Some Facts about Boy *vs.* Girl Health Indicators in India: 1992 to 2005

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Abstract

Despite fast rates of economic growth, poor nutritional status and high mortality rates persist among Indian children. We use data from three waves of the Indian National Family and Health Survey to examine gender-specific trends in key indicators of child health between 1992-93 and 2005-06. We find that the most recent changes in indices of nutritional status have been overall similar between genders, reverting a movement towards male advantage observed in the 1990s. However, we also document that improvements in different mortality indices during the period were relatively larger for boys.

Key words: Anemia, Child nutrition, Gender, India, Child Mortality

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1 Introduction

High rates of child malnutrition and disease remain common in developing countries, and are often associated with serious physical, psychological and monetary costs. In addition, a growing body of research documents the importance of infant and child health (and even in utero conditions) for long-term health and other forms of human capital such as schooling or wages (see Glewwe and Miguel 2008 and Strauss and Thomas 2008 for excellent reviews). Given the key role of nutrition as a health input, it is not surprising that several studies have found a strong association between early-life nutrition and health and/or socio-economic status in adulthood. A leading hypothesis is that poor nutrition in utero or during early childhood triggers physiological mechanisms that favor short and medium-term survival at the expense of long-term susceptibility to chronic disease (Barker and Osmond 1986, Godfrey and Barker 2000). Case and Paxson (2008) find that the association between better child nutritional status, as measured by height, and higher-pay jobs in adulthood is largely explained by better cognitive abilities among taller children. Using data from the well-known INCAP study in Guatemala, Hoddinott et al. (2008) show that nutrient supplementation for children up to three years of age was associated with significant increases in child height and, later in life, with higher hourly wages among men.

India, one of the most populous countries in the world, also accounts for a disproportionate share of child malnutrition. Despite the impressive rates of gross domestic product (GDP) growth achieved during the last two decades, rates of stunting (that is, low height given age), wasting (low weight given height) and underweight (low weight given age) are among the highest in the world, and progress has been slow (Svedberg 2002, Tarozzi and Mahajan 2007, Deaton and Drèze 2009). Estimates from the third round of the National Family and Health Survey (NFHS), conducted in 2005-06, showed that 48% of Indian children below the age of five were stunted, 43% were underweight and 20% were wasted (IIPS 2007). Large parts of India also suffer from extensive presence of bias against girls and women. Several studies have found that the preference for sons is often stronger where the cultural, social, and economic roles of women in society and/or within the household are weaker because, for instance, women are less important as bread earners, dowries are more common, or bequests favor sons over daughters (see, e.g., Miller 1981, Basu 1992, Murthi et al. 1996, and Drèze and Sen 2002 for extensive references). Some key indicators of gender bias have shown no sign of improvements in recent years. Provisional figures from the latest 2011 Census of India show that the sex ratio among children aged 0 to 6 years has continued to decline, following a worrisome long-term trend (John 2011).[1]

Despite the extensive evidence of gender bias, most studies have found mixed or no evidence of gender differences in nutrient intakes and nutritional status (Harriss 1995).[2] Data from the 1992-93 NFHS actually showed that girls had overall better weight and height performances than boys when normalized relative to a reference population of well-fed children (Svedberg 2002, Tarozzi and Mahajan 2007). However, data from the following round of the NFHS, conducted in 1998-99, showed that improvements in weight and height performances relative to 1992-93 were significantly larger for boys than for girls

[1] The provisional figures show a ratio of 914 girls per every 1,000 boys. The figure was 945 in 1991, and 927 in 2001.

[2] A recent exception is Jayachandran and Kuziemko (2010), who find that daughters are on average weaned sooner than sons when they have no older brothers, because parents are more likely to try again for a son.

(Tarozzi and Mahajan 2007). indices of height actually saw a small *decline* among girls in rural areas, while they improved among boys, although not by much. Tarozzi and Mahajan (2007) also show that the gender differences were mostly driven by rural areas of north India, where preference for sons has been historically stronger.

The primary objective of this paper is to update the findings in Tarozzi and Mahajan (2007) using the more recent 2005-06 NFHS data. In particular, we examine whether the movement towards male advantage in height and weight performances observed between 1992-93 and 1998-99 was still ongoing in 2005-06. We show that the answer is no, and that the latest estimates display a very gender-neutral picture of the most commonly used anthropometric indicators.

A second objective is to evaluate gender-specific changes in child hemoglobin levels between 1998-99 and 2005-06 (hemoglobin was not measured in 1992-93). Hemoglobin (Hb) is a protein, contained in the red blood cells, that plays a key role in the energy-producing metabolism. Oxygen binds with hemoglobin and is transported from the lungs to the rest of the body, where it is used to produce energy. Low Hb levels therefore decrease blood oxygen-carrying capacity, are a primary cause of anemia, and can lead to fatigue, reduced child development and increased disease incidence. Low levels of Hb are widespread among the poor, and are often caused by conditions such as iron deficiency anemia (primarily caused by low consumption of meat and fish), high loads of intestinal worms, or frequent exposure to malaria parasites among the others. Earlier studies have found that, despite the reduction in poverty levels in India over the last two decades, low Hb levels remained extremely high among children between 1998-99 and 2005-06 (IIPS 2007). We show that prevalence is similar between genders, and that both genders share the same overall time trends, with small improvements in severe anemia (defined as Hb$<$ 8 grams per deciliter of blood), but also small *worsening* is moderate anemia (Hb$<$ 11 g/dl).[3]

Finally, we use NFHS data on the complete history of live births for all interviewed women to look at gender-specific changes in neonatal, infant, child and under-5 mortality. The higher mortality rates among young girls relative to boys is one of the most visible indicators of gender bias in India (Murthi et al. 1996). We show that all mortality indicators show progress during the years covered by the NFHS, but that improvements were larger among boys.

The paper is organized as follows. The next section describes in detail the data and discusses a number of comparability issues across the three surveys. We then move to the discussion of the results on anthropometric indices (Section 3), hemoglobin levels (Section 4) and mortality rates (5). Section 6 concludes and discusses both limitations of this study and directions for future research.

2 Data and Outcomes

The data used in this paper come from the three Indian National Family and Health Surveys (NFHS) available at the time of writing. The surveys were completed in 1992-93 (NFHS-1), 1998-99 (NFHS-2)

[3] In India, like in many developing countries, anemia rates are significantly higher among women relative to men. However, such gender differences emerge only later in life, while in this paper we focus on children under five years old or younger.

and 2005-06 (NFHS-3). The data include rich household and individual-level information, with a focus on fertility and health-related outcomes of ever married women on fertility age. Records also include weight and height of young children and (in the second and third round) of adults. Each data set is broadly representative of the whole country, and was formed by stratified, two-stage random sampling, with different samples drawn independently in each round. The NFHS are among the largest household surveys in India, and included data from a total of 88,562 households in 1992-93, 92,486 households in 1998-99 and 109,041 households in 2005-06.

The NFHS surveys were conducted by the International Institute for Population Sciences, Mumbai, with financial and technical support from several organizations. Key technical assistance was also provided by Macro International USA, that is primarily responsible for the well-known Demographic and Health Surveys (DHS) conducted in many developing countries worldwide. For this reason, the survey instruments adopted by the NFHS follows the standard DHS format, and also record a complete birth history of the targeted women.

Because the main focus of this paper is on changes in health-related indicators over time, it is crucial that some significant differences in design across the surveys are taken into account. The first survey (NFHS-1) measured weight of all children less than four years old born of ever married women age 13-49. Height was also recorded, but lack of appropriate measuring tools during the first months of the survey (known as 'Phase 1') meant that this indicator is missing for the states of Andhra Pradesh, Himachal Pradesh, Madhya Pradesh, Tamil Nadu, and West Bengal. In contrast, both height and weight were recorded in all states in NFHS-2, but only for the last two births younger than three of ever married women of age 15-49. The two-year increase in the age of the youngest women included in the survey is of small consequence, because the fraction of married women of age 13 and 14 with children in NFHS-1 was very small. However, the change in the age group of the children targeted for measurement is important, because the average anthropometric performance of children is usually strongly associated with age (see Tarozzi and Mahajan 2007, Figure 1). Another difference between the first two waves of NFHS is that the 1998-99 data also include hemoglobin levels (Hb) of both the women and their children (if targeted for anthropometric measurement). Finally, NFHS-3 recorded height, weight and Hb of *all* children younger than five, regardless of birth order, mother's age or marital status.[4]

A separate comparability concern stems from possible *sampling* differences in NFHS-3 relative to the earlier surveys (Irudaya Rayan and James 2008, Deaton and Drèze 2009). Deaton and Drèze (2009) document that cohorts of women who already achieved adult height in NFHS-2 appear to be on average 0.16 cm *taller* in NFHS-3, a finding that cannot be plausibly explained by differential mortality. The authors estimate, however, that the difference is sufficiently small that it may only have had a negligible impact on the observed changes in children's anthropometric outcomes (Deaton and Drèze 2009, p. 53). Hence, in interpreting the results we will ignore this issue.

