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# The Other Asian Enigma

## Explaining the Rapid Reduction of Undernutrition in Bangladesh

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## ABSTRACT

South Asia has long been synonymous with persistent and unusually high rates of child undernutrition—the so-called Asian enigma. Yet contrary to this stereotype, Bangladesh has managed to sustain a rapid reduction in the rate of child undernutrition for at least two decades. In this paper we aim to understand the sources of this unheralded success with the aspiration of deriving policy-relevant lessons from Bangladesh's experience. To do so we employ a regression analysis of five rounds of Demographic and Health Surveys covering the period from 1997 to 2011. Statistical decompositions suggest that five broad factors explain slightly more than half of the improvement in height-for-age z scores and stunting rates: rapid gains in both maternal and paternal education, wealth accumulation, increased utilization of or access to prenatal and neonatal health services, reductions in open defecation, and demographic changes in the form of reduced fertility rates and longer birth intervals. Most of these broader economic and social improvements can be plausibly linked to pro-poor economic policies and community-led development schemes, and for the most part the results are robust to various sensitivity analyses. However, it is also notable that our statistical model leaves a substantial share of Bangladesh's success an unexplained enigma.

**Keywords: undernutrition; Bangladesh; wealth; education; family planning; sanitation; health services**

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# 1. INTRODUCTION

In the nutrition literature South Asia is synonymous with unusually high rates of child undernutrition relative to its income levels as well as sluggish reduction in undernutrition, particularly in India (Deaton and Dreze 2008). This so-called Asian enigma (Ramalingaswami, Jonson, and Rohde 1997) has spawned substantial research into possible explanations, including gender and intrahousehold biases (Jayachandran and Pande 2013; Pande 2003), unusually high rates of open defecation (Spears 2013; Spears, Ghosh, and Cumming 2013), genetic predispositions (Nubé 2009), poor-quality diets and food systems (Headey, Chiu, and Kadiyala 2012), and the inefficacy of nutritional programs and strategies (Das Gupta et al. 2005; World Bank 2005a).

Yet this literature has largely ignored Bangladesh's sustained reduction in child undernutrition for at least two decades. A recent cross-country study by Headey (2013) concluded that from 1997 to 2007 Bangladesh recorded one of the fastest prolonged reductions in child underweight and stunting prevalence in recorded history, 1.1 and 1.3 percentage points per year, respectively, narrowly behind the much more celebrated case of Thailand in the 1980s (Heaver and Kachondam 2002) and just ahead of several success stories identified in the nutrition literature, such as Brazil, Mexico, and Honduras (World Bank 2006). Strikingly, Bangladesh now has lower stunting rates (41.3 percent) than India recorded in its 2005–2006 survey (47.5 percent) or Pakistan did in its 2012 survey (44.8 percent), despite both countries' having higher mean incomes.

This puzzling neglect of Bangladesh's nutritional success is seemingly explained by the absence of any highly regarded nutrition strategy. In particular, assessments of Bangladesh's Integrated Nutrition Program 1995–2004 (BINP) suggest at best a modest impact on nutrition outcomes (Hossain, Duffield, and Taylor 2005; Levinson and Eliot Rohde 2005; Sack et al. 2005; White 2005; World Bank 2005a, 2005b). The most critical of the assessments stated that "the BINP has not achieved its objective to reduce child malnutrition at a population level" (Hossain, Duffield, and Taylor 2005, 39). An apparent outcome of the poor reputation of BINP is that while Bangladesh is widely recognized for its remarkable progress in poverty reduction and delivering effective health and family planning services (The Economist, 2012; World Bank 2005b), the country's success in reducing child malnutrition remains largely overlooked and certainly understudied.

In this paper we seek to remedy this knowledge gap through an analysis of the drivers of nutritional change in Bangladesh between 1997 and 2011. In doing so we expand on a growing literature that seeks to explain nutritional change as a function of a wide array of nutrition-sensitive interventions. In addition to the well-documented effects of income on nutrition (Behrman and Deolalikar 1987; Haddad et al. 2003; Headey 2013; Heltberg 2009; Smith and Haddad 2000), there is various evidence linking nutrition outcomes to education (Burchi 2012; Headey 2013; Thomas, Strauss, and Henriques 1991; Webb and Block 2004), demography and family planning (Dewey and Cohen 2007; Headey 2013; Horton 1988; Jensen 2012; Rutstein 2008), gender empowerment and cultural norms (Jayachandran and Pande 2013; Pande 2003), improved sanitation (Humphrey 2009; Lin et al. 2013; Spears 2013), and health service utilization (Headey 2013). Understanding the contribution of such factors to historical changes in nutrition outcomes is an important area of ongoing research to which this paper aims to make a contribution.

The paper is structured as follows. Sections 2 and 3 outline the data and analytic methods used in the paper. Section 4 presents our principal statistical models, including our main decomposition analysis. Section 5 discusses a range of sensitivity tests. Section 6 concludes.

## 2. DATA

We use the 1997, 2000, 2004, 2007, and 2011 rounds of the Bangladesh Demographic and Health Survey (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013), hereafter DHS. These data are well suited to our purposes insofar as they are high quality, are nationally representative, are substantially standardized across rounds, and cover a broad range of the hypothesized drivers of nutritional change. We focus on height-for-age z (HAZ) scores for preschool children as measured against World Health Organization growth standards as described in de Onis et al. (2007). Linear growth is now widely regarded as the single most relevant indicator of overall nutrition, and the reduction in stunting (HAZ scores of 2 standard deviations or less) is the standard metric of nutritional success. However, several authors in the statistical epidemiology literature have persuasively argued against the use of dichotomous rather than continuous variables on the grounds that dichotomizing variables unnecessarily weaken the power of statistical tests (Royston, Altman, and Sauerbrei 2006; Weinberg 1995). In our case our pooled sample size is large enough to greatly reduce this concern, but we nevertheless focus on the full spectrum of HAZ scores as well as rates of stunting (HAZ < –2) and severe stunting (HAZ < –3).

Table 2.1 presents trends in HAZ scores and stunting prevalence for the seven samples analyzed in this paper: a total sample of all areas and all ages in the 0- to 59-month bracket for which we have observations, rural and urban samples (0–59 months), male and female samples (0–59 months), and samples of children 0 to 6 months of age and 7 to 24 months of age. Mean HAZ scores and stunting prevalence improved rapidly between 1997 and 2011 by almost 0.6 standard deviations in the case of HAZ scores and 19 points in the case of stunting. In percentage terms the change in stunting was slightly larger than the change in mean HAZ scores. Figure 2.1 also shows the distribution of HAZ scores across both rounds and confirms a larger shift in the lower tail. Indeed, severe stunting (not shown) fell by more than 100 percent (half), from 30.9 percent in 1997 to 14.4 percent in 2011.

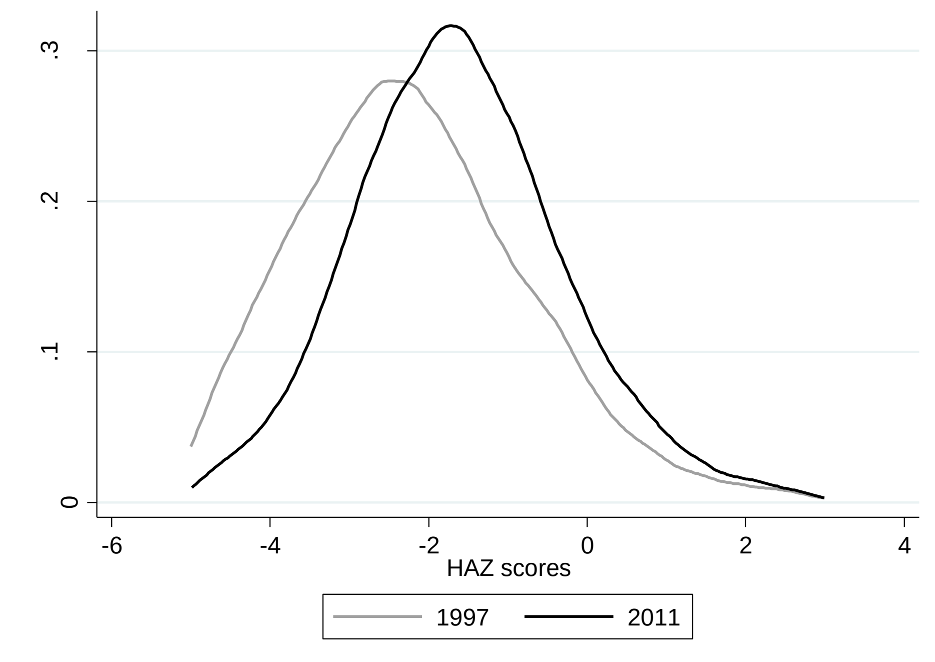
**Table 2.1 Changes in mean HAZ scores and stunting prevalence for different samples across the five Bangladesh Demographic and Health Survey rounds**

