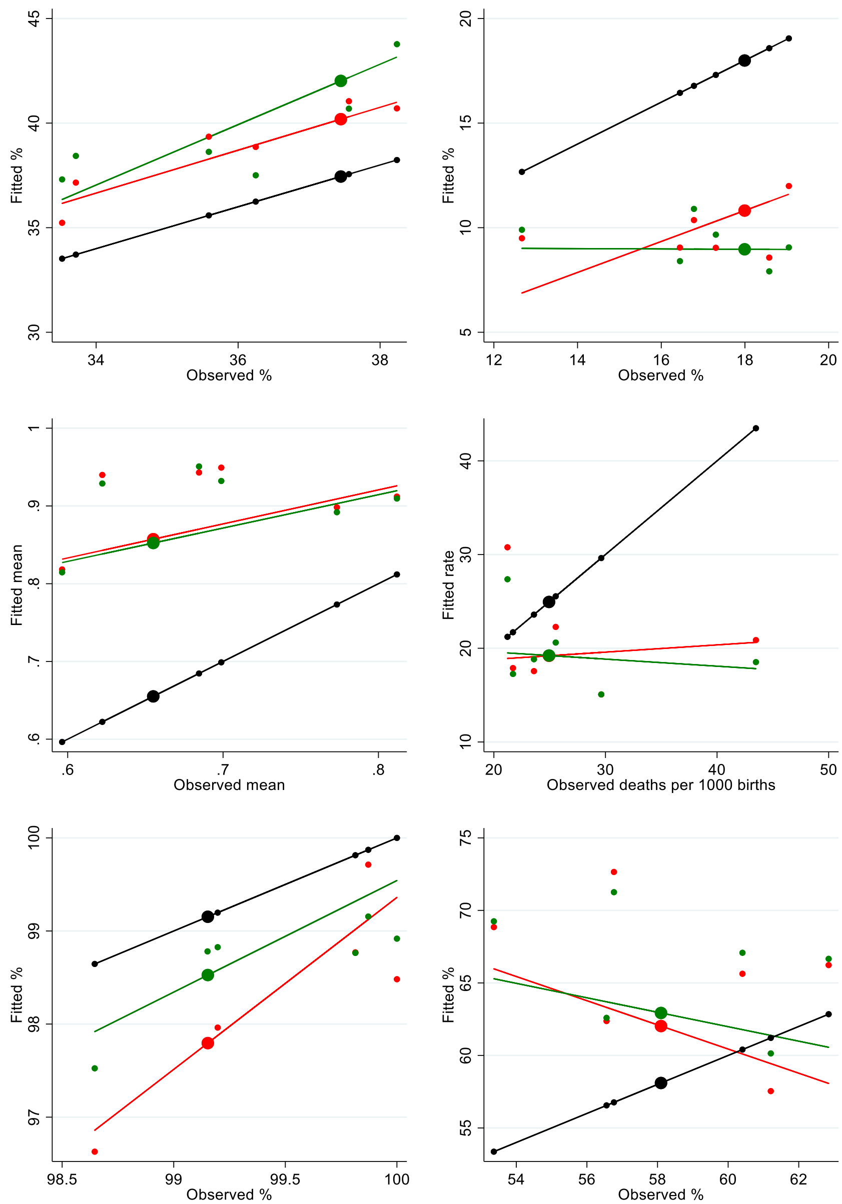
Appendix A2 Figures for Countries, by Outcomes and Strata

Figure A2.1 Bangladesh: projections of each outcome, nationally and disaggregated by strata



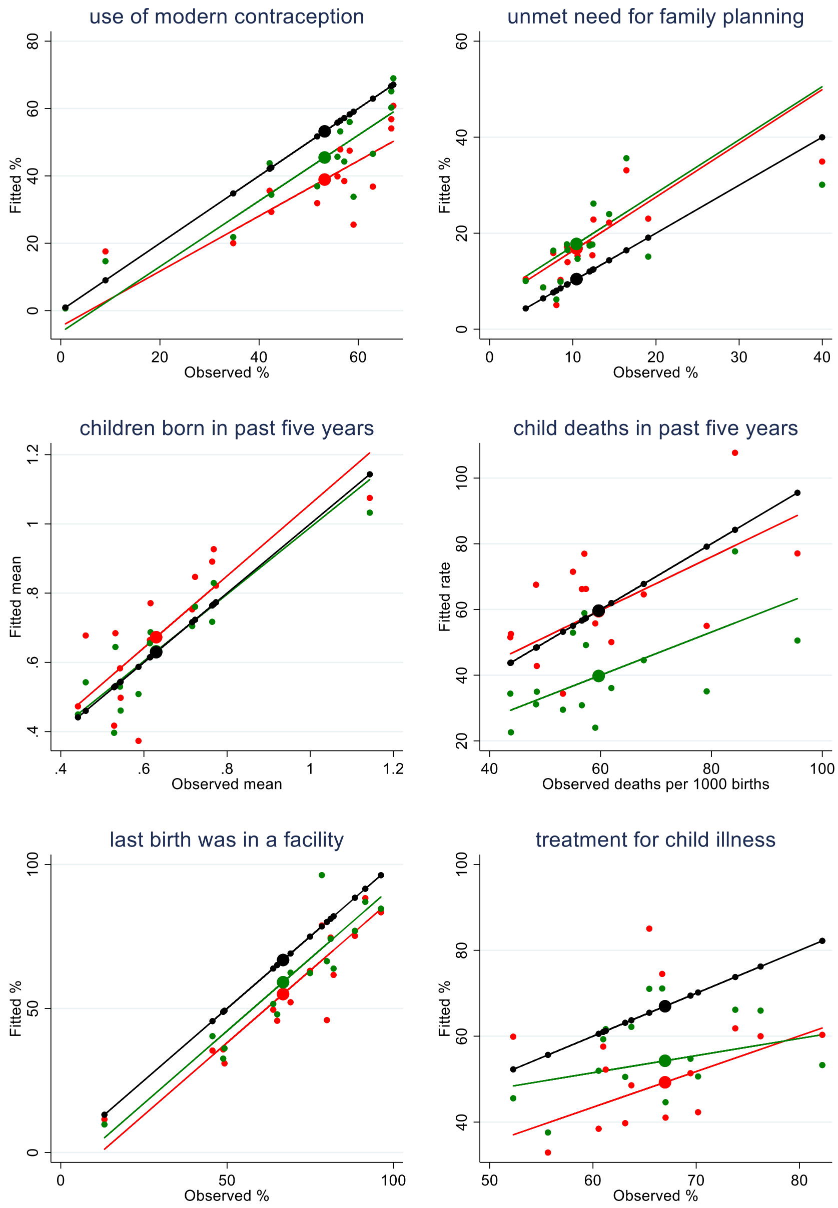
Black: observed; red: first order projection; green: second order projection.