One final comparability issue is related to the age distribution of children. Even when all the sample differences listed above are dealt with, it is possible that changes in the distribution of anthropometric

[4]In addition, the survey also measured Hb and anthropometric indices of both women and (a sub-sample of) men.

indices are at least partly explained by differences across waves in the distribution of age (in months) within the 0 to 3 year old range among the last two births. This is potentially important, given the pronounced age pattern in anthropometric indices, which on average tend to decline significantly after birth (see Tarozzi and Mahajan 2007, Figure 1). Indeed, although the age distribution of children 0 to 3 is very similar in NFHS-1 and 2, the share of older children is somewhat larger in NFHS-3 (results available upon request). To probe this issue further, we estimated counterfactual rates of underweight, stunting and wasting in NFHS-2 and NFHS-3, assuming that the age-specific rates remain those estimated in NFHS-1, but calculating the overall rates by using the age distributions from the later surveys. Overall, we find that the predicted changes are very small (1.5 pp or less). Changes in the age distribution of 0 to 3 years old do not appear thus to generate a key comparability problem across waves, and we will ignore this issue in the remaining of the paper.

2.1 Anthropometric indices

Most of the results in this paper relate to indices of child weight and height performance that are normalized relative to a reference population. Such indices, usually referred to as z-scores, allow the evaluation of growth performances relative to a reference of well-fed children, and also transform weight and height into units (standard deviations) that are comparable across children of different age and gender. We will then consider z-scores of height conditional on age and gender ('height-for-age', HAZ), weight given age and gender ('weight-for-age', WAZ) and weight given height and gender ('weight-for-height', WHZ). Such indices have been used for decades by researchers interested in evaluating child growth in many countries (Waterlow et al. 1977, WHO Working Group 1986, Gorstein et al. 1994). Because height reflects, together with genetic components, the cumulative impact of nutrition and disease during growth, HAZ is often used as a key indicator of long-term child health. In contrast, WAZ is significantly more responsive to short-term factors, although it cannot distinguish between short but well-fed children and tall, undernourished ones. The preferred indicator of short-term nutritional status is therefore WHZ.

Each NFHS round includes, together with the raw height and weight measures, z-scores for each of the three indices described above. However, the z-scores are not fully comparable across surveys. Both NFHS-1 and 2 calculated the z-scores using child growth references introduced in 1977, and estimated from a population of U.S. children by the Center for Disease Control and prevention and the National Center for Health Statistics. Despite their widespread use, these charts have a number of shortcomings (Kuczmarski et al. 2000). First, they were constructed using a sample of exclusively Caucasian infants from predominantly middle-class families. Second, all younger children belonged to a relatively small community. In addition, successive measurements of sample children were taken at long time interval, and a large number of measured infants were bottle-fed, contrary to World Health Organization (WHO) recommendations. New charts were then developed by the WHO Multicentre Growth Reference Study, using a sample of healthy breastfed infants and young children from Brazil, Ghana, India, Norway, Oman and the United States (World Health Organization 2006). These more recent charts were adopted in

NFHS-3, causing comparisons with z-scores calculated in earlier rounds problematic, because the choice of reference has a significant impact on the estimation of malnutrition rates (see for instance Tarozzi 2008). To restore comparability of the indices among surveys, I therefore re-calculate all z-scores from the raw height, weight and age data, using the more recent WHO charts.[5]

3 Gender-specific Changes in Child Growth Performance

In this section, we look at gender-specific changes over time in the distribution of z-scores. For each of the three indices (WAZ, HAZ and WHZ), we estimate gender and survey-specific densities using standard non-parametric kernel-based estimators. We use a biweight kernel, and choose the bandwidth according to the criterion proposed by Silverman (1986) for approximately normal distributions. For each index, we then calculate the cumulative distribution functions (CDFs) by numerically integrating the densities.[6] We also use the CDFs to estimates gender and round-specific rates of stunting, wasting and underweight, summarized in Figure 1. Following standard terminology, we categorize a child as 'stunted', 'wasted' or 'underweight' when his/her z-score for respectively HAZ, WHZ or WAZ falls below the threshold of -2, while the indices denote 'severe'undernutrition when the z-scores are below -3. For a given index, we also evaluate changes over time by looking at the differences in the CDFs between two NFHS rounds, calculated over the whole relevant range of z-scores. Given two NFHS rounds at times t and $t+1$, we calculate the changes as $CDF_{t+1}(z) - CDF_t(z)$, so that improvement in growth performances are reflected in *negative* differences.

To address the comparability issues described above, and unless indicated otherwise, we will focus on the last two births below the age of 3 years, born of ever married mothers between the age of 15 and 49. We only show aggregate results for the whole of India, excluding only states in Phase 1 of NFHS-1 when data were not available. This choice allows us to ignore factors related to rural-urban or inter-state migration, although it has the drawback of ignoring likely interesting patterns that could emerge from a more disaggregated analysis.

3.1 Height-for-age

We first look at height-for-age, one of the best indicators of cumulative net nutrient intakes. Recall that height was not measured in NFHS-1 in the states of Andhra Pradesh, Himachal Pradesh, Madhya

[5]The z-scores that used the 1977 charts were calculated as simple standardized ratios, using mean and standard deviation of children of the same gender and of the same age (or height) in the reference population. In contrast, the new charts adopt the so-called LMS model (Cole 1988, Cole and Green 1992), which takes explicitly into account the possible non-normal distribution of weight and height in the reference population. In this approach, the z-score for a given anthropometric measure x_{ig} of child i is calculated using mean and standard deviation not of the same measures in the reference group g (defined by gender and either age or height), but of a Box-Cox transformation of the measures (see Box and Cox 1964, or Davidson and MacKinnon 1993, Ch. 14.). The z-score is then calculated as $z_{ig} = [(x_{ig}/M_g)^{L_g} - 1]/(L_g S_g)$ where L_g is the 'power' of the Box-Cox transformation and M_g and S_g are the mean and the standard deviation of the transformed variable in the reference population. Hence, the new charts provide the parameters L_g, M_g and S_g necessary for the calculation of the z-scores.

[6]Given the large sample sizes, all results are substantively very similar if one estimates the CDFs directly from the micro-data. We choose the numerical integration merely because the graphs look smoother.

Pradesh, Tamil Nadu, and West Bengal, which accounted for approximately 25% of the total Indian population.

Growth performances in 1992-93 were strikingly poor, with 55.4% of boys and 51.8% of girls being stunted and 35.5% of boys and 31.7% of girls being severely stunted, see Figure 1. At the beginning of the 1990s, girls were thus doing *better* than boys relative to the new gender-specific growth charts developed by the WHO. These results are consistent with those in Tarozzi and Mahajan (2007), who used the earlier 1977 charts.[7]

The top panel of Figure 2 shows that the WHO 2006 charts confirm one of the key findings in Tarozzi and Mahajan (2007), that is, a small improvement in HAZ for boys between 1992-93 and 1998-99, accompanied by a small *decline* in height performances among girls. Here, we estimate that the proportion of stunted children decreased by 1.3 percentage points (pp) among boys, but increased by 0.8 pp among girls.[8] The bottom panel of Figure 2 shows very different changes between 1998-99 and 2005-06, once again excluding states in Phase 1 of NFHS-1. First, there is no sign that the movement towards a male advantage continued after 1998-99: the changes over time are very similar between genders over the whole range of z-scores, and if anything we find that improvements were marginally larger among girls. Second, child height shows massive improvements over a relatively short period of time: stunting and severe stunting declined by 6.2 and 7.6 pp respectively among boys, and by 6.9 and 8 pp among girls. These large decline in stunting have been documented before (IIPS 2007, Deaton and Drèze 2009), although the gender differences have not been considered in detail. The decline remains very similar when we estimate it including also the states for which height was not recorded in 1992-93 (see Figure 1).

Next, in Figure 3 we show gender-specific densities and CDFs of HAZ including all the available height data from NFHS-3. Note that the population of children described in this graph is not the same as in the previous estimates, because now we include *all* children under the age of five (U5), regardless of their birth order, and regardless of mother's age or marital status. The estimated distribution are strikingly similar between genders, and show that Indian children remain overall very small relative to the reference populations: almost half (48%) of the U5 children in the sample are stunted, and about one quarter are severely stunted (25.7% of boys, and 25% of girls). Still, a key finding is that the remarkable improvements between 1998-99 and 2005-06 were shared by both genders, so that we find no evidence of the continuation of the movement towards male advantage in z-scores documented by Tarozzi and Mahajan (2007) between the first and the second round of the NFHS. When we look at rates of stunting only among children less than three years old for the whole of India (Figure 1), we actually find a small but noticeable return towards *lower* rates of stunting among girls.

[7]For brevity, we omit the gender-specific densities and CDFs from NFHS-1 and NFHS-2. Both are available upon request from the author.

[8]These changes in stunting prevalence are different from those one can calculate from the estimates in Figure 1, because the latter do not exclude Phase 1 states in 1998-99.

3.2 Weight-for-age

Unlike for HAZ and WHZ, the calculation of WAZ does not require height, which was not measured in states surveyed during the 'Phase 1' of NFHS-1. For this outcome, we therefore look at estimates for all India. The summary statistics in Figure 1 show that, for this growth index as well, girls had overall *better* z-scores than boys in 1992-93. The rate of underweight at the time was 47.3% among girls, and 52% among boys, while severe underweight was respectively 23.2 and 26%.

In the short six-year interval between NFHS-1 and NFHS-2, underweight declined considerably, although it did so significantly more for boys than for girls (Figure 4, top panel). This finding was already highlighted by Tarozzi and Mahajan (2007), although they used the earlier 1977 reference charts. While underweight and severe underweight declined by 7.2 and 5.2 pp respectively among boys, the declines were less than half as large among girls (3.3 and 2.2 pps).