| | Mean HAZ scores | | | | | | |
|---|---|---|---|---|---|---|---|
| **Sample** | **Total** | **Rural** | **Urban** | **Girls** | **Boys** | **0–6 months** | **6–24 months** |
| 1997 | –2.19 | –2.25 | –1.81 | –2.18 | –2.21 | –1.09 | –2.09 |
| 2000 | –1.91 | –2.01 | –1.63 | –1.91 | –1.92 | –0.98 | –1.88 |
| 2004 | –1.89 | –1.96 | –1.70 | –1.87 | –1.90 | –1.03 | –1.78 |
| 2007 | –1.72 | –1.83 | –1.51 | –1.73 | –1.71 | –0.91 | –1.51 |
| 2011 | –1.61 | –1.69 | –1.43 | –1.65 | –1.57 | –0.62 | –1.64 |
| Change | 0.58 | 0.57 | 0.37 | 0.53 | 0.64 | 0.47 | 0.45 |
| Change (%) | –26.6 | –25.2 | –20.6 | –24.4 | –28.8 | –43.0 | –21.6 |
| | **Stunting** | | | | | | |
| 1997 | 0.59 | 0.60 | 0.46 | 0.58 | 0.59 | 0.28 | 0.55 |
| 2000 | 0.49 | 0.52 | 0.41 | 0.49 | 0.49 | 0.23 | 0.47 |
| 2004 | 0.49 | 0.51 | 0.43 | 0.49 | 0.49 | 0.23 | 0.46 |
| 2007 | 0.43 | 0.46 | 0.37 | 0.43 | 0.43 | 0.22 | 0.36 |
| 2011 | 0.40 | 0.42 | 0.35 | 0.40 | 0.39 | 0.16 | 0.40 |
| Change | –0.19 | –0.18 | –0.11 | –0.18 | –0.20 | –0.12 | –0.14 |
| Change (%) | –32.1 | –30.5 | –24.7 | –30.3 | –33.7 | –42.0 | –25.9 |

Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).

Note: HAZ = height-for-age z score.

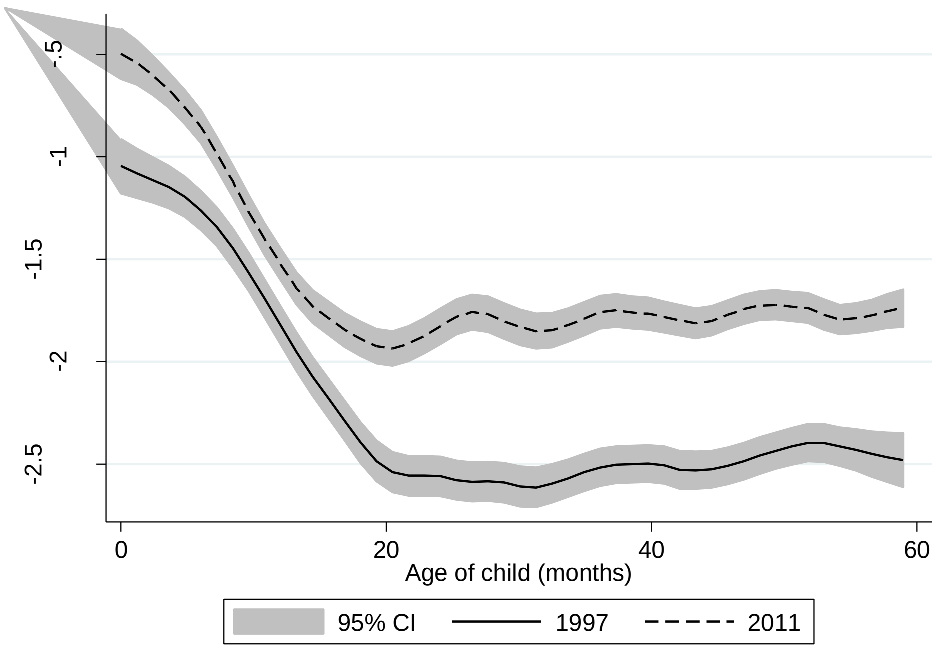
**Figure 2.1 The distribution of HAZ scores, 1997 and 2011**




Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).
Note: HAZ = height-for-age z score.

There are several other findings of note. The speed of nutritional gains was somewhat larger in rural areas than in urban areas. Indeed, from 2000 to 2004 there was a slight deterioration in nutritional status in urban areas. There was a larger improvement among boys than girls, although the difference is a small one in the case of stunting. The absolute improvements in younger groups (0–6 months and 6–24 months) were somewhat smaller in absolute terms but still large in relative terms. Figure 2.2 shows HAZ scores by child age. The confidence intervals for the two curves never overlap, suggesting significant improvements in HAZ scores for all ages. However, the shift is larger for some age brackets than for others. At the youngest ages we observe a large shift in HAZ scores. Though the 2011 round continues to show a very sharp process of growth faltering from several months of age onward, the pace of faltering slows down much earlier in 2011 compared to 1997 (at around 14 months instead of 20 months in 1997) and bottoms out earlier.

**Figure 2.2 HAZ scores by child age, 1997 and 2011**




Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).
Note: HAZ = height-for-age z score; CI = confidence interval.

What might explain these large changes in nutrition outcomes? In the parlance of the UNICEF (1990) framework, updated by Black et al. (2013), nutrition outcomes are the end result of a causal chain that starts with "basic determinants" (policies, culture, agroecology, and so on), which influence "intermediate" determinants (household food security, care practices, disease environment), which determine the "immediate determinants" of nutrition, notably food intake and utilization. In the DHS, we observe the intermediate determinants (that is, household wealth and demography, parental education, health service utilization, infrastructure) rather than any basic (policy) determinants. Table 2.2 summarizes basic information about several broad sources of nutritional change linked to these intermediate determinants that are available to us in the DHS data.[1]

[1] In our Introduction, we noted that Bangladesh's largest nutrition-specific intervention (Bangladesh's Integrated Nutrition Program 1995–2004 [BINP]) was not particularly successful. Beyond BINP, however, there is little evidence about the impacts and scale of the myriad of other nutrition-specific interventions carried out by government and nongovernmental organization bodies. Some specific interventions have met with some success, particularly maternal vitamin A and iron supplementation, but the general perception of the literature is that nutrition interventions have been marginalized relative to basic health and family planning objectives (Taylor 2012). Consequently, the absence of information about standard nutrition-specific interventions in the Demographic and Health Survey (DHS) is not a concerns for our analysis.