Figure A2.2 Jordan: projections of each outcome, nationally and disaggregated by strata



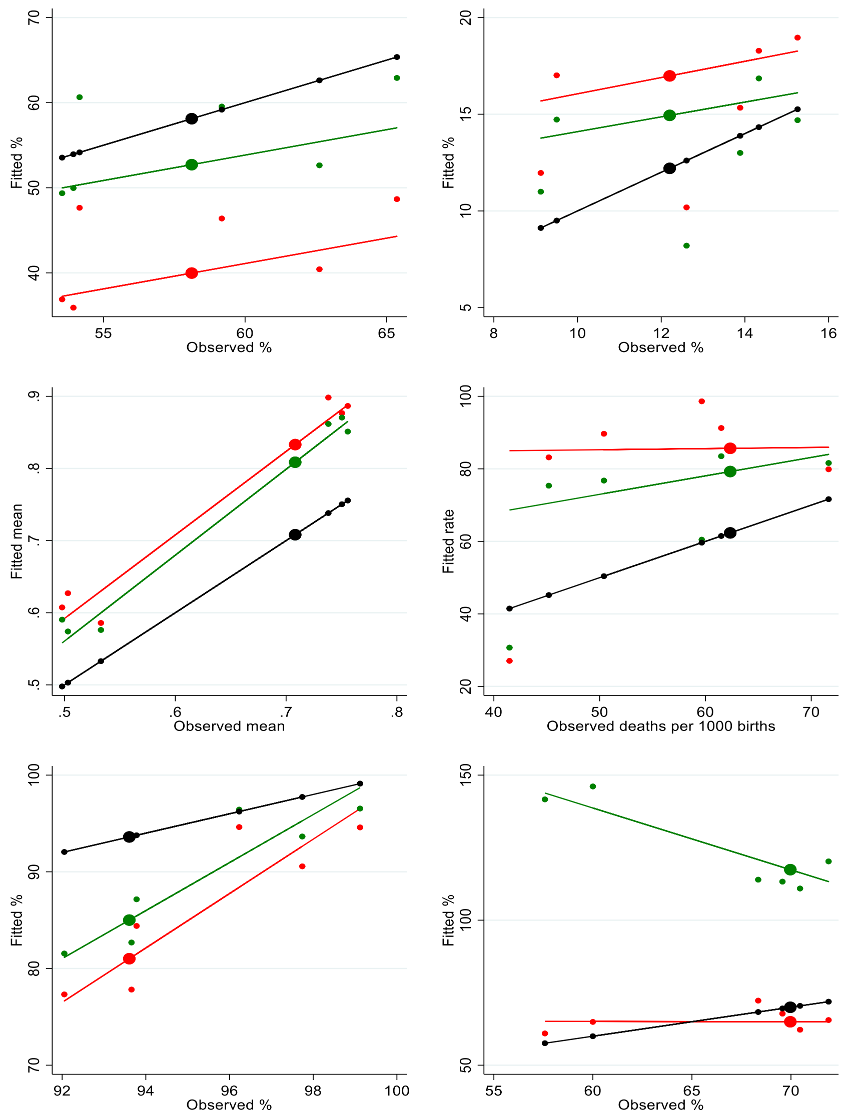
Black: observed; red: first order projection; green: second order projection.

Figure A2.3 Kenya: projections of each outcome, nationally and disaggregated by strata