In contrast, the bottom panel of Figure 4 shows that, like for HAZ, the next six years saw a reversion of this movement towards male advantage in z-scores. The changes in CDFs actually show that, while improvements among less than 3 years old girls between NFHS-2 and NFHS-3 were similar to those observed in the previous time interval, the change was strikingly smaller among boys. Underweight and severe underweight declined by 2.5 and 3.6 pp among female children, but only by 2.2 pp (both measures) among boys. Overall, underweight declined from 52 to 42.6% among boys under three between 1992-93 and 2005-06 (an 18% decline), and it declined from 47.3 to 41.5% among girls (a 12% decline), see Figure 1. Although the relative improvement was larger among boys, the gap is largely explained by the changes between 1992-93 and 1998-99, while the improvements were overall very similar between genders in the following time interval. Like for HAZ, then, we find no evidence of a continuation of the movement towards male advantage in z-scores observed by Tarozzi and Mahajan (2007). When we look at the whole sample of children whose weight was measured in 2005-06 (which includes all U5 regardless of birth order or mother's age or marital status), we see that the WAZ distributions show almost no gender differences (Figure 5).

3.3 Weight-for-Height

We next turn to changes in weight conditional on height, an indicator often used as a measure of short-term nutritional status. Like for HAZ, recall that this index is missing for 1992-93 for the states in Phase I of that survey. Consistent with the results for HAZ and WAZ, the estimates in Figure 1 show that in 1992-93 wasting was widespread, and was *more* so among boys. Rates of wasting were considerably lower than rates of stunting and underweight. This is a common phenomenon in poor countries, where often low weight is compensated by small height. In 1992-93, we estimate that about a quarter of children under three were wasted, and about one in ten was severely wasted. Wasting was 16% more common among boys relative to girls (28.3 vs. 24.3%), while severe wasting was 31% more common (12.7 vs. 9.7%).

The distribution of WHZ in non-Phase I states shows significant improvements between 1992-93 and 1998-99, although such improvements were significantly larger among boys (Figure 6, top panel). This result once again mirrors what found by Tarozzi and Mahajan (2007) using the 1977 reference charts. When we look at the changes between NFHS-2 and 3, we find instead a considerable *worsening* in WHZ (bottom panel). The changes are very similar between genders, although the decline was marginally larger among girls. Even for this index, we find thus that the sharp trend towards male advantage in z-scores observed between NFHS-1 and NFHS-2 almost completely disappeared.

Note that although the change at the bottom of the distribution was moderate, leading to a small increase in wasting, the increase in the proportion of children with WHZ below zero is stark, about 5 pp for both genders. The small increase in wasting (not disaggregated by gender) had also been observed in IIPS (2007) and Deaton and Drèze (2009) for the whole of India, including the states in Phase I of NFHS-1. This worsening in WHZ at the same time of sharp declines in stunting remains a puzzle, more so because Deaton and Drèze (2009) also show that alternative data from the National Nutritional Monitoring Bureau show, during a similar time span, the opposite result of large declines in stunting and small increases in wasting.

When we look at all available data for U5s in 2005-06, we find that the two gender-specific distributions are very close, similar to what we observed for HAZ and WAZ. A worrisome result is that, overall, the prevalence of wasting remained virtually unchanged between 1992-93 and 1998-99, as shown in the bottom row of Figure 1.

4 Hemoglobin Levels and Anemia

Next, we turn to the analysis of child hemoglobin levels (Hb), an important health marker whose deficiency is widespread in developing countries. Newborn infants normally have elevated Hb levels (17-22 g/dl being a normal range). A typical age profile then sees Hb levels rapidly declining (with a normal range of 11-15 g/dl for one-month children) followed usually by a gradual and slow increase after weaning, when food intakes start including iron-rich foods such as fish and meat. Among adults, 11 or 11.5 g/dl are often taken as the threshold below which a person is considered to be 'anemic', although sometimes different thresholds are chosen depending for instance on gender or altitude. In the data, Hb is only available for NFHS-2 and NFHS-3. In addition, in NFHS-2 Hb was measured only for children below three years of age included among the last two births of interviewed ever-married women, while in NFHS-3 blood tests were taken for U5 children more than 6-month old.

In Figure 8 we show non-parametric, locally linear regressions (Fan 1992) of Hb on age (in months), separately by gender and survey round. The data used for this figure include all available data, regardless of birth order or mother's marital status. The shapes of the curves is typical, with Hb declining rapidly after birth, and then increasing slowly after one-two years of age. However, the *levels* of the curves show that on average both boys and girls had very low levels of Hb, to the point that the whole regressions lie underneath the 11 g/dl threshold for children older than three months. Overall, not unlike most of the anthropometric indices discussed earlier, the gender differences do not appear large. Also, Hb levels are *higher* among girls for almost all ages in 1998-99, and for ages 6-25 months in 2005-06.

Another key finding is that there is no apparent improvement in Hb between the two survey rounds. On the contrary, over the overlapping age range, there is some evidence of *lower* Hb levels in the latest round. An increase in anemia between NFHS-2 and NFHS-3 was indeed documented in IIPS (2007, Table 10.14) together with a decline in severe anemia, although gender-specific estimates had not been highlighted before. Hence, in Figure 9 we look at anemia prevalence, and to ensure comparability we restrict the sample to the last two births of age 6-35 months born of ever married mothers aged 15-49. We define anemia as Hb$<$ 11 g/dl, and we use a threshold of 8 g/dl for severe anemia. The estimates confirm that anemia rates increased, and that the increase affected both genders. Anemia prevalence increased from 73 to 78.5% among girls between the two waves, while among boys the increase was from 74.5 to 79.3%. Similarly, we find that the small decline in severe anemia already highlighted in IIPS (2007) was shared by both girls and boys. Between the two surveys, this indicator declined from 12.2 to 10.8% among girls, and from 14.6 to 12.6% among boys.

A potential concern in comparing anemia rates between NFHS-2 and NFHS-3 is the marked seasonality of hemoglobin levels, which can respond quickly to changes in nutrition or in the epidemiological environment. Indeed, in 1998-99 moderate anemia affects about 80% of children measured between November and March, but only 40-50% between August and October (detailed results are available upon request). On the one hand, comparability issues are reduced by the fact that in both surveys about 90% of child Hb measurements were taken between December and June of the following year. On the other hand, seasonality may have had a non-negligible role because of discrepancies in the timing of the surveys across specific geographical areas.[9]

Unfortunately, the different timing of the geographical coverage of the two surveys means that it is not straightforward to "re-weight" observations to produce counterfactual predictions of what anemia rates would have been if the only difference between surveys had been the different timing of the field work. In fact, in several cases there is no overlap between month-state pairs in NFHS-2 and month-state pairs in NFHS-3. Keeping this caveat in mind, we have constructed such counterfactual rates as follows. In a first step, we regress indicators of severe or moderate anemia on state and month dummies, by gender, using 1998-99 data. In the second step, we calculate predicted values using the estimated coefficients, but with the predictors from 2005-6. These calculations lead to lower estimates of moderate anemia in 2005-06 relative to the unadjusted figures, while rates of severe anemia remain almost identical. Specifically, the counterfactual rates of moderate anemia are 74.1% for boys and 71.3% among girls, as compared to the unadjusted figures of 79.3 and 78.5 respectively. Taken at face value, these estimates would indicate very small improvements in moderate anemia relative to NFHS-2, although the cautionary notes described above need to be taken into account.

In sum, we find scant evidence of improvements in Hb levels between 1998-99 and 2005-06, with some good news only from the bottom tail of the distribution. We also find that changes over time were very similar between genders, and that the differences between boys and girls have remained overall small

[9]For instance, Hb measurements in Uttar Pradesh (the largest Indian state, and one of the poorest) were mostly taken between December and February in NFHS-2, and between December and April in NFHS-3. In Bihar, another large and relatively poor state, most surveys were completed between December and March in NFHS-2, and between April and July in NFHS-3.

and, if anything, show better values among female children.

5 Infant and Child Mortality

All NFHS surveys include, for each woman interviewed, a complete history of births. This allows the estimation of child mortality rates, by gender. We look at four different indicators, that is, neonatal, infant, child and under five (U5) mortality. Neonatal mortality (q_0) is defined as the number of deaths before the first month of life for every 1,000 live births. Infant and U5 mortality ($q_{0,11}$ and $q_{0,59}$ respectively) are the number of deaths before the first or fifth birthday for every 1,000 live births. Finally, child mortality ($q_{12,59}$) is the number of deaths before age five for every 1,000 children who survived at least one year. Mortality rates may be biased by recall errors in births, but confining the focus of the analysis on relatively recent events should limit such concerns. By using information about births that took place approximately in the five years before the interview we also ensure that there is no overlap in the time intervals considered in the three NFHS rounds.

We calculate infant and child mortality rates from sub-group mortality rates.[10] Specifically, let $q_{s,t}$ denote the number of children who die before t months of age, for every 1,000 children who survived up to age $s < t$ months. We estimate infant mortality rates as

$$q_{0,11} = 1 - (1 - q_0)(1 - q_{1,2})(1 - q_{3,5})(1 - q_{6,11}),$$

and child mortality rates as

$$q_{12,59} = 1 - (1 - q_{12,23})(1 - q_{24,35})(1 - q_{36,47})(1 - q_{48,59}).$$

Finally, we calculate U5 mortality as

$$q_{0,59} = 1 - (1 - q_{0,11})(1 - q_{12,59}).$$

The results, displayed in Figure 10, show a number of key patterns. First, all mortality indices show gradual and relatively large improvements over time. Second, despite the improvements, mortality rates remain very high. Third, while neonatal mortality is very similar between genders (and indeed shows a small female advantage), lower mortality rates among boys emerge soon after birth and increase substantially among older children. Let us examine these patterns in some detail.