**Table 2.2 Changes in the means of key variables across the five rounds of Bangladesh Demographic and Health Survey data**

| Year | Wealth (0–10) | Maternal education (Years) | Paternal education (Years) | Mother can travel to health clinic alone (%) | Mothers have prenatal doctor visit (%) | Mothers have prenatal visit with other health professional (%) |
|---|---|---|---|---|---|---|
| 1997 | 3.2 | 2.5 | 3.60 | 20.1 | 19.7 | 9.7 |
| 2000 | 3.6 | 3.3 | 4.20 | 26.7 | 26.0 | 11.4 |
| 2004 | 4.1 | 3.8 | 4.30 | 51.8 | 32.8 | 21.7 |
| 2007 | 4.7 | 4.9 | 4.90 | 64.1 | 34.6 | 21.7 |
| 2011 | 4.9 | 5.6 | 5.60 | 79.3 | 37.2 | 28.1 |
| Change 1997–2011 | 1.6 | 3.1 | 1.91 | 59.2 | 17.5 | 18.4 |
| % change 1997–2011 | 50.6 | 126.0 | 52.2 | 295.1 | 89.1 | 190.4 |
| Mean over all rounds | 4.2 | 4.1 | 4.5 | 40.0 | 31.0 | 19.0 |
| Standard deviation | 2.5 | 4.0 | 4.7 | 49.0 | 46.0 | 39.0 |

| Year | All vaccinations (%) | Child born in a medical facility (%) | No toilet—village (%) | Water—piped (%) | Birth order (Rank) | Birth interval (Months) |
|---|---|---|---|---|---|---|
| 1997 | 47.4 | 3.1 | 24.7 | 4.4 | 3.1 | 31.1 |
| 2000 | 50.2 | 5.8 | 15.9 | 6.5 | 2.9 | 32.5 |
| 2004 | 62.4 | 7.8 | 11.2 | 7.4 | 2.8 | 32.9 |
| 2007 | 49.6 | 13.7 | 6.3 | 6.3 | 2.6 | 33.2 |
| 2011 | 46.5 | 25.4 | 4.2 | 9.4 | 2.4 | 34.9 |
| Change 1997–2011 | –0.9 | 22.2 | –20.4 | 5.0 | –0.71 | 3.79 |
| % change 1997–2011 | –1.9 | 706.7 | –82.9 | 114.4 | –22.9 | 12.2 |
| Mean over all rounds | 61.0 | 12.0 | 11.5 | 7.0 | 2.7 | 2.8 |
| Standard deviation | 49.0 | 33.0 | 18.5 | 2.6 | 1.9 | 2.6 |

Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).

Notes: "All vaccines" is measured only for children older than six months.

One candidate for sustained nutritional change is general economic progress, which facilitates larger expenditures on food, health, and other nutrition-relevant expenditures on stunting (Behrman and Deolalikar 1987; Haddad et al. 2003; Headey 2013; Heltberg 2009; Smith and Haddad 2000). While Bangladesh has not achieved economic growth rates as impressive as East Asian countries', it has achieved pro-poor economic growth on the back of rapid agricultural growth, successful nonfarm diversification, labor-intensive manufacturing, and—more recently—a sharp upsurge in overseas remittances. These underlying drivers contributed to an 18-point decline in hunger prevalence compared to 1990–2010 (FAO 2012), and a 23-point decline in the $1.25 poverty headcount compared to 1990–2010 (World Bank 2012). Although the DHS does not contain information about income, it does collect on a consistent basis information about assets. These include ownership of household durables (TV, radio, motorcycle, tables and chairs, wardrobe), housing characteristics (floor, wall and roof materials, access to electricity), house ownership, and farmland ownership. We use this information to construct an asset (or wealth) index. The weights of the different assets in this index were derived by running principal components analysis for the pooled five rounds of data. The index was then adjusted to vary between 0 and 10, with 10 being the maximum score observed across all rounds. Consistent with this pro-poor growth, the value of the index rises by 50 percent between 1997 and 2011. More details about this index are given in Appendix A.[2] Among other things, Appendix A shows that our asset index performs just as well in predicting child growth outcomes as household expenditure in a recent non-DHS household survey from Bangladesh.

Another significant change in Bangladesh is the rapid expansion of education, which began in the early 1990s when the government and various development partners began subsidizing secondary education, particularly for girls via a stipend program designed to keep them in school. According to the World Bank (2005b) the best estimates are that the stipend accelerated female secondary school enrollment 20 percent above other factors. As a result, growth rates of secondary school enrollment were three times as fast for females compared to males. Table 2.2 reflects this, with increases in grade attainment for women rising two and a half times faster than for men. The gender gap in grade attainment that existed in 1997 disappeared by 2011; in fact, the DHS data for 2011 show that among parents younger than 25, mothers have almost one full year of education more than fathers. Given that maternal education has often been strongly linked to nutrition outcomes (Behrman and Wolfe 1984; Burchi 2012; Headey 2013; Ruel and Alderman 2013), these changes may well have played a role in the reductions in child undernutrition reported above. Consistent with this rapid improvement in women's education, we also find substantial improvement in one indicator of women's empowerment collected across all DHS rounds, the percentage of women who report that they can travel to a health clinic by themselves. In our robustness tests we also examine an alternative index of women's involvement in household decisionmaking.

In terms of health, Bangladesh is also well known for impressive improvements in a range of indicators, particularly child mortality. These achievements have taken place despite relatively low levels of spending on health, but with substantial innovations in community-based service delivery (Chowdhury et al. 2013; El Arifeen et al. 2013). Major successes—going back to the 1980s—include health extension worker programs, traditional birth attendants (more controversially), and programs to improve treatment of diarrhea. However, the limited budget for health expenditure—which is currently about half of the education budget—may also explain historically low levels of antenatal, neonatal, and postnatal care in public hospitals and clinics. As a result, the last decade has seen a marked shift toward private and nongovernmental organization (NGO) provision of healthcare, as seen in Table 2.2. A range of indicators of health service utilization was also available to us, including vaccinations, sources of antenatal care, place of delivery, and medical attendance at delivery. One issue of some concern is that some of these variables—such as antenatal care and place of birth—are correlated with unobservables, such as

[2] Such indexes are now standard in the analysis of DHS data and have been demonstrated to be very efficacious (Filmer and Pritchett 2001; Filmer and Scott 2012; Rutstein and Staveteig 2013). We also find that our index is a strong predictor of nutrition and other welfare outcomes, including household expenditure (see Appendix A).

household income, rather than with any public policies. Hence, as a robustness test we also estimate models that drop these variables.

A more recent success story pertains to infrastructure development, particularly sanitation. Table 2.2 reports this measure at the village level. The existing literature provides a clear justification for this since there are obvious grounds to believe that a poor sanitation environment within the village is a more important determinant of a child's exposure to disease than household-level toilet facilities (Spears 2013; Spears, Ghosh, and Cumming 2013). The proportion of villages with no toilet (that is, engaging in open defecation) declined from 24.7 percent in 1997 to just 4.2 percent in 2011. In addition to public infrastructure efforts, community-led total sanitation approaches were first pioneered in Bangladesh in the late 1990s, seemingly to substantial effect (Kar 2003; World Bank 2012). In light of recent evidence pointing to open defecation's being a leading explanation of South Asia's unusually high rates of child undernutrition (Lin et al. 2013; Mondal et al. 2012; Spears 2013; World Bank 2012) it is of interest to assess whether this decline in open defecation explains some of the reduction in child undernutrition in recent years. This large change in sanitation contrasts with the very small change in access to piped water (Table 2.2).

One of Bangladesh's most unambiguous success stories is the reduction of fertility rates (Kohler 2012). At independence from Pakistan, Bangladesh had the highest population density in the developing world and one of the highest fertility rates. The government and its development partners therefore placed high priority on family planning immediately after independence. Family Health Visitor training schools were set up at scale in the mid-1970s to promote contraception, and by 1978 some 16,700 family planning workers had been posted (World Bank 2005b). By the early 1990s several evaluations clearly established sizeable impacts of family planning on fertility outcomes (despite the inhospitable cultural and economic setting), most notably Cleland et al. (1994). The World Bank (2005b) also reviews this literature and empirically demonstrates that Bangladesh has achieved exceptionally rapid fertility reductions relative to its economic growth. Consistent with these changes, Table 2.2 shows a lengthening of birth intervals and a reduction in birth rank. An existing literature suggests that these fertility changes might have driven substantial nutritional improvements. Rutstein (2008) provides a comprehensive review and 265,000 stunting observations from 52 DHSs to identify a highly significant curvilinear relationship between preceding birth intervals, with stunting declining markedly as the birth interval increases after 18 months (we closely replicate this finding below). There is also a small literature—largely in economics—on birth order (in effect, fertility) and nutrition in developing countries (Behrman 1988; Horton 1988; Jayachandran and Pande 2013). But while there is certainly a literature linking demographic outcomes to nutrition outcomes, fertility is a household choice variable and therefore potentially correlated with household unobservables (though we do control for wealth and parental education, two variables that are indeed highly correlated with fertility outcomes). Some authors therefore prefer excluding these variables. Hence we also estimate models that exclude fertility outcomes from the right-hand side.