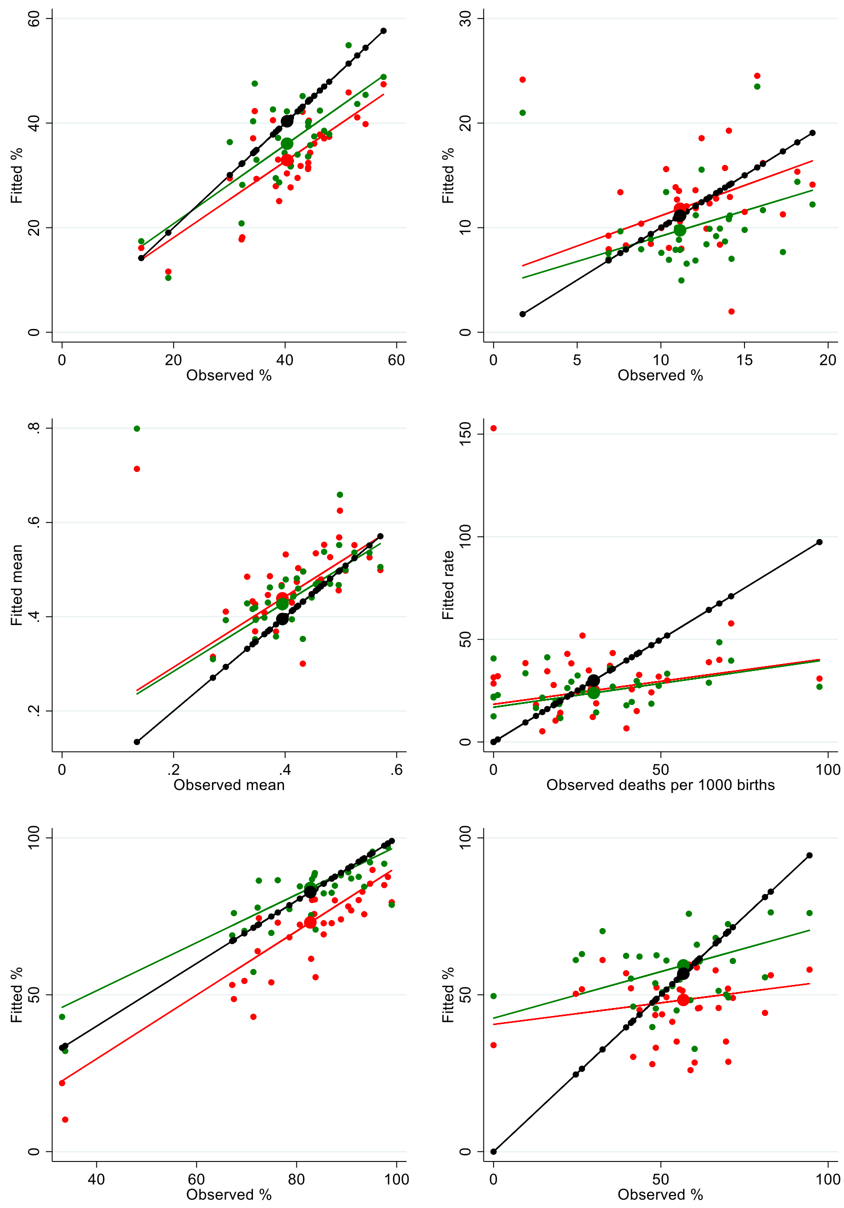
Black: observed; red: first order projection; green: second order projection.

Figure A2.4 Malawi: projections of each outcome, nationally and disaggregated by strata



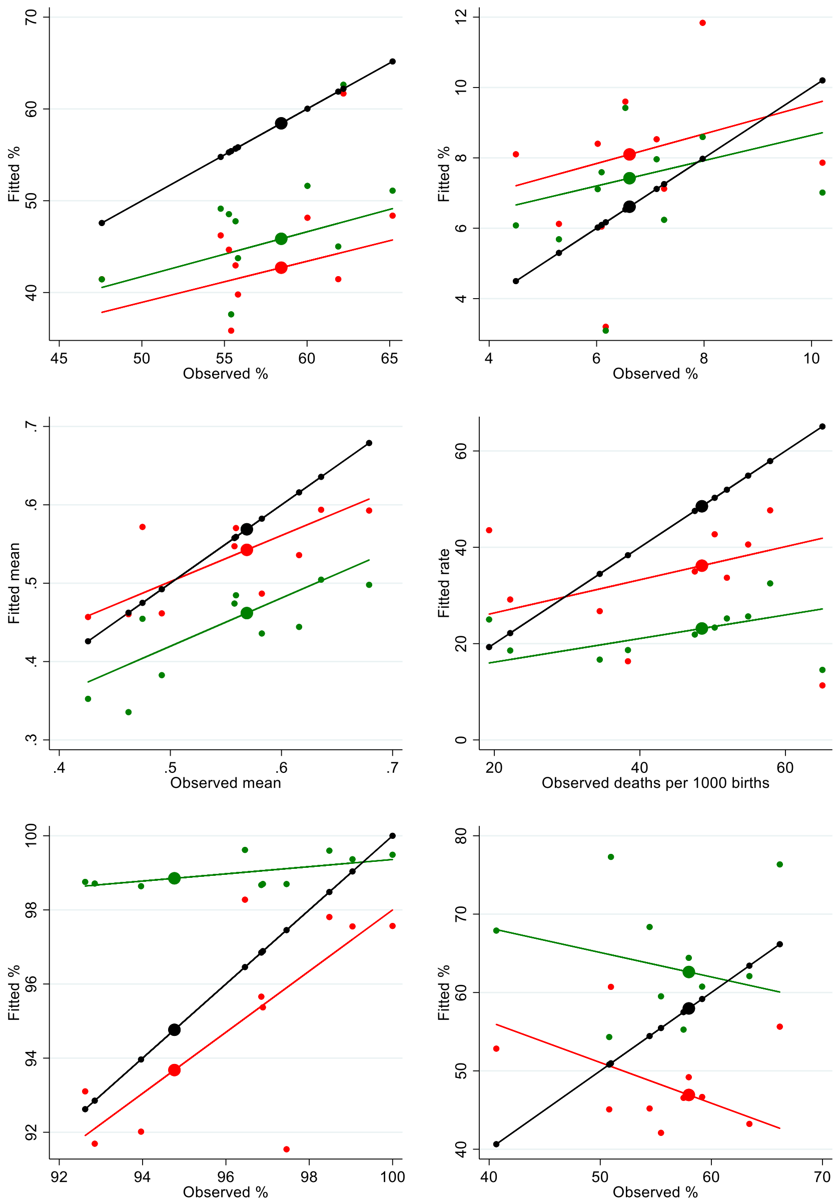
Black: observed; red: first order projection; green: second order projection.