In 1992-93, 48.2 girls and 48.4 boys died every 1,000 live births. The lower female mortality rates are considered normal in well-off populations, where such differences actually exist among all age groups except the very old. The levels are, however, very high. For perspective, in 2001 neonatal mortality among whites in the United States was 3.8 every 1,000 births, that is, less than one-tenth as large as in India (Elder et al. 2011). Data from NFHS-2 and 3 show marked improvements, so that in the latest round mortality was 38/1,000, still high but about 20% lower than in 1992-93. Note, however, that the very small female advantage has completely disappeared over time.

Further, the data show, within each NFHS round, the emergence of a marked gender difference in mortality among older children, and there is some evidence that the girl disadvantage has increased over time in relative terms. In 1992-93, infant mortality was 77.2 among boys and 79.4 among girls, while in

[10] This is consistent with the methodology adopted in NFHS reports, see e.g. IIPS (2007, p.179).

2005-06, the two figures were 54.4 and 60.4 respectively. On the one hand, this confirms relatively large improvements over time, although infant mortality remains more than 10 times as large as among the high and middle-income countries that are members of the Organization for Economic Co-operation and Development (OECD).[11] On the other hand, mortality declined by 30% among boys, but only by 24% among girls. Hence, the ratio of female to male infant mortality rate increased from 1.03 in 1992-93, to 1.06 in 1998-99, to 1.11 in 2005-06. Similar patterns emerge from the estimates of U5 mortality, although for this index the increase in male advantage is less pronounced. In 1992-93, more than one every ten children died before his/her fifth birthday, with the mortality risk being significantly higher among girls, 120.1 every 1,000 births, vs. 101.6 among boys. By 2005-06, the rates declined to 83.7 among girls (a 30.3% drop) and to 68.3 among boys (a 32.8% drop). The female to male U5 mortality increased then from 1.18 to 1.23 in the 13 years between NFHS-1 and NFHS-3.

6 Conclusions

The Indian economy has seen impressive rates of growth over the last decades. Between 1992 and 2006, GDP per head almost doubled, growing at a compound rate of five percent per year.[12] However, several researchers have documented how these impressive results have been accompanied by disappointing improvements in several key indicators of child health and nutritional status. Data from the 2005-06 Indian National Family and Health Survey (NFHS) show that almost half of children under three years of age were stunted (that is, had low height given age), and almost one in four was severely stunted. Rates of underweight were only slightly lower, while wasting (low weight given height) affected one child every four, with about one child every ten being severely wasted. In addition, almost 80% of these children were anemic. Mortality rates also remained extremely high, and more so among girls. In 2005-06, 84 every 1,000 girls did not survive to age five, while the rate among boys was 68 every 1,000 live births. For comparisons, in 2006 under-five mortality was 10/1000 among OECD countries.

The primary objective of this paper was to evaluate gender-specific trends in indicators of child health using data from three waves of the NFHS, conducted in 1992-93, 1998-99 and 2005-06. A key motivation for this analysis was the unexpected finding, explored in Tarozzi and Mahajan (2007), that indicators of child nutritional status improved significantly more for boys than for girls between 1992-93 and 1998-99. The updated analysis in this paper show that such movement towards male advantage in anthropometric indices did *not* continue between 1998-99 and 2005-06. The overall changes were very similar between genders, including the surprising coexistence of large improvements in height-for-age with much smaller improvements in weight-for-age and a large *worsening* in weight-for-height. The overall trends have been described before (IIPS 2007, Deaton and Drèze 2009), but to the best of our knowledge the separate analysis by gender is new. We also show that boys and girls between 6 and 35 months of age shared

[11] In 2007, infant mortality among OECD countries was 4.9 deaths every 1,000 births, with rates ranging from a high of 20.7 in Turkey to a low of 2 in Iceland. See http://www.oecd.org/infigures.

[12] According to the World Penn Tables (version 7.0), PPP converted GDP per capita (chain series), at 2005 constant prices was 1,401 USD in 1992, and 2,760 USD in 2006 (Heston et al. 2011). The compound rate of growth can then be calculated as $(2760/1401)^{1/14} - 1$.

similar changes in hemoglobin (Hb) levels (a key health indicator) during the time between the two latest NFHS surveys. We observe small *increases* in anemia (low Hb) for both genders, together with small *declines* in severe anemia. The increase in moderate anemia may be partly due to the marked seasonal patterns of this indicator, due to the different timing of the two surveys across Indian states, although the evidence is not conclusive.

Finally, we show that different indicators of child mortality improved over time between 1992-93 and 2005-06, but that improvements were proportionally larger among boys, despite the fact that girl mortality was already higher in 1992-93. Infant mortality (the number of children who do not survive up to one year every 1,000 live births), declined by 30% among boys and only by 24% among girls, leading the female to male infant mortality rate to increase from 1.03 in 1992-93, to 1.06 in 1998-99, and finally to 1.11 in 2005-06. When we look at under-five mortality, the decline between 1992-93 and 2005-06 was 32.8% among boys and 30.3% among girls, leading to an overall increase of the female to male mortality ratio from 1.18 to 1.23 in the 13 years between NFHS-1 and NFHS-3.

While we think that these findings are interesting, much remains to be done. A first limitation of the analysis of this paper is that we do not disaggregate the statistics by geographic area. On the one hand, pooling all data together allows us to ignore issues of inter-state or urban-rural migration but, on the other hand, we ignore the likely existence of interesting geographical patterns in gender-specific changes. Indeed, Tarozzi and Mahajan (2007) showed that the apparent movement toward male advantage in nutritional status that took place between 1992-93 and 1998-99 were largely attributable to North India, an area where preference for sons has been historically strong. A second limitation of our analysis stems from its purely descriptive nature. We do not attempt to uncover the reasons behind the observed trends, including why the gender-specific trends observed between NFHS-1 and NFHS-2 did not continue afterwards. Such causal analysis is beyond the scope of this paper, but we think it remains an important topic of research.

Another key question that remains unanswered is why did short-term and long-term anthropometric indices evolve so differently over time? Data from NFHS show barely any change in HAZ distributions between 1992-93 and 1998-99, while very large improvements were observed in 2005-06. The opposite is true for WHZ, the best indicator of short-term nutritional status among the three anthropometric indices discussed in this paper. Indeed, NFHS data show large improvements in the distribution of WHZ between 1998-99 and 2005-06, but also a sharp *increase* in stunting during the same period. In principle, different changes in stunting *versus* wasting could be rationalized by the fact that WHZ can change quickly with changes in net nutrition, while HAZ is a long-term indicator. To illustrate, consider children below the age of three years measured in NFHS-2. The large reduction in stunting relative to NFHS-1 may have been explained by relatively favorable conditions in the economic and/or disease environment in the months before the survey was conducted. However, if the 2-3 years preceding NFHS-2 had experienced poor conditions, for instance because of widespread droughts due to the failure of the monsoon, good WHZ performances may have coexisted with no improvements in HAZ. Symmetric arguments may help rationalizing the changes between NFHS-2 and NFHS-3.

Data from the Indian Institute of Tropical Meteorology, however, do not lend much support to this hypothesis. In fact, each of the three NFHS waves were conducted during years of relatively 'normal' all-India summer monsoon, defined as periods with rainfall within a 10% band of a secular average. Also, monsoon rainfall during the three years preceding NFHS-1 and NFHS-2 were similarly normal, and each three-year pre-survey period included both above-average and below-average years. The only wave that was preceded by exceptional years was NFHS-3, which was preceded by a droughts both one (2004) and three years earlier (2002, a year of El Niño, with rainfall more than 20% below the long-term average). This latter observation could have thus perhaps explained relatively small improvements in height between NFHS-2 and NFHS-3, but these are not what we observe in the data.

Of course, these considerations may be too broad-brush to reject the hypothesis that contrasting changes in WAZ versus HAZ may be explained by the specific timing of shocks in net nutrition. Studying rigourously this issue would require detailed data on nutrition and diseases environment between conception (and possibly before, given the likely role of maternal health status) and weight/height measurements. Much of this information is missing in the NFHS, but one could conceivably explore this idea making use of the information that does exist on prenatal and child care, including breastfeeding patterns. These data could be bridged with detailed information on rainfall, likely to be especially important in rural areas, and perhaps with National Sample Survey data on consumption patterns. A thorough explanation should also take into account the likely role of fertility responses and changes in child mortality in explaining changes in overall anthropometric indicators. This kind of exploration would be worthwhile, but is beyond the scope of this paper.

To complicate matters, as observed in Deaton and Drèze (2009), the puzzling patterns that emerge from NFHS data are at odds with those observed for U5 children using an alternative data set, collected by the National Nutrition Monitoring Bureau (NNMB) in 1996-97, 2001-02 and 2004-05. The timing of these measurements was close although not identical to those of the NFHS. These data show substantial improvements in stunting during the first period, with an overall decline from 58 to 49% between 1996-97 and 2001-02, but they also show a later *increase* in the rate of stunting, with the index reaching 52% in 2004-05. In contrast, wasting *increased* from 19 to 23% between 1996-97 and 2001-02, and *decreased* considerably to 15% by 2004-05. The patterns are then quite the contrary of what shown using NFHS data. The NNMB sample, unlike NFHS, was not nationally representative, but Deaton and Drèze (2009) show that the overall patterns of changes in the overlapping states remains at odds between the two data sources. Both, however, agree in showing the persistence of poor growth performances among Indian children.