# 3. ANALYSIS

We use linear regression models and linear probability models to assess the associations between nutrition outcomes (N) for a child *i* at time t and a vector of time-varying intermediate determinants (**X**), a vector of control variables (maternal height, child and maternal age dummies, location fixed effects; $\boldsymbol{\mu_i}$) and trend effects represented by a vector of year dummy variables (**T**). The vector of coefficients ($\boldsymbol{\beta}$) constitutes the set of parameters of principal interest. With the addition of a standard white noise term ($\varepsilon_{i,t}$), we represent this relationship by equation 1:

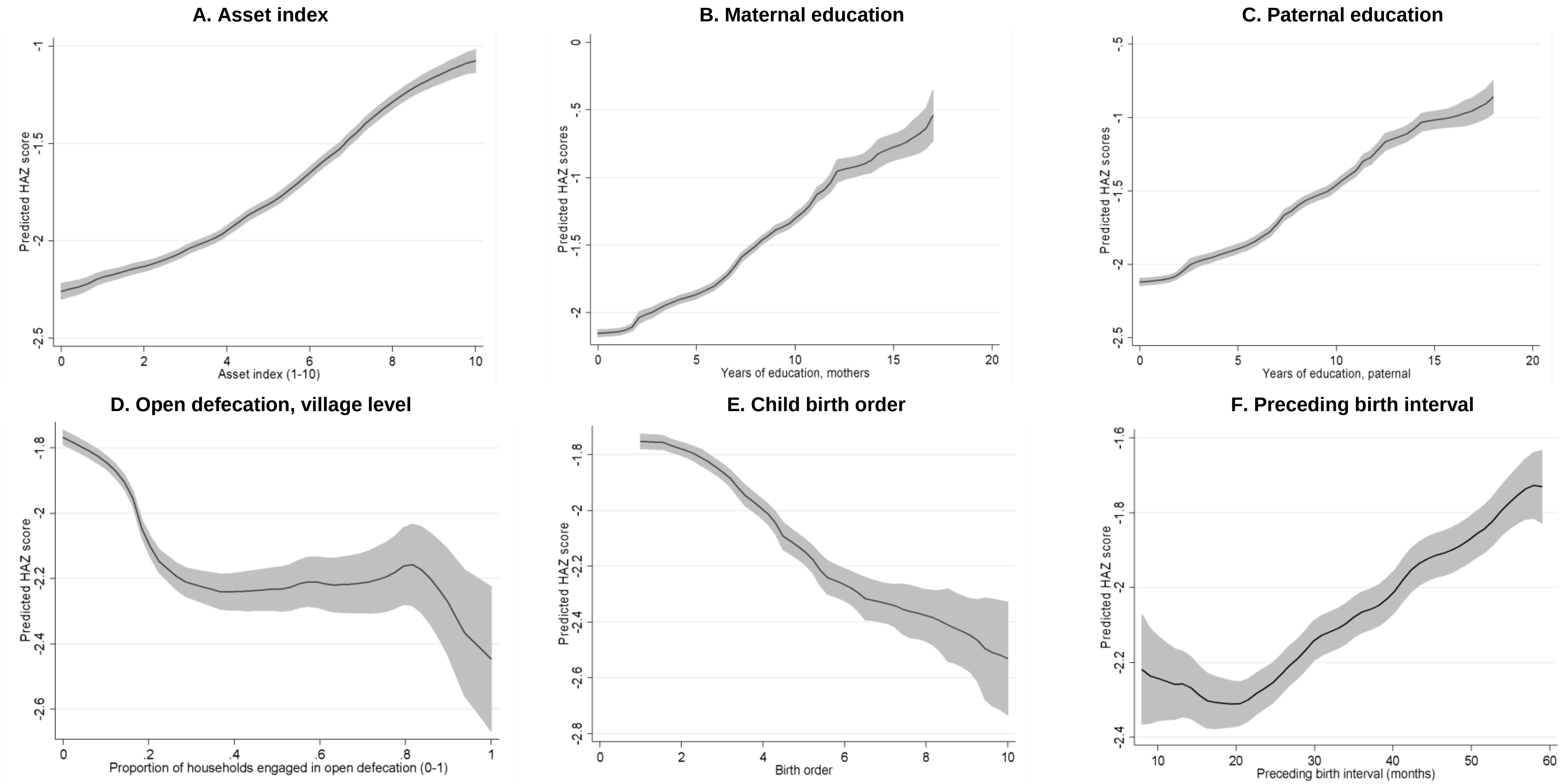
$$N_{i,t} = \boldsymbol{\beta X}_{i,k} + \boldsymbol{\mu_i} + \boldsymbol{T} + \varepsilon_{i,t} \, . \tag{1}$$

Apart from the standard least squares assumptions, a crucial assumption of the model is that we adequately control for all potentially confounding factors, with the most important of these being wealth and education, since these two variables can clearly drive a range of other endogenous behaviors, such as demand for health service utilization and demand for the number of children (or contraception). Without adequate control for physical and human capital the coefficients on these other variables are less interesting since they might substantially reflect increased household demand rather than any impact of sector-specific policies. Conversely, if a household's physical and human capital is adequately captured in the model, then statistically significant coefficients on other variables in the model are suggestive of important supply-side drivers in the domains of healthcare, family planning, and infrastructure provision. Hence, as noted above, we estimate models that exclude potentially endogenous health and fertility variables.

A second important assumption in equation 1 is that the model is appropriately specified in other dimensions, particularly in terms of capturing various nonlinearities in nutrition relationships. To that end we took two steps. First, we adopted a very flexible specification of the time-invariant determinants including monthly dummy variables to capture the progressive growth-faltering process that malnourished populations undergo until around two years of age (Shrimpton et al. 2001; Victora et al. 2009). Second, we undertook nonparametric graphical analyses of all time-varying continuous variables to examine whether there exist nonlinearities in their relationships with HAZ scores. Figure 3.1 shows that most of the continuous explanatory variables have approximately linear relationships with HAZ scores with two exceptions.

First, open defecation at the village level has a strikingly nonlinear relationship. In the range of 0 to 30 percent open defecation (approximately) the gradient is steeply negative, but thereafter it is mostly flat, before becoming negative again for the few very high levels of open defecation. This nonlinearity is quite different from Spear's (2013) findings for an Indian DHS sample but similar to his estimates for an African DHS sample. Moreover, an earlier literature on sanitation and health outcomes had hypothesized that there were increasing health benefits as communities move toward total eradication of open defecation (Shuval et al. 1981). To capture this nonlinear relationship in our regression models we use a fractional polynomial transformation by raising this variable to the power of one-third, a transformation that performed better than alternatives with which we experimented. The second nonlinear relationship pertains to birth order. Figure 3.1, panel E, suggests that first- and second-born children have similar predicted HAZ scores, but HAZ scores decline for all lower-order births. Hence we interact a dummy variable for birth orders greater than two with the raw birth order variable to capture this nonlinearity.

**Figure 3.1 Nonparametric estimates of the relationship between HAZ scores and continuous variables**




Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).

Note: HAZ = height-for-age z score.

We then use the estimated parameters from equation 1 to conduct a decomposition analysis, taking the first difference of the estimates in equation 1. Under the assumption that the $\boldsymbol{\beta}$ coefficients are time invariant and the error term has a mean of zero, the first difference of equation 1 between time 1 and time K is given by

$$\Delta\bar{N}_{i,t} = \boldsymbol{\beta}(\bar{\boldsymbol{X}}_{t=K} - \bar{\boldsymbol{X}}_{t=1}) \quad (2)$$

where bars represent sample means.