Figure A2.5 Philippines: projections of each outcome, nationally and disaggregated by strata



Black: observed; red: first order projection; green: second order projection.

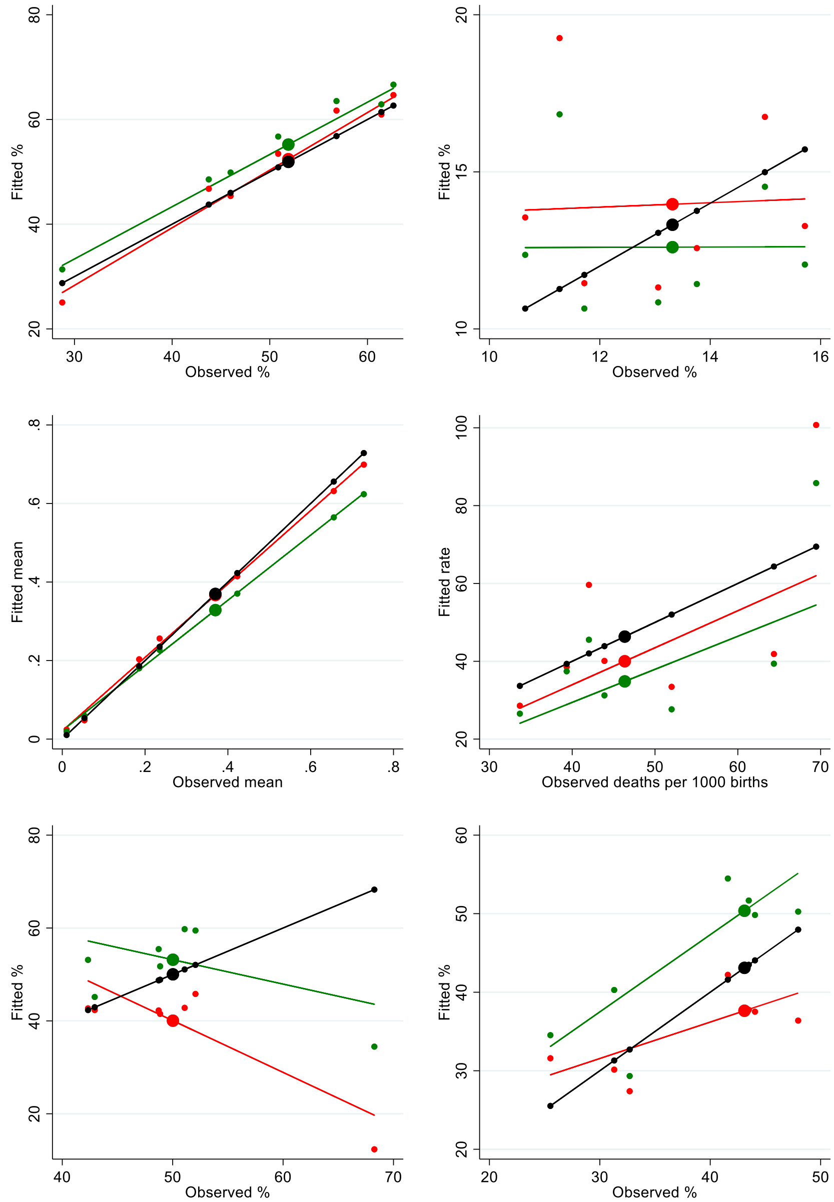
Figure A2.6 Rwanda: projections of each outcome, nationally and disaggregated by strata



Black: observed; red: first order projection; green: second order projection.

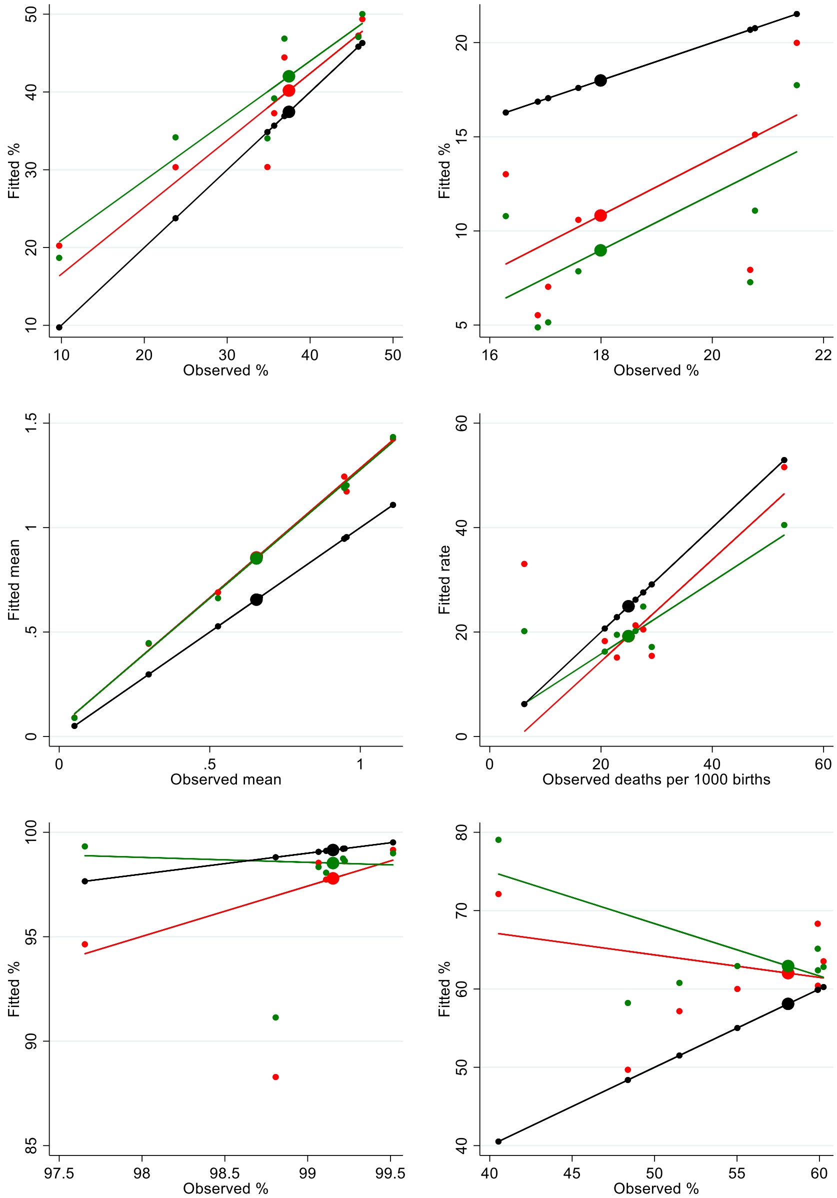
Appendix A3 Figures for Countries, by Outcomes and Age Groups