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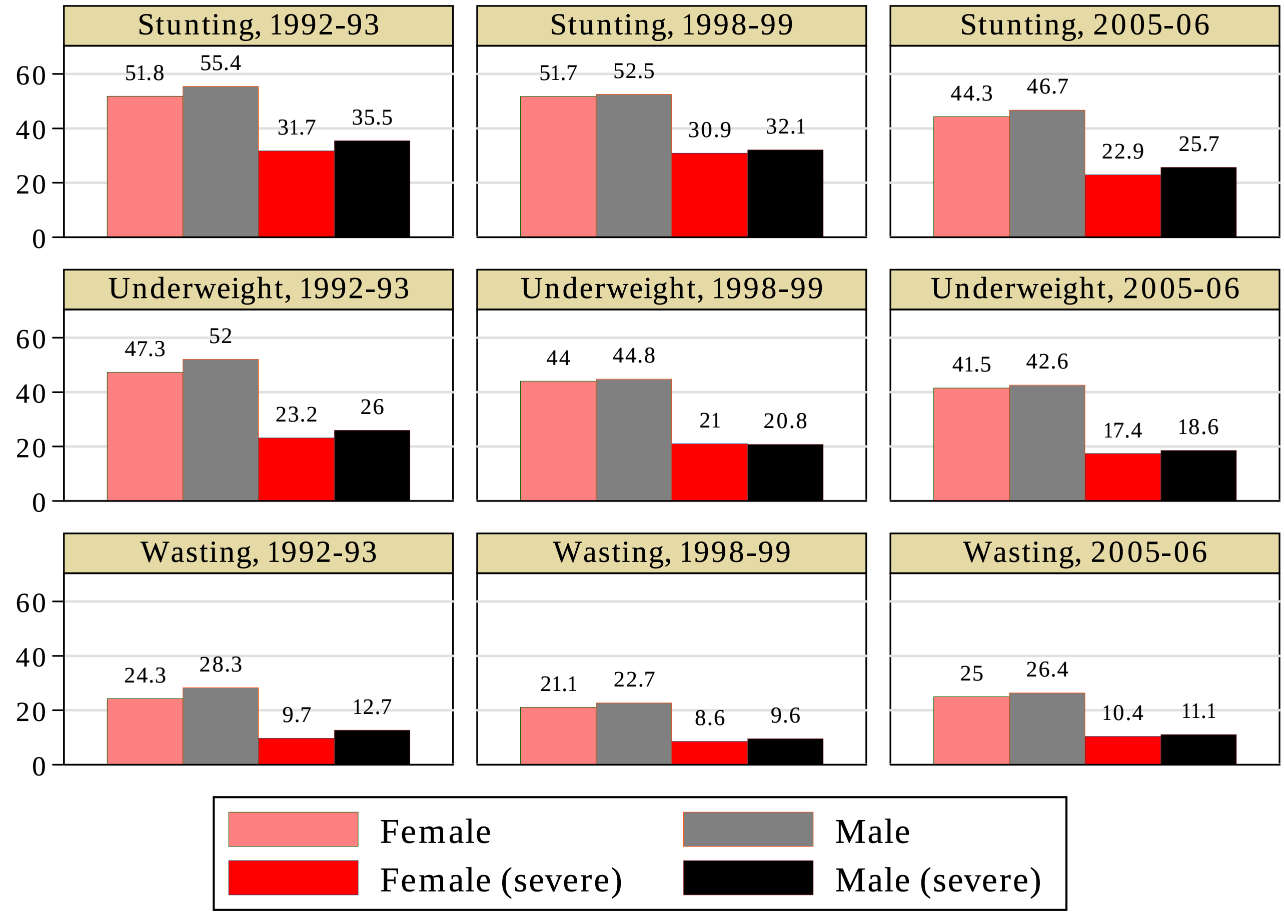

Figure 1: Changes in Stunting, Underweight and Wasting

Source: Author's estimates from NFHS-1, NFHS-2 and NFHS-3. The figures show the gender-specific rates of stunting (HAZ< -2, or < -3 when 'severe'), underweight (WAZ< -2 or < -3) and wasting (WHZ< -2 or < -3) among children less than three years old, born of ever married mothers 15-49 years old. Only the last two births are included. Data from NFHS-1 do not include HAZ and WHZ for Andhra Pradesh, Himachal Pradesh, Madhya Pradesh, Tamil Nadu and West Bengal. All figures are calculated from CDFs obtained by numerical integration of densities estimated non-parametrically using kernel-based estimators (see text for details). The figures obtained directly from the z-score micro-data are almost identical. The z-scores are calculated using the WHO 2006 reference growth charts (see text for details). Note that given the large sample sizes (each bar is estimated with about 10-14,000 observations) the indices are estimated very precisely, with standard errors that remain always well below 1 pp. The full results are available upon request from the author.

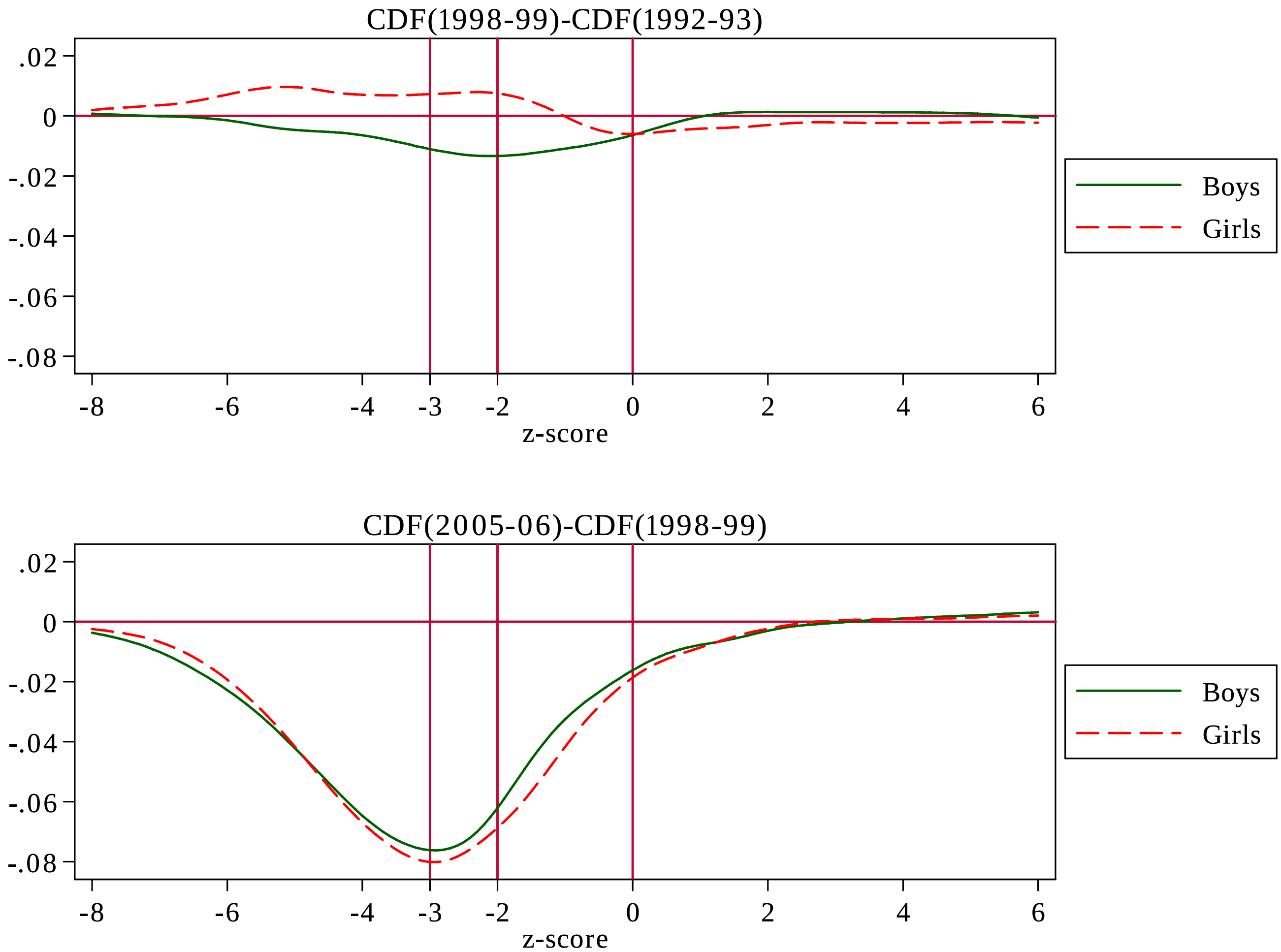

Figure 2: Height-for-age z-scores, Changes

Source: Author's estimates from NFHS-1 (1992-93), NFHS-2 (1998-99) and NFHS-3 (2005-06). Children less than three years old, born of ever married mothers 15-49 years old. Only the last two births are included. Estimates exclude Andhra Pradesh, Himachal Pradesh, Madhya Pradesh, Tamil Nadu and West Bengal, where height was not measured in NFHS-1. The z-scores are calculated using the WHO 2006 reference growth charts (see text for details).