If, however, we assume that the $\boldsymbol{\beta}$ coefficients are time varying, a different approach is needed. Specifically, we would need to use a Oaxaca-Blinder decomposition to break up the estimated change in the dependent variable into changes in endowment, changes in coefficients, and interactions between the two (Jann 2008 and Elder, Goddeeris, and Haider 2010 provide detailed explanations of this approach). If there is a high degree of parameter stability across time, however, the two decomposition techniques are equivalent. But one limitation of the Oaxaca-Blinder analysis is that parameter instability can sometimes be an erroneous artifact of measurement issues in particular rounds. For example, our sanitation variable—open defecation—had a relatively high mean in the beginning of the sample but was close to 0 by 2011. A regression using only 2011 data therefore indicates that open defecation is not a significant determinant of nutrition precisely because there is so little variation in this indicator by the end of our period of analysis. In light of this we would prefer to avoid the Oaxaca-Blinder decomposition if the regressions show sufficiently high degrees of parameter stability. In the next section we therefore examine parameter stability using a barrage of Chow tests to test for differences in the $\boldsymbol{\beta}$ coefficients across rounds. We find little evidence of parameter instability, though we also conduct Oaxaca-Blinder decompositions as a further robustness test.

# 4. RESULTS

We now turn to formally deriving answers to two related but distinct questions: which factors explain growth outcomes across children, and which factors explain child growth trends from 1997 to 2011? Our estimates of equation 1 are reported in Table 4.1. While these are based on pooling all five rounds together, we account for trend effects through a series of year dummy variables with the 1997 round as the base and present separate regressions for different subsamples of the pooled data. All our regressions include time-invariant control variables (monthly child age dummies, maternal age bracket dummies, month of birth dummies, regional dummies) but these are omitted from Table 4.1 for the sake of brevity. We find moderately large impacts of household wealth on HAZ scores with the impact of a 1-point increase in the asset index (measured on a 1–10 scale) usually around 0.05. In other words, the predicted HAZ difference between a child in the poorest household in our sample and the richest is 0.5 standard deviations (the exception is the sample of children 0–6 months of age, in which household wealth has no significant effect on HAZ scores). For both maternal and paternal education we find that an extra year typically adds 0.02 to 0.03 standard deviations to predicted HAZ, such that a household in which both parents completed high school could be expected to have a child around 0.5 standard deviations taller than a child from a household in which neither parent had attended school. Also of note is that the nutritional impacts of maternal and paternal education are never statistically different from each other. We also do not find any significant association between our female empowerment variable (can walk to health clinic alone) and growth outcomes, although this variable may capture only limited dimensions of empowerment. However, when we tested a simple index of maternal involvement in four areas of household decisionmaking—an index available from the 2000 round onward—we found no significant coefficient on this variable either (results available on request).

In terms of health variables we find no robust impact of vaccinations, though the coefficient on this variable is moderately significant in some samples, particularly the 7 to 24 months sample. Prenatal visits to doctors has a highly significant and stable coefficient across samples, predicting a relatively large impact on HAZ scores varying between 0.16 and 0.21 standard deviations. However, visits to other health professionals—such as nurses and midwives—does not significantly predict HAZ scores (though in results below we find that this variable predicts improvement in severe stunting). A child being born in any kind of medical facility (government, private, NGO) is a robust predictor of HAZ, with coefficients varying between 0.08 and 0.12. It therefore appears that access to doctors and larger medical facilities before and during birth is important for child growth around the mean, although we note that the importance of these factors may be exaggerated by their associations with household economic status.

Consistent with the graphical result in Figure 3.1, panel B, open defecation has a robust but nonlinear negative association with linear growth outcomes. As in Spears (2013), we find that the impact of open defecation is somewhat larger in urban areas, presumably because of greater population density's strengthening the disease vectors associated with open defecation. The regressions also suggest that sanitation is not a significant determinant of nutrition for girls, although this peculiar result appears to stem from multicollinearity, particularly sensitivity to the inclusion of the asset index in the regression for girls. Moreover, bivariate graphical results reported in the Appendix D suggest no significant difference in the sanitation-HAZ relationship between samples of boys and girls. In contrast to sanitation, we find no effect of piped water supplies on growth outcomes. It is possible that water sources are a poor proxy for water quality.

**Table 4.1 Height-for-age z regressions pooled across years for various samples**

| Model | Full sample (baseline) | Rural Only | Urban Only | Boys Only | Girls Only | 0–6 Months | 7–24 Months |
|---|---|---|---|---|---|---|---|
| Asset index, 1–10 | 0.046*** | 0.045*** | 0.051*** | 0.043*** | 0.050*** | 0.019 | 0.051*** |
| | 0.004 | 0.005 | 0.008 | 0.006 | 0.006 | 0.013 | 0.008 |
| Maternal education (years) | 0.016*** | 0.014*** | 0.016*** | 0.021*** | 0.011** | 0.023** | 0.009* |
| | 0.003 | 0.004 | 0.006 | 0.005 | 0.004 | 0.009 | 0.005 |
| Paternal education (years) | 0.020*** | 0.016*** | 0.029*** | 0.018*** | 0.023*** | 0.024*** | 0.020*** |
| | 0.002 | 0.003 | 0.005 | 0.004 | 0.004 | 0.008 | 0.004 |
| All vaccines[a] | 0.037* | 0.027 | 0.051 | 0.028 | 0.046 | | 0.071** |
| | 0.02 | 0.023 | 0.04 | 0.029 | 0.028 | | 0.032 |
| Prenatal doctor visit | 0.176*** | 0.165*** | 0.189*** | 0.163*** | 0.190*** | 0.161** | 0.202*** |
| | 0.021 | 0.025 | 0.041 | 0.03 | 0.03 | 0.063 | 0.036 |
| Prenatal health professional visit | 0.027 | 0.023 | 0.061 | 0.022 | 0.034 | 0.055 | 0.008 |
| | 0.022 | 0.026 | 0.043 | 0.031 | 0.031 | 0.065 | 0.038 |
| Born in medical facility | 0.115*** | 0.096*** | 0.092** | 0.121*** | 0.112*** | –0.051 | 0.134*** |
| | 0.027 | 0.037 | 0.039 | 0.037 | 0.038 | 0.08 | 0.044 |
| Open defecation[b] | –0.027*** | –0.023*** | –0.054*** | –0.041*** | –0.008 | –0.023 | –0.041*** |
| | 0.007 | 0.008 | 0.018 | 0.01 | 0.01 | 0.022 | 0.013 |
| Piped water | 0 | 0.065 | –0.019 | 0.027 | –0.026 | –0.193* | 0.006 |
| | 0.034 | 0.092 | 0.04 | 0.048 | 0.048 | 0.107 | 0.061 |
| Birth order | –0.038*** | –0.031*** | –0.065*** | –0.041*** | –0.034*** | 0.036* | –0.034*** |
| | 0.007 | 0.008 | 0.016 | 0.01 | 0.01 | 0.021 | 0.012 |
| Birth interval (years)[c] | 0.028*** | 0.028*** | 0.031*** | 0.032*** | 0.024*** | 0.034*** | 0.029*** |
| | 0.003 | 0.004 | 0.006 | 0.005 | 0.005 | 0.01 | 0.006 |
| Health clinic alone | 0.006 | 0.014 | –0.008 | 0.036 | –0.027 | 0.093* | –0.017 |
| | 0.017 | 0.021 | 0.031 | 0.024 | 0.024 | 0.053 | 0.03 |
| Maternal height | 0.051*** | 0.050*** | 0.054*** | 0.054*** | 0.049*** | 0.045*** | 0.056*** |
| | 0.002 | 0.002 | 0.003 | 0.002 | 0.002 | 0.004 | 0.003 |
| Male child | –0.009 | 0.014 | –0.062** | | | –0.075 | –0.094*** |
| | 0.016 | 0.019 | 0.029 | | | 0.047 | 0.027 |
| Year 2000 | 0.219*** | 0.208*** | 0.200*** | 0.205*** | 0.237*** | 0.086 | 0.136*** |
| | 0.028 | 0.03 | 0.063 | 0.041 | 0.039 | 0.083 | 0.049 |
| Year 2004 | 0.202*** | 0.216*** | 0.130** | 0.183*** | 0.223*** | –0.026 | 0.125** |
| | 0.028 | 0.03 | 0.061 | 0.04 | 0.039 | 0.083 | 0.049 |
| Year 2007 | 0.272*** | 0.298*** | 0.180*** | 0.287*** | 0.270*** | 0.059 | 0.308*** |
| | 0.031 | 0.034 | 0.062 | 0.044 | 0.043 | 0.104 | 0.054 |
| Year 2011 | 0.270*** | 0.307*** | 0.154** | 0.248*** | 0.296*** | 0.275*** | 0.03 |
| | 0.03 | 0.033 | 0.062 | 0.043 | 0.042 | 0.095 | 0.053 |
| *R*-squared | .252 | .235 | .273 | .251 | .263 | .134 | .233 |
| *N* | 23,114 | 16,651 | 6,463 | 11,776 | 11,338 | 3,124 | 7,964 |

Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).