Figure A3.1 Bangladesh: projections of each outcome, nationally and disaggregated by age



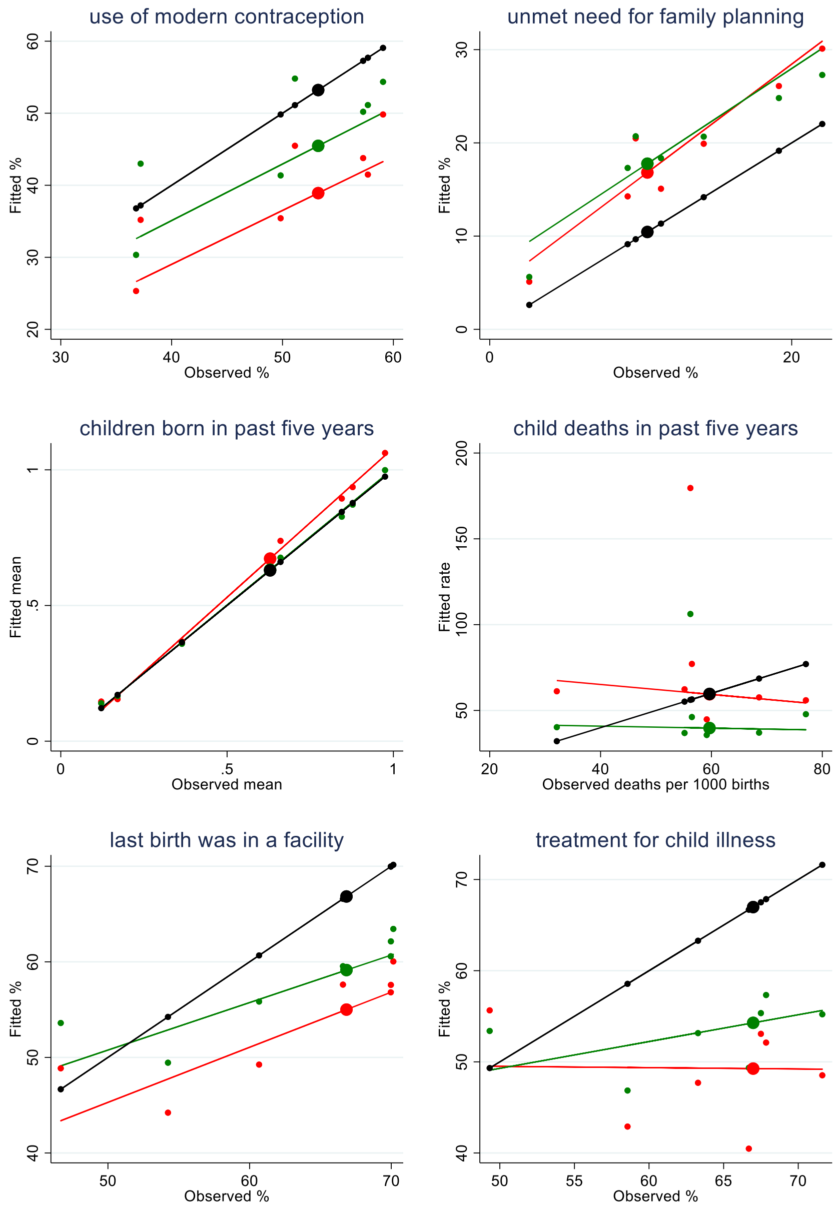
Black: observed; red: first order projection; green: second order projection.