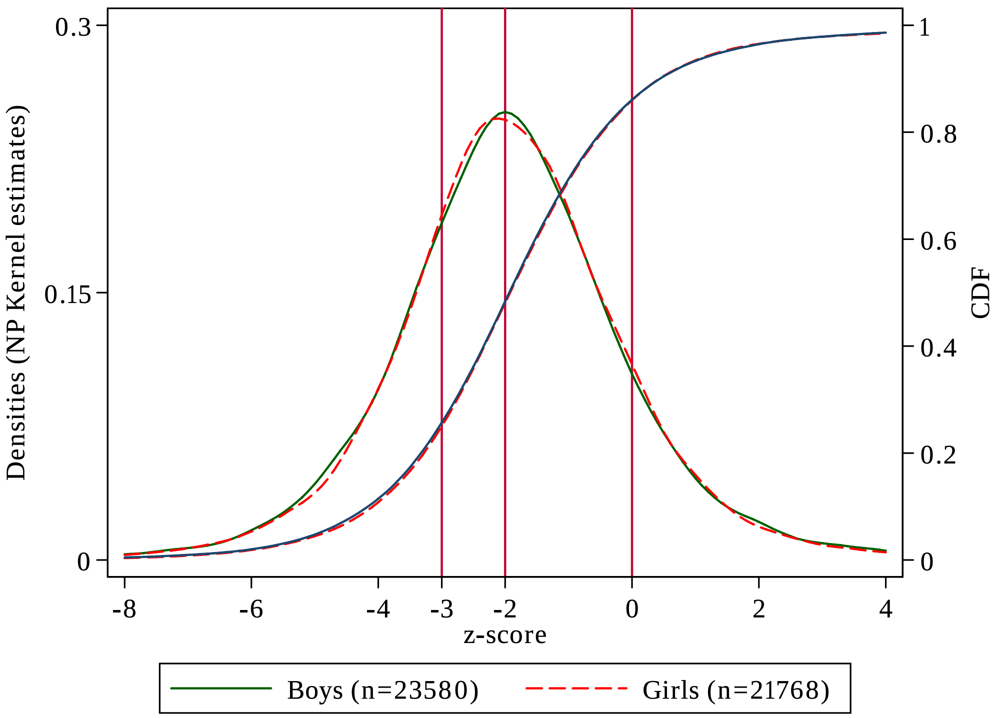

Figure 3: Height-for-age z-scores, NFHS-3 (2005-06)

Source: Author's estimates from NFHS-3 (2005-06). All India. All children under five, regardless of birth order, mother's age and marital status. The densities are estimated using non-parametric kernel-based estimators, with a biweight kernel and the bandwidth chosen using Silverman's criterion for approximately normal distributions. The CDFs are estimated by numerically integrating the densities. The z-scores are calculated using the WHO 2006 reference growth charts (see text for details).

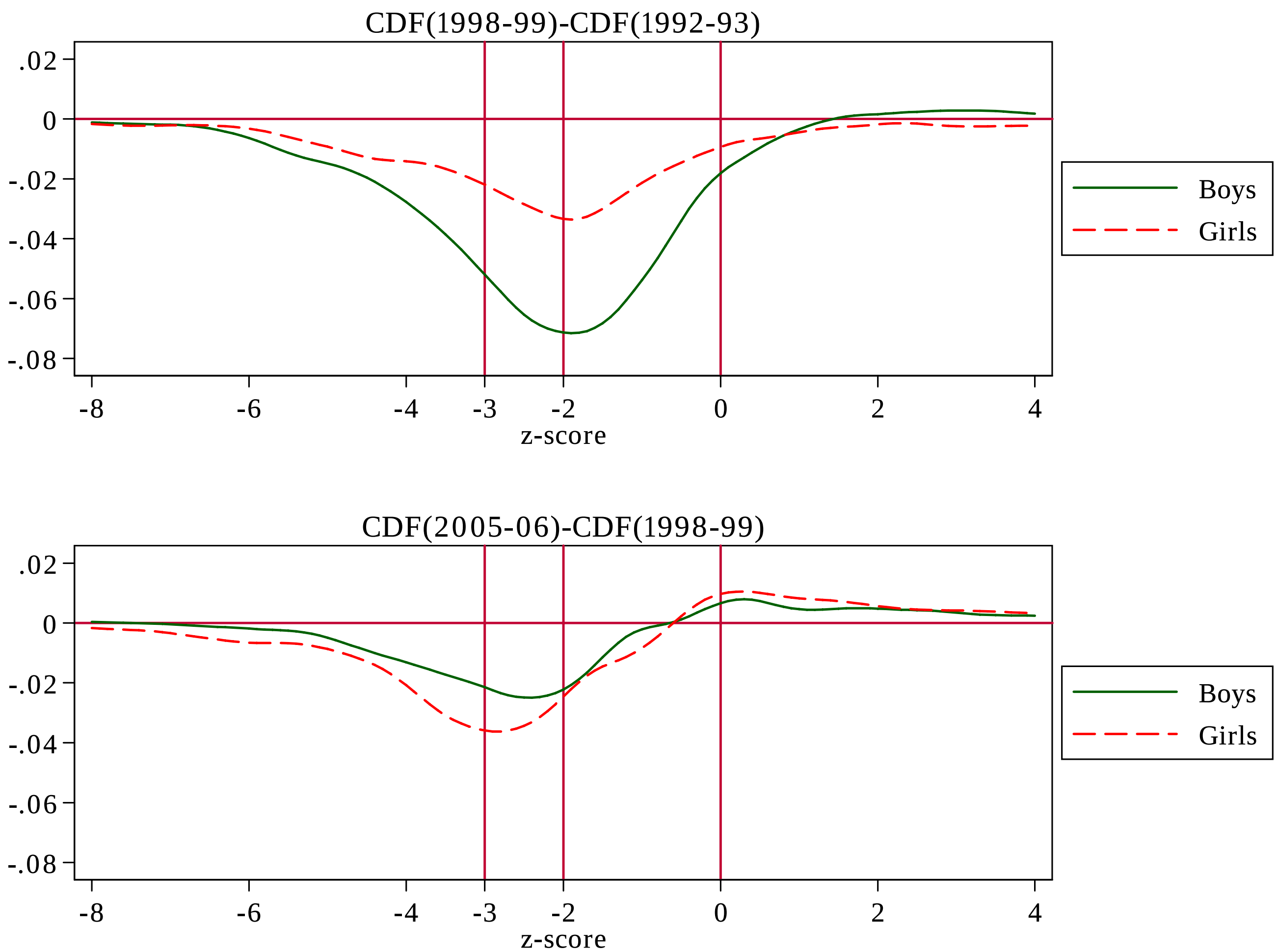

Figure 4: Weight-for-age z-scores, Changes

Source: Author's estimates from NFHS-1 (1992-93), NFHS-2 (1998-99) and NFHS-3 (2005-06). All India. Children less than three years old, born of ever married mothers 15-49 years old. Only the last two births are included. The z-scores are calculated using the WHO 2006 reference growth charts (see text for details).

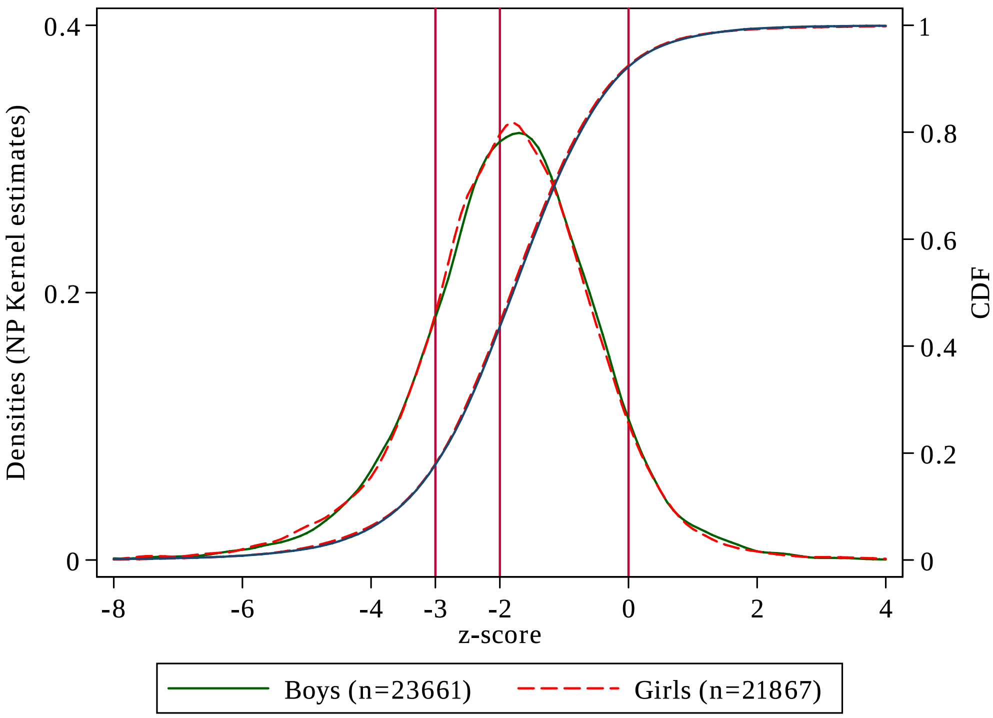

Figure 5: Weight-for-age z-scores, NFHS-3 (2005-06)

Source: Author's estimates from NFHS-3 (2005-06). All India. All children under five, regardless of birth order, mother's age and marital status. The densities are estimated using non-parametric kernel-based estimators, with a biweight kernel and the bandwidth chosen using Silverman's criterion for approximately normal distributions. The CDFs are estimated by numerically integrating the densities. The z-scores are calculated using the WHO 2006 reference growth charts (see text for details).