Note: Village-clustered standard errors are in parentheses. The regressions include a number of time-invariant controls, including regional fixed effects, month-specific child age dummy variables, and dummy variables for various categories of maternal age. ***10 percent, **5 percent, and ***1 percent significance levels. [a]. Vaccinations are measured for children 6 months or older only. [b]. Open defecation is measured as a cubic fraction to capture the non-linear relationships observed in our non-parametric graphs. [c]. Birth intervals are measured for proceeding children only.

Both household demography variables—birth order and birth interval—yield statistically significant coefficients that are also quite stable across samples. Individually, each variable has modest slope coefficients, but together these two variables suggest that household demography is an important predictor of HAZ scores. In the full sample, every additional child (after the second child) has a predicted HAZ score that is 0.03 to 0.04 standard deviations lower that the next-highest-order child. So relative to first and second children, a child born sixth in a family could be expected to be around 0.20 standard deviations shorter. Similarly, an extra year between births increases HAZ scores by around 0.03 standard deviations, so a five-year gap yields a 0.15 standard deviation improvement in height.

The coefficient on maternal height is significant in all samples, representing an important intergenerational transmission of nutrition. Male children have some tendency to be smaller, at least in urban areas and in the samples of younger children. Indeed, graphical results reported in Appendix Figure A.3 suggest that girls are slightly taller than boys until three years of age, but thereafter boys become significantly taller than girls.

Another finding of note is that many of the variables that appear to be robustly significant across different samples turn out to be insignificant in the sample of children aged 0 to 6 months. As noted above, wealth appears irrelevant for this sample, but so too does being born in a medical facility and village sanitation, though parental education is still important, as are prenatal doctor visits and the demographic variables.

The results above answer the question of what the general determinants of malnutrition are in Bangladesh. We now turn to the second question: which of these significant determinants of nutrition appear to have driven changes in nutritional outcomes during this period of rapid progress? To implement a decomposition of the sources of predicted change over time, we first need to establish whether there is substantive evidence of changes in coefficients across rounds. Table 4.2 reports two types of evidence to inform these issues. First, we report regressions for the full sample (total population of children 0–59 months). The changes in point estimates and standard errors across rounds give an approximate idea of coefficient stability and any potential trends in coefficients over time that might be suggestive of meaningful change (as opposed to just random change). Second, the last column of Table 4.2 summarizes the results of formal tests of differences in parameter values. Specifically we conducted Chow tests for significant differences between the coefficients of each X variable in the 1997 round against all the other rounds.

There are few signs of significant changes in coefficients across rounds. Consistent with results above, the coefficient on all vaccines shows some signs of instability. In fact, this variable is significant only in the 2011 round, and its coefficient sometimes changes signs across rounds. We interpret this as further evidence that vaccinations are not a strong predictor of changes in HAZ scores, though we show some evidence below that they are a reasonably strong predictor of changes in severe stunting. Being "born in a medical facility" has insignificant coefficients in the first two rounds when medical facility births were relatively rare (with sample means of just 3.1 percent and 5.8 percent). Third, "open defecation" likewise has an insignificant coefficient in the last round when there was again very little variation (a mean of just 4.2 percent). Fourth, the coefficient on birth intervals shows some signs of instability. In 1997 the coefficient is positive but insignificant, but the coefficient is then relatively large in 2000 and 2004, and then more modest thereafter. Chow tests suggest that the coefficients in 2000 and 2004 are significantly different from 1997 but that the 2007 and 2011 coefficients are not significantly different from 1997. Finally, we find very small but statistically significant differences in the coefficients attached to maternal height.

**Table 4.2 Height-for-age z regressions for the full sample by round with tests for coefficient differences over time**

| Model | 1997 | 2000 | 2004 | 2007 | 2011 | Significant differences?[c] |
|---|---|---|---|---|---|---|
| Asset index, 1–10 | 0.052***<br>0.011 | 0.041***<br>0.01 | 0.066***<br>0.009 | 0.029***<br>0.01 | 0.036***<br>0.009 | No |
| Maternal education (years) | 0.022**<br>0.008 | 0.021***<br>0.008 | 0.017**<br>0.007 | 0.011<br>0.007 | 0.017***<br>0.006 | No |
| Paternal education (years) | 0.026***<br>0.007 | 0.017***<br>0.006 | 0.013**<br>0.006 | 0.022***<br>0.005 | 0.022***<br>0.005 | No |
| All vaccines[a] | –0.071*<br>0.042 | 0.04<br>0.043 | 0.065<br>0.044 | –0.009<br>0.051 | 0.096**<br>0.047 | Yes |
| Prenatal doctor visit | 0.178***<br>0.053 | 0.221***<br>0.049 | 0.195***<br>0.046 | 0.181***<br>0.051 | 0.109***<br>0.042 | No |
| Prenatal health professional visit | 0.085<br>0.066 | –0.025<br>0.059 | 0.067<br>0.045 | 0.025<br>0.049 | –0.025<br>0.041 | No |
| Born in medical facility | –0.039<br>0.114 | 0.052<br>0.076 | 0.175***<br>0.066 | 0.196***<br>0.061 | 0.128***<br>0.04 | Yes |
| Open defecation[b] | –0.032*<br>0.016 | –0.031*<br>0.018 | –0.056***<br>0.017 | –0.039**<br>0.019 | –0.008<br>0.018 | No |
| Piped water | 0.063<br>0.112 | –0.03<br>0.082 | –0.059<br>0.072 | –0.029<br>0.082 | 0.04<br>0.06 | No |
| Birth order | –0.033**<br>0.015 | –0.039***<br>0.015 | –0.029*<br>0.015 | –0.041**<br>0.018 | –0.041**<br>0.016 | No |
| Birth interval (years) | 0.014<br>0.009 | 0.037***<br>0.008 | 0.049***<br>0.007 | 0.027***<br>0.008 | 0.016***<br>0.006 | Yes |
| Health clinic alone | 0.012<br>0.048 | 0.034<br>0.042 | –0.03<br>0.037 | –0.058<br>0.04 | 0.057*<br>0.032 | No |
| Maternal height (centimeters) | 0.046***<br>0.004 | 0.049***<br>0.004 | 0.054***<br>0.003 | 0.057***<br>0.004 | 0.053***<br>0.003 | Yes |
| *R*-squared | .253 | .279 | .258 | .251 | .224 | |
| *N* | 4,512 | 4,019 | 4,750 | 3,962 | 5,871 | |

Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).

Note: Village-clustered standard errors are in parentheses. The regressions include a number of time-invariant controls, including regional fixed effects, month-specific child age dummy variables, and dummy variables for various categories of maternal age. ***10 percent, **5 percent, and ***1 percent significance levels. [a.] Vaccinations are measured for children 6 months or older only. [b.]Open defecation is measured as a cubic fraction to capture the non-linear relationships observed in our non-parametric graphs. [c.] Birth intervals are measured for proceeding children only.