Figure A3.2 Jordan: projections of each outcome, nationally and disaggregated by age



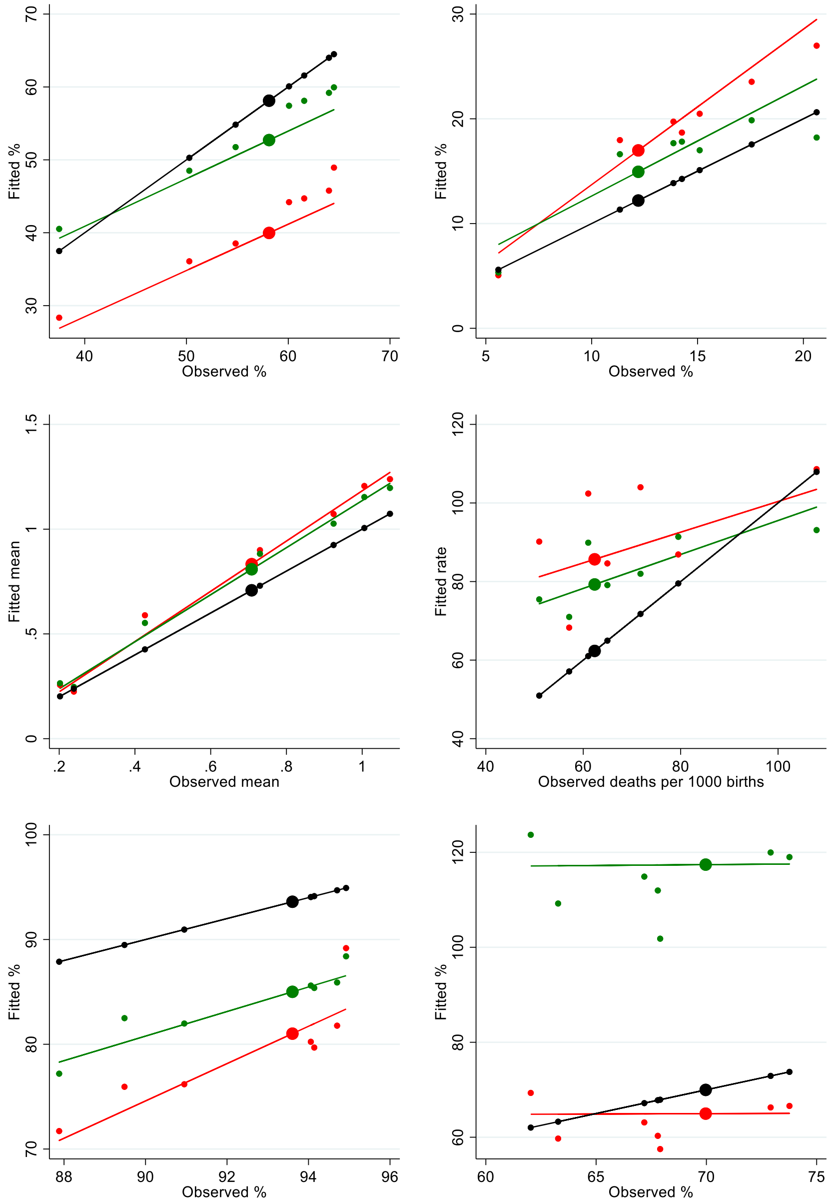
Black: observed; red: first order projection; green: second order projection.

Figure A3.3 Kenya: projections of each outcome, nationally and disaggregated by age



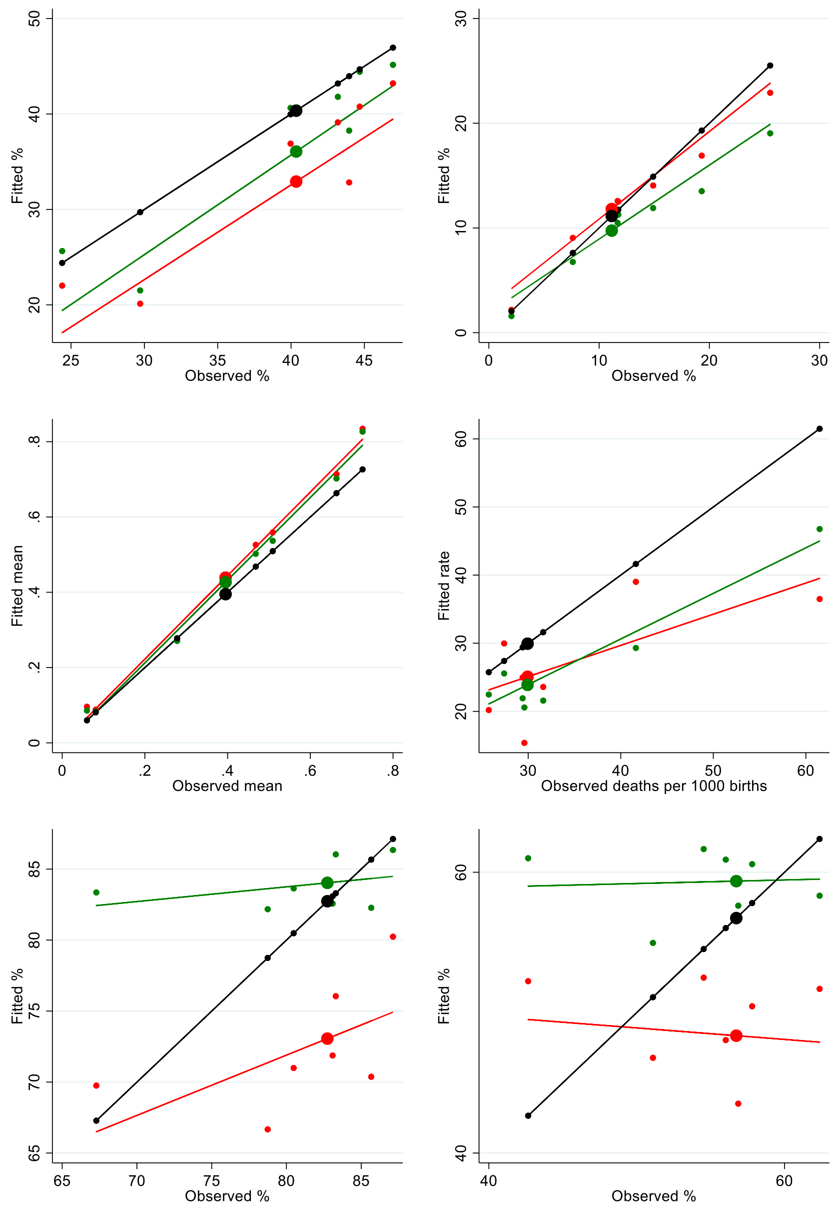
Black: observed; red: first order projection; green: second order projection.