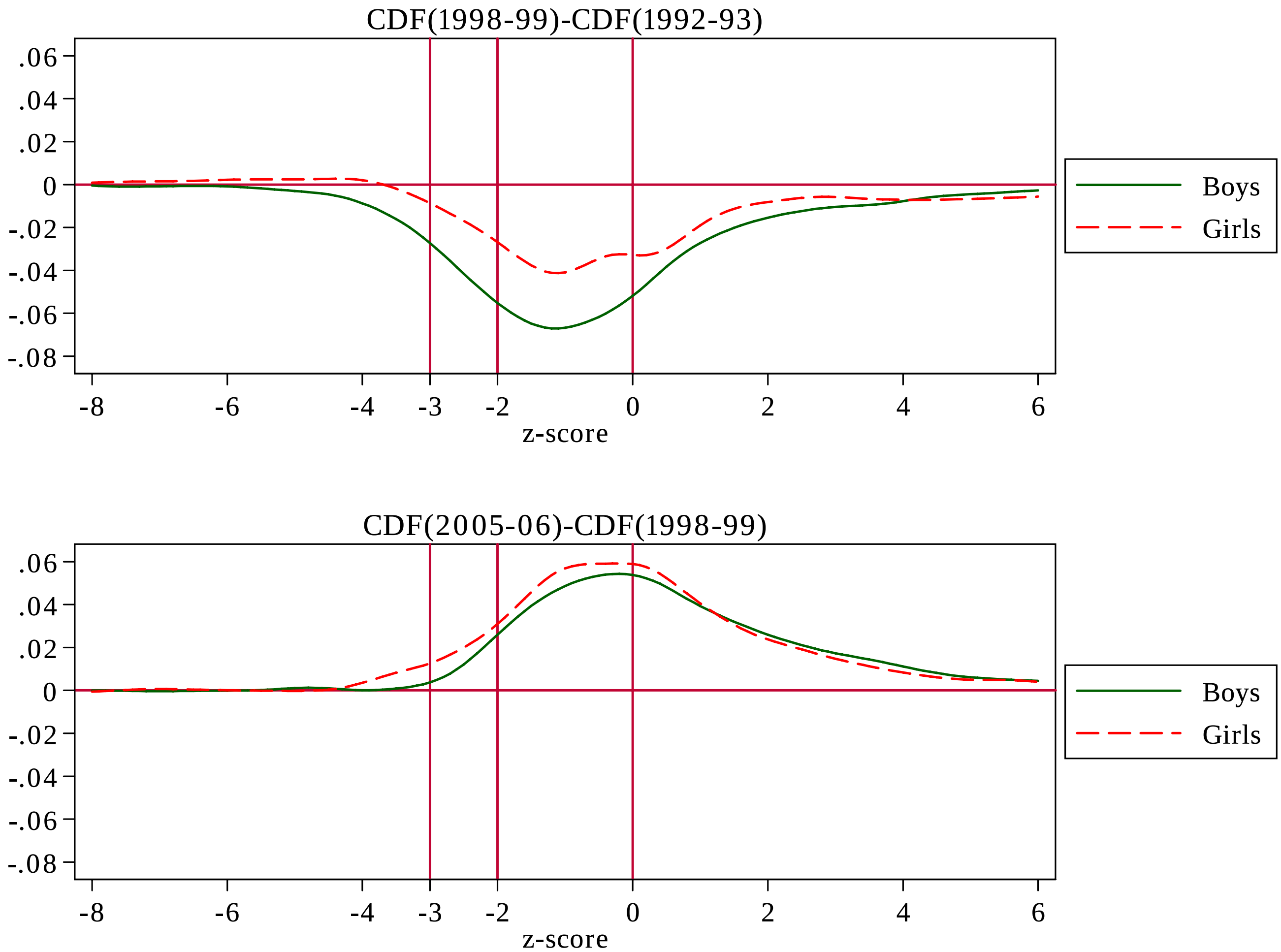

Figure 6: Weight-for-Height z-scores, Changes

Source: Author's estimates from NFHS-1 (1992-93), NFHS-2 (1998-99) and NFHS-3 (2005-06). Children less than three years old, born of ever married mothers 15-49 years old. Only the last two births are included. Estimates exclude Andhra Pradesh, Himachal Pradesh, Madhya Pradesh, Tamil Nadu and West Bengal, where height was not measured in NFHS-1. The z-scores are calculated using the WHO 2006 reference growth charts (see text for details).

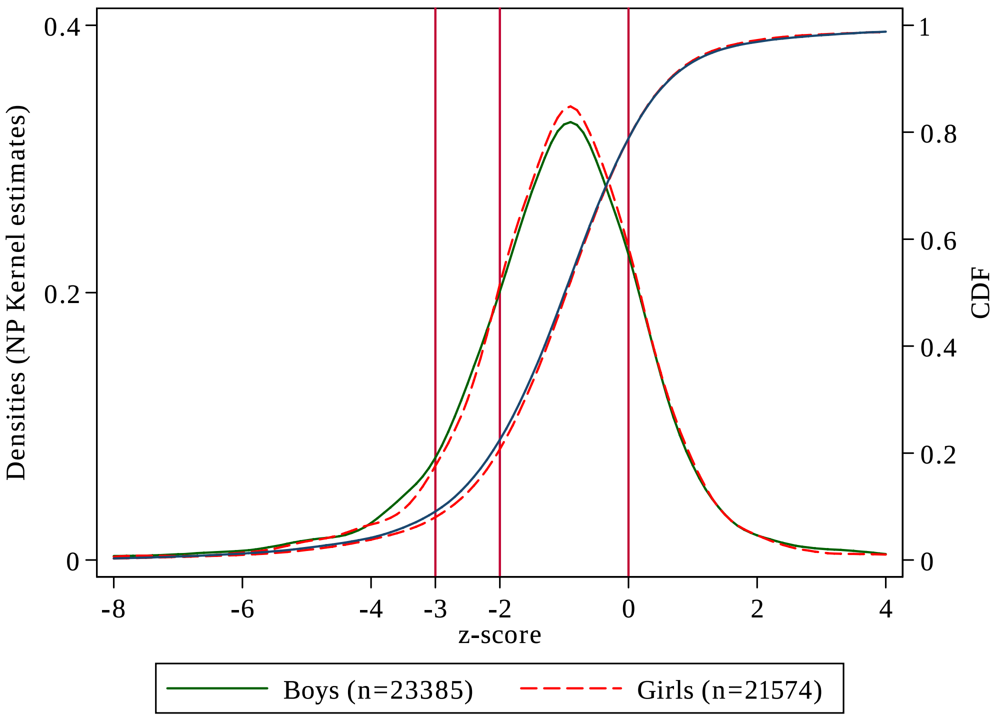

Figure 7: Weight-for-Height z-scores, NFHS-3 (2005-06)

Source: Author's estimates from NFHS-3 (2005-06). All India. All children under five, regardless of birth order, mother's age and marital status. The densities are estimated using non-parametric kernel-based estimators, with a biweight kernel and the bandwidth chosen using Silverman's criterion for approximately normal distributions. The CDFs are estimated by numerically integrating the densities. The z-scores are calculated using the WHO 2006 reference growth charts (see text for details).