Based on these tests, we conclude that there are few signs of any secular changes in the main parameters of interest and that some of the changes we do observe are driven by lack of variation in certain variables in either the beginning or end rounds. Oaxaca-Blinder decompositions using starting and end rounds would therefore suggest that changes in these variables had no significant impact on HAZ scores, a conclusion that would appear erroneous based on our pooled regression results. We therefore prefer the simple linear decompositions described in the previous section, in which we use the coefficients from Table 4.1. Table 4.3 reports detailed decomposition results for the full sample using only those variables that are statistically significant at the 5 percent level or higher in the first column of Table 4.1. The first column reports the estimated coefficient from that regression. The next three columns, respectively, report the 1997 and 2011 sample means and the change in means across time. The predicted change in HAZ scores is the product of this change in means and the estimated coefficient (for example, the predicted change in HAZ scores resulting from asset accumulation is 0.05 × 1.65 = 0.08). The last column reports the share of predicted change accounted for by each variable.

There are two important findings from Table 4.3. First, the model explains slightly more than half (55.7 percent, or 0.33 standard deviations) of the actual change in HAZ scores observed during this period (0.58 standard deviations). Second, among the sources of predicted change, wealth accumulation stands out as the single largest factor, explaining 23.4 percent of the predicted change in HAZ scores. However, when maternal and paternal education are combined they are an equally important factor (25.8 percent), with the bulk of the change resulting from the more rapid accumulation of education among the female population. After wealth and human capital accumulation, health factors emerge as the third-most-important factor, with prenatal doctor visits and medical facility births jointly accounting for 17.3 percent of the predicted change. However, it is difficult to link this contribution to explicit policies or programs. Finally, open defecation accounts for a relatively modest 12.1 percent of the predicted change, demographic changes (lower mean birth orders and shorter birth intervals) jointly account for 11.8 percent of the total change, and improvements in maternal height account for just less than 10 percent.

**Table 4.3 Decomposing sources of nutritional change for the full sample, 1997–2011**

| Variable | (1) Estimated coefficient | Sample mean: 1997 | Sample mean: 2011 | (2) Change in means | Predicted change in HAZ = (1) × (2) | Share of predicted change (%) |
|---|---|---|---|---|---|---|
| HAZ score (dependent variable) | | –2.19 | –1.61 | 0.58 | 0.33 | 100.00 |
| Asset index, 1–10 | 0.046 | 3.26 | 4.91 | 1.65 | 0.08 | 23.40 |
| Maternal education (years) | 0.016 | 2.45 | 5.56 | 3.10 | 0.05 | 15.30 |
| Paternal education (years) | 0.002 | 3.64 | 5.35 | 1.70 | 0.03 | 10.50 |
| Prenatal doctor visit | 0.176 | 0.20 | 0.37 | 0.18 | 0.03 | 9.50 |
| Born in medical facility | 0.115 | 0.03 | 0.25 | 0.22 | 0.03 | 7.80 |
| Open defecation | –0.027 | 2.25 | 0.80 | –1.46 | 0.04 | 12.10 |
| Birth order | –0.038 | 3.09 | 2.38 | –0.71 | 0.03 | 8.30 |
| Birth interval (years) | 0.028 | 2.36 | 2.76 | 0.40 | 0.01 | 3.50 |
| Maternal height (centimeters) | 0.051 | 150.33 | 150.95 | 0.62 | 0.03 | 9.70 |
| ***Ratio of predicted HAZ change to actual (%)*** | | | | | ***55.70*** | |

Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).

Note: HAZ = height-for-age z.

## 5. ROBUSTNESS TESTS

The decomposition in Table 4.3—and the regression underlying it—is obviously only one of many ways of analyzing these data, and there are a number of conceptual and statistical reasons to consider a range of alternative samples and estimators, including endogeneity problems, omitted variable biases, distributional concerns, and demographic issues. This section therefore describes the results of the following tests. First, we decompose changes in stunting and severe stunting instead of changes in mean HAZ scores for reasons stated above. Second, we use quantile regressions as an alternative means of exploring these distributional issues.[3] Third, we add maternal body mass index (BMI) to the model on the grounds that this indicator of maternal undernutrition may help explain increases in child growth in early life (0–6 months), including birth size (on the other hand, BMI may be endogenous, so we excluded it from our preferred model). Fourth, we perform decompositions for rural and urban subsamples. Fifth, we perform decompositions for under-twos instead of under-fives. Sixth, we estimate models that exclude indicators of antenatal and neonatal care and demographic variables on the grounds that these potentially may be driven by demand-side factors (for example, economic growth, changes in preferences) rather than supply-side factors (particularly government- or NGO-based health service provision). The inclusion of health factors as potentially endogenous variables in the model could potentially bias other coefficients in the model, suggesting there are grounds to consider excluding them. Some of these results are reported in Table 5.1, and others are reported in the Appendix A.

Starting with the switch from the continuous HAZ variable to stunting and severe stunting, we find that the stunting results are quite similar to the HAZ results (unsurprisingly since the mean HAZ score in the pooled sample is close to –2). Moreover, the quantitative significance of the results also appears broadly similar (for example, the ratio of the asset index coefficient to the two educational coefficients). However, when we consider severe stunting, we find that prenatal visits with other health professionals—mostly government or NGO health workers—yields a statistically significant coefficient that is strongly associated with reducing the risk of severe stunting. By contrast, being born in a medical facility is no longer an important predictor, perhaps because only children of much wealthier households tend to be born in medical facilities. Our quantile regression results (reported in Appendix Table A.4) tell a similar story. Results at the 50th HAZ quantile (the median) are very similar to the ordinary least squares result, as expected, but results at the 25th HAZ quantile (which is –2.9) are similar to the regressions on severe stunting: vaccinations and prenatal visits from other health professionals now become significant. The only difference is that being born in a medical facility still significantly predicts child growth at the 25th percentile.

Table 5.1 also reports results from adding the log of maternal BMI to the model. We add this variable for an estimation on the full sample and for the restricted sample of children aged 0 to 6 months. In the full sample we observe a large and highly significant coefficient of 0.63 on this variable. As noted above, however, this coefficient could be biased because maternal BMI and child nutrition outcomes could be jointly correlated with some unobservable third factor(s). Since we primarily expect maternal undernutrition to influence child growth through intrauterine growth and the first few months of exclusive breast-feeding, restricting the sample to children aged 0 to 6 months may give a truer estimate of the relevance of maternal undernutrition. When we implement this restriction the coefficient drops from 0.63 to 0.43. We use this more conservative marginal effect of 0.43 in our decomposition below.

Another endogeneity concern pertains to the health and fertility variables. The last column in Table 5.1 reports this result for HAZ scores. As might be expected, we find that excluding health and fertility variables does affect the coefficient on the asset index and the maternal education variable (since maternal education tends to affect fertility rates more than paternal education; see Schultz 1997). However, by far the larger effect is on the asset index coefficient, which increases by 24 percent (a similar result holds for stunting and severe stunting—see Appendix Table A.5). This larger coefficient on the asset index will obviously mean that a larger share of the nutritional change from 1997 to 2011 may be attributed to wealth (see below).

[3] See Block, Masters, and Bhagowalia (2012) and Srinivasan, Zanello, and Shankar (2013) for other examples of this approach in the nutrition literature.