Figure A3.4 Malawi: projections of each outcome, nationally and disaggregated by age



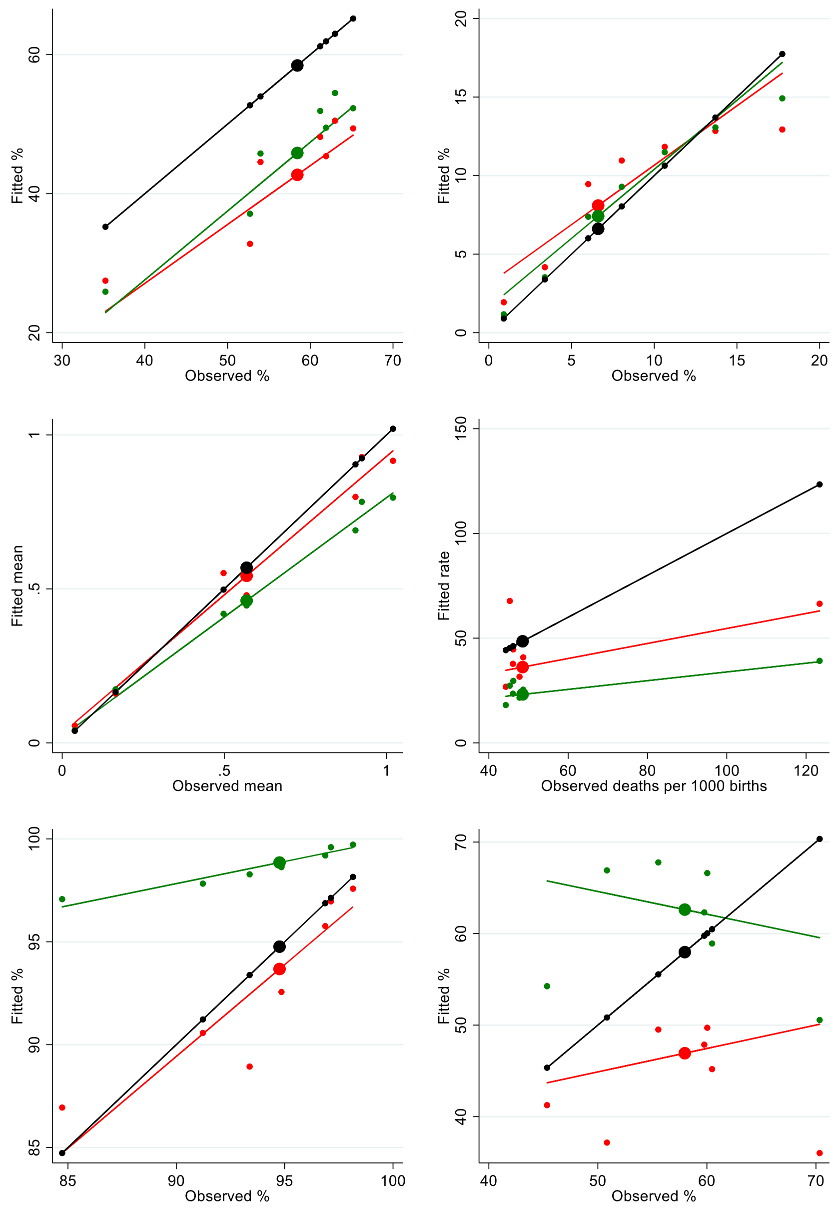
Black: observed; red: first order projection; green: second order projection.

Figure A3.5 Philippines: projections of each outcome, nationally and disaggregated by age



Black: observed; red: first order projection; green: second order projection.

Figure A3.6 Rwanda: projections of each outcome, nationally and disaggregated by age



Black: observed; red: first order projection; green: second order projection.

Appendix A4 Tables Summarizing Model Fit and Deviations

Table A4.1 Projection of use of modern contraception, nationally and disaggregated by strata

Country	Observed	Order	Projected	Tjur coefficient	Pseudo R^2	National deviation	National relative deviation (%)
Bangladesh	51.9	1	52.4	0.0768	0.0688	−0.5	−1.0
Bangladesh	51.9	2	55.2	0.0709	0.0612	−3.3	−6.4
Jordan	37.4	1	40.2	0.0838	0.0690	−2.7	−7.3
Jordan	37.4	2	42.0	0.0812	0.0654	−4.6	−12.2
Kenya	53.2	1	38.9	0.0997	0.1041	14.3	26.9
Kenya	53.2	2	45.5	0.1141	0.1310	7.7	14.6
Malawi	58.1	1	40.0	0.0380	0.0323	18.1	31.2
Malawi	58.1	2	52.7	0.0398	0.0523	5.4	9.3
Philippines	40.4	1	32.9	0.0829	0.0726	7.4	18.4
Philippines	40.4	2	36.1	0.0803	0.0695	4.3	10.6
Rwanda	58.4	1	42.7	0.0388	0.0298	15.7	26.9
Rwanda	58.4	2	45.9	0.0437	0.0411	12.6	21.5

Table A4.2 Projection of unmet need for family planning, nationally and disaggregated by strata