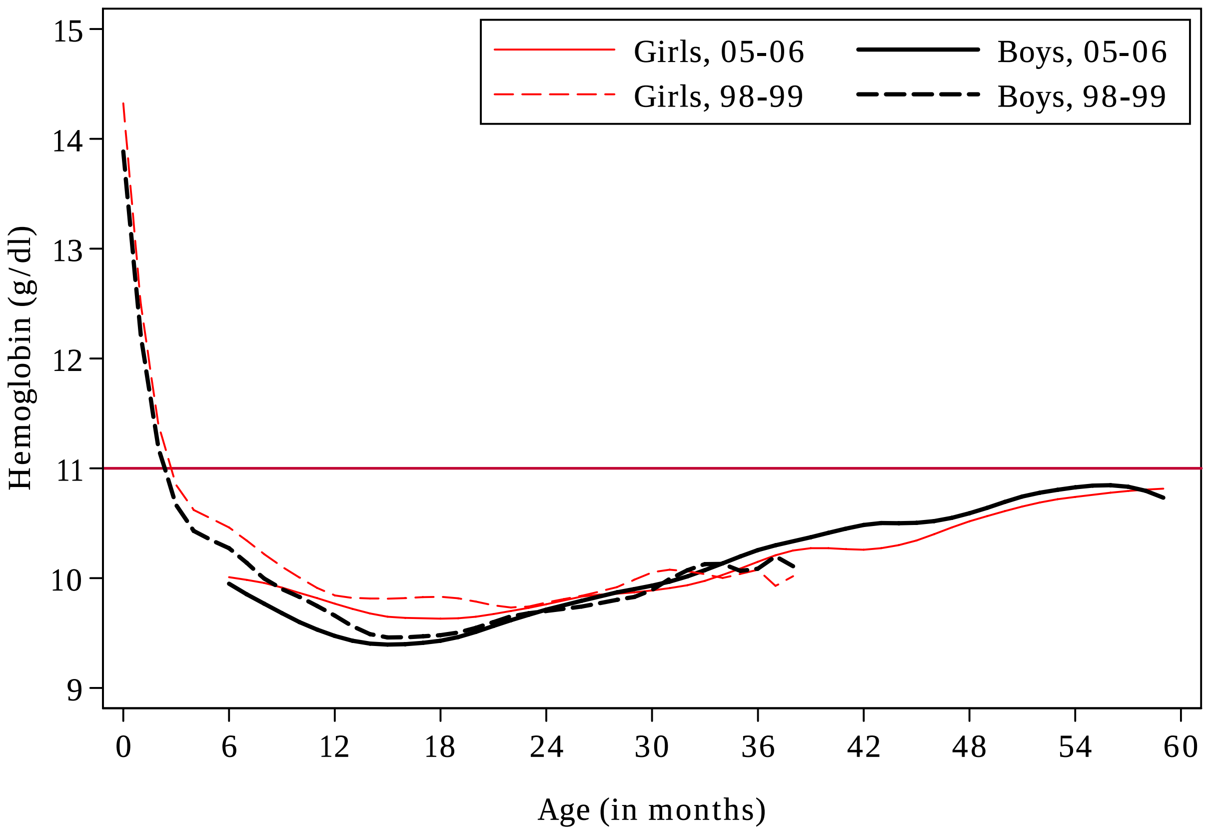

Figure 8: Hemoglobin Levels: by gender, age and survey round

Source: Author's estimates from NFHS-2 (1998-99) and NFHS-3 (2005-06). Hemoglobin is expressed as grams per deciliter of blood. All curves are non-parametric, locally weighted regressions. The horizontal line is drawn at 11 g/dl, sometimes used as a threshold below which non-infants are considered to be anemic.

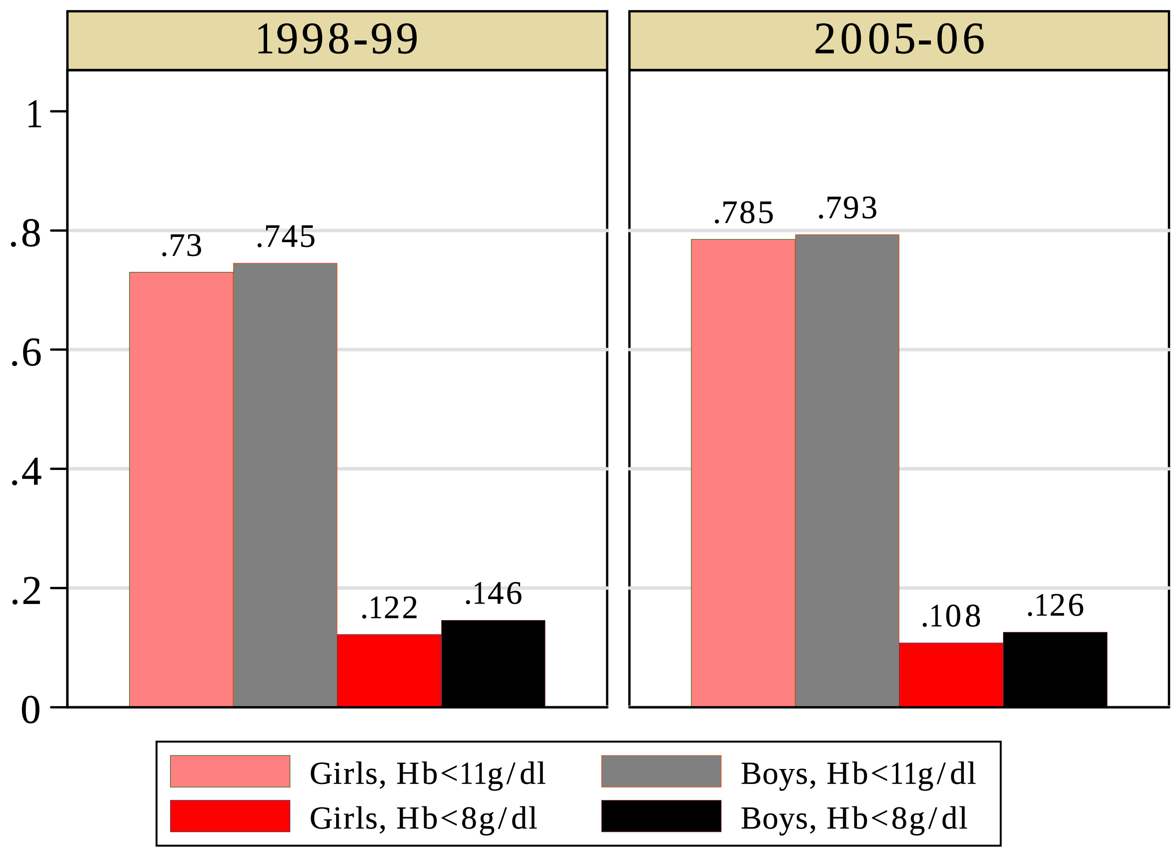

Figure 9: Anemia and Severe Anemia: by gender and survey round

Source: Author's estimates from NFHS-2 (1998-99) and NFHS-3 (2005-06). Children under three years of age, last two births, from ever married mothers of age 15-49. The sample includes 10,871 boys and 9,763 girls from NFHS-1, and 10.371 boys and 9,304 girls from NFHS-3. Given the large sample sizes the indices are estimated very precisely, with standard errors of 0.6 or below. The full results are available upon request from the author.

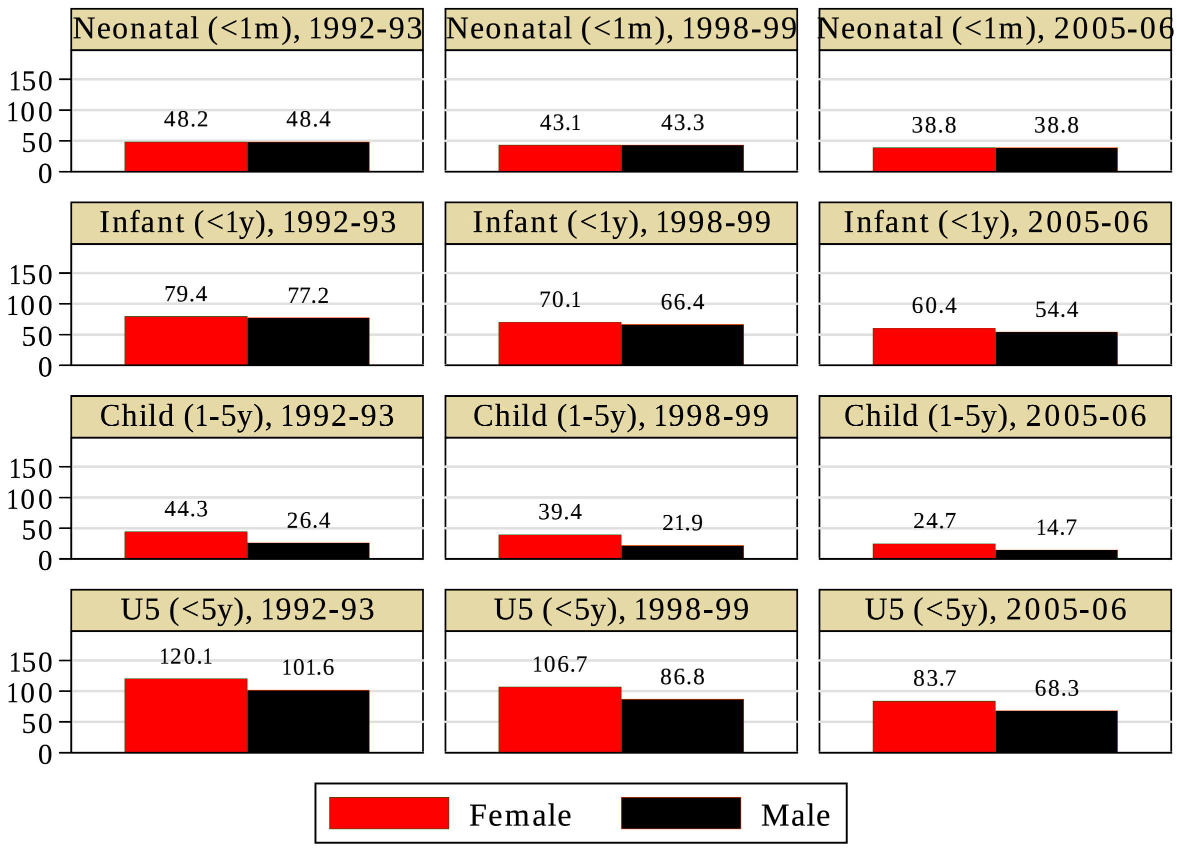

Figure 10: Mortality Rates, by Survey Round, Age Group and Gender

Source: Author's estimates from NFHS-1 (1992-93), NFHS-2 (1998-99) and NFHS-3 (2005-06). Neonatal mortality is the number of deaths before the first month of life for every 1,000 live births. Infant and U5 mortality are the number of deaths before the first or fifth birthday for every 1,000 live births. Child mortality is the number of deaths before age five for every 1,000 children who survived at least one year. For additional details see text.