Country	Observed	Order	Projected	Tjur coefficient	Pseudo R^2	National deviation	National relative deviation (%)
Bangladesh	13.3	1	14.0	0.0265	0.0439	–0.7	−4.9
Bangladesh	13.3	2	12.6	0.0250	0.0389	0.7	5.4
Jordan	18.0	1	10.8	0.0070	0.0472	7.2	39.9
Jordan	18.0	2	9.0	0.0056	0.0428	9.0	50.2
Kenya	10.4	1	16.8	0.0909	0.1167	−6.4	−61.1
Kenya	10.4	2	17.8	0.0901	0.1140	−7.3	−70.1
Malawi	12.2	1	17.0	0.0310	0.0631	−4.8	−39.2
Malawi	12.2	2	14.9	0.0238	0.0555	−2.7	−22.4
Philippines	11.1	1	11.8	0.0537	0.0865	−0.7	−6.0
Philippines	11.1	2	9.7	0.0461	0.0945	1.4	12.5
Rwanda	6.6	1	8.1	0.0431	0.0805	−1.5	−22.5
Rwanda	6.6	2	7.4	0.0483	0.1030	−0.8	−12.2

Table A4.3 Projection of children born in past 5 years, nationally and disaggregated by strata

Country	Observed	Order	Projected	Tjur coefficient	Pseudo R^2	National deviation	National relative deviation (%)
Bangladesh	0.37	1	0.37		0.2397	0.0	0.8
Bangladesh	0.37	2	0.33		0.2432	0.0	11.2
Jordan	0.66	1	0.86		0.2856	−0.2	−30.9
Jordan	0.66	2	0.85		0.2728	−0.2	−30.1
Kenya	0.63	1	0.67		0.3123	0.0	−6.9
Kenya	0.63	2	0.63		0.2958	0.0	−0.4
Malawi	0.71	1	0.83		0.2959	−0.1	−17.6
Malawi	0.71	2	0.81		0.2794	−0.1	−14.2
Philippines	0.40	1	0.44		0.2552	0.0	−11.1
Philippines	0.40	2	0.43		0.2633	0.0	−8.0
Rwanda	0.57	1	0.54		0.2999	0.0	4.6
Rwanda	0.57	2	0.46		0.3137	0.1	18.8

Table A4.4 Projection of child deaths in past 5 years, nationally and disaggregated by strata

Country	Observed	Order	Projected	Tjur coefficient	Pseudo R^2	National deviation	National relative deviation (%)
Bangladesh	46.3	1	40.0		0.0291	6.3	13.7
Bangladesh	46.3	2	34.8		0.0209	11.5	24.8
Jordan	24.9	1	19.2		0.0338	5.7	23.0
Jordan	24.9	2	19.2		0.0232	5.7	22.9
Kenya	59.7	1	59.5		0.0638	0.2	0.3
Kenya	59.7	2	39.8		0.0594	19.9	33.3
Malawi	62.3	1	85.7		0.0125	−23.3	−37.4
Malawi	62.3	2	79.3		0.0100	−16.9	−27.1
Philippines	29.9	1	25.1		0.0848	4.9	16.2
Philippines	29.9	2	23.9		0.0516	6.0	20.2
Rwanda	48.5	1	36.2		0.0355	12.3	25.4
Rwanda	48.5	2	23.1		0.0255	25.4	52.3

Table A4.5 Projection of last birth was in a facility, nationally and disaggregated by strata

Country	Observed	Order	Projected	Tjur coefficient	Pseudo R^2	National deviation	National relative deviation (%)
Bangladesh	50.0	1	40.0	0.1955	0.1858	10.0	19.9
Bangladesh	50.0	2	53.2	0.1976	0.2054	−3.1	−6.3
Jordan	99.2	1	97.8	0.0439	0.1004	1.4	1.4
Jordan	99.2	2	98.5	0.0313	0.1070	0.6	0.6
Kenya	66.8	1	55.0	0.3038	0.2319	11.8	17.7
Kenya	66.8	2	59.1	0.3053	0.2227	7.7	11.5
Malawi	93.6	1	81.0	0.0504	0.0634	12.6	13.5
Malawi	93.6	2	85.0	0.0421	0.0744	8.6	9.2
Philippines	82.7	1	73.1	0.2663	0.2116	9.7	11.7
Philippines	82.7	2	84.0	0.2176	0.2549	−1.3	−1.6
Rwanda	94.8	1	93.7	0.0873	0.1066	1.1	1.1
Rwanda	94.8	2	98.9	0.0145	0.1718	−4.1	−4.3

Table A4.6 Projection of treatment for child illness, nationally and disaggregated by strata

Country	Observed	Order	Projected	Tjur coefficient	Pseudo R^2	National deviation	National relative deviation (%)
Bangladesh	43.1	1	37.6		0.0390	5.5	12.7
Bangladesh	43.1	2	50.4		0.0482	−7.3	−16.9
Jordan	58.1	1	62.0		0.0130	−3.9	−6.8
Jordan	58.1	2	62.9		0.0049	−4.8	−8.3
Kenya	67.0	1	49.3		0.0420	17.7	26.5
Kenya	67.0	2	54.3		0.0238	12.7	19.0
Malawi	70.0	1	65.0		0.0091	5.0	7.1
Malawi	70.0	2	117.4		0.0807	−47.4	−67.8
Philippines	56.7	1	48.4		0.0308	8.4	14.8
Philippines	56.7	2	59.4		0.0330	−2.6	−4.6
Rwanda	58.0	1	46.9		0.0266	11.0	19.0
Rwanda	58.0	2	62.6		0.0368	−4.6	−8.0