**Table 5.1 Comparing the baseline model to stunting, severe stunting, and models with maternal BMI included**

| Sample<br>Model | Full sample<br>HAZ, baseline | Full sample<br>Stunting | Full sample<br>Severe stunting | Full sample<br>HAZ, BMI added | 0–6 months<br>HAZ, BMI added | Full sample<br>HAZ, no health or fertility variables |
|---|---|---|---|---|---|---|
| Asset index, 1–10 | 0.046*** | –0.014*** | –0.010*** | 0.040*** | 0.015 | 0.057*** |
| | 0.004 | 0.002 | 0.001 | 0.004 | 0.013 | 0.004 |
| Maternal education (years) | 0.016*** | –0.005*** | –0.004*** | 0.015*** | 0.022** | 0.023*** |
| | 0.003 | 0.001 | 0.001 | 0.003 | 0.009 | 0.003 |
| Paternal education (years) | 0.020*** | –0.007*** | –0.003*** | 0.019*** | 0.022*** | 0.024*** |
| | 0.002 | 0.001 | 0.001 | 0.002 | 0.008 | 0.002 |
| All vaccinations[a] | 0.037* | –0.01 | –0.018*** | 0.034* | | |
| | 0.02 | 0.008 | 0.007 | 0.02 | | |
| Prenatal doctor visit | 0.176*** | –0.059*** | –0.038*** | 0.163*** | 0.159** | |
| | 0.021 | 0.008 | 0.007 | 0.021 | 0.063 | |
| Prenatal health professional visit | 0.027 | –0.012 | –0.023*** | 0.027 | 0.054 | |
| | 0.022 | 0.009 | 0.007 | 0.022 | 0.065 | |
| Born in medical facility | 0.115*** | –0.035*** | 0.008 | 0.088*** | –0.067 | |
| | 0.027 | 0.01 | 0.007 | 0.027 | 0.08 | |
| Open defecation[b] | –0.027*** | 0.010*** | 0.009*** | –0.024*** | –0.02 | –0.026*** |
| | 0.007 | 0.003 | 0.002 | 0.007 | 0.022 | 0.008 |
| Piped water | 0.000 | 0.011 | 0.01 | –0.019 | –0.203* | |
| | 0.034 | 0.012 | 0.009 | 0.034 | 0.107 | |
| Birth order | –0.038*** | 0.012*** | 0.013*** | –0.036*** | 0.037* | |
| | 0.007 | 0.003 | 0.002 | 0.007 | 0.021 | |
| Birth interval (years)[c] | 0.028*** | –0.009*** | –0.008*** | 0.026*** | 0.033*** | |
| | 0.003 | 0.001 | 0.001 | 0.003 | 0.01 | |
| Health clinic alone | 0.006 | 0.001 | –0.001 | 0.007 | 0.098* | |
| | 0.017 | 0.007 | 0.005 | 0.017 | 0.053 | |
| Maternal height | 0.051*** | –0.017*** | –0.011*** | 0.052*** | 0.045*** | 0.051*** |
| | 0.002 | 0.001 | 0 | 0.002 | 0.004 | 0.002 |
| Male child | –0.009 | 0.006 | 0.006 | –0.008 | –0.076 | |
| | 0.016 | 0.006 | 0.005 | 0.016 | 0.047 | |
| Maternal BMI, log | | | | 0.625*** | 0.432** | |
| | | | | 0.062 | 0.18 | |
| *R*-squared | .252 | .181 | .121 | .256 | .136 | .239 |
| *N* | 23,114 | 23,114 | 23,114 | 23,106 | 3,123 | 27,130 |

Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).

Note: BMI = body mass index; HAZ = height-for-age z. Village-clustered standard errors are in parentheses. The regressions include a number of time-invariant controls, including regional fixed effects, month-specific child age dummy variables, and dummy variables for various categories of maternal age. Dashes indicate the variable was not included in the model. ***10 percent, **5 percent, and ***1 percent significance levels. [a.] Vaccinations are measured for children 6 months or older only. [b.] Open defecation is measured as a cubic fraction to capture the non-linear relationships observed in our non-parametric graphs. [c.] Birth intervals are measured for proceeding children only.

Indeed, in Table 5.2 we examine how the different models and samples used in Tables 4.1 and 5.1 influence the decomposition results. Specifically, we compare the baseline full-sample HAZ result to results for rural and urban areas, to models with stunting and severe stunting as the dependent variables, and to the model that includes maternal BMI as an explanatory variable. Along with reporting the contributions of each variable to total predicted change, we also report more aggregated effects (for example, maternal and paternal education are aggregated into "education") and also how well each model does in terms of explaining actual changes in the dependent variables.

**Table 5.2 Decomposition based on alternative samples and dependent variables**

| **Dependent Variable** | **HAZ** | **HAZ** | **HAZ** | **HAZ** | **Stunting** | **Severe stunting** | **HAZ** |
|---|---|---|---|---|---|---|---|
| **Area** | **All** | **Rural** | **Urban** | **All** | **All** | **All** | **All** |
| **Model** | **Full** | **Full** | **Full** | **BMI added** | **Full** | **Full** | **No health, fertility** |
| **Disaggregated sources of predicted change (%)** | | | | | | | |
| Asset index, 1–10 | 23.4 | 24.0 | 21.8 | 17.8 | 22.6 | 20.6 | 33.7 |
| Maternal education (years) | 15.3 | 15.4 | 13.3 | 12.2 | 14.9 | 14.5 | 26.4 |
| Paternal education (years) | 10.5 | 8.2 | 12.5 | 8.6 | 11.0 | 6.5 | 14.5 |
| All vaccines (0–1) | | | | | | 5.7 | |
| Prenatal doctor visit | 9.5 | 8.4 | 7.0 | 7.7 | 9.0 | 8.0 | |
| **Prenatal other health professional** | | | | | | 5.3 | |
| Born in medical facility | 7.8 | 8.6 | 6.5 | 5.2 | 7.2 | | |
| Open defecation | 12.1 | 12.3 | 19.7 | 9.3 | 13.3 | 16.0 | 13.9 |
| Birth order | 8.3 | 7.7 | 11.9 | 6.8 | 8.3 | 11.2 | |
| Birth interval (years) | 3.5 | 4.4 | 3.3 | 2.8 | 3.4 | 4.0 | |
| Maternal height (centimeters) | 9.7 | 10.9 | 4.1 | 20.1 | 10.2 | 8.2 | 11.5 |
| Maternal BMI | | | | 9.5 | | | |
| Sum | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| **Aggregated sources of predicted change (%)** | | | | | | | |
| Wealth | 23.4 | 24.0 | 21.8 | 17.8 | 22.6 | 20.6 | 33.7 |
| Education | 25.8 | 23.6 | 25.7 | 20.8 | 25.9 | 21.0 | 40.9 |
| Health | 17.3 | 17.0 | 13.5 | 12.9 | 16.3 | 19.0 | |
| Sanitation | 12.1 | 12.3 | 19.7 | 9.3 | 13.3 | 16.0 | 13.9 |
| Demography | 11.8 | 12.1 | 15.2 | 9.6 | 11.7 | 15.2 | |
| Maternal nutrition | 9.7 | 10.9 | 4.1 | 29.6 | 10.2 | 8.2 | 11.5 |
| Sum | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | |
| **Predictive power of model** | | | | | | | |
| (1) Actual change in nutrition | 0.58 | 0.57 | 0.58 | 0.58 | –0.19 | –0.16 | 0.58 |
| (2) Predicted change in nutrition | 0.33 | 0.24 | 0.37 | 0.39 | –0.10 | –0.08 | 0.28 |
| Predictive power: (2) / (1) (%) | 55.7 | 47.8 | 67.6 | 63.9 | 56.1 | 49.1 | 47.4 |

Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).

Note: HAZ = height-for-age z; BMI = body mass index.

Overall, the conclusions of the baseline model are fairly robust, though with some exceptions. Switching to a rural sample makes almost no difference, but switching to the urban sample unsurprisingly increases the contribution of improved sanitation to nutritional change from 12.5 percent in the baseline to 19.7 percent in urban areas. The model for urban areas also has greater explanatory power, accounting for two-thirds of the actual change in HAZ scores in urban Bangladesh. The model with maternal BMI added as an explanatory variable also explains about two-thirds of the actual change in HAZ scores for the country as a whole, and maternal height and body mass together account for almost 30 percent of the predicted change (even after using the more conservative marginal effect of maternal BMI), making improvements in maternal undernutrition the single largest driver of change. Switching to stunting instead of HAZ scores makes almost no difference to the contributions of the different factors, but switching to severe stunting suggests that vaccinations and prenatal visits have contributed significantly to reducing severe undernutrition. Moreover, in this model wealth, education, and health variables each account for about 20 percent of the predicted change.

Finally, if we view the health and fertility variables with some suspicion and exclude them from the model, then—as expected—wealth accumulation becomes a much more important factor, accounting for around one-third of the predicted change in mean HAZ scores.

# 6. CONCLUSIONS

While South Asia is generally synonymous with high rates of undernutrition and poor progress against this problem, Bangladesh has managed to consistently reduce rates of stunting for at least two decades. Given that this progress was seemingly achieved without the aid of highly effective nutrition programs, this paper sought to understand which "nutrition-sensitive" factors appear to have been driving these changes.

Our principal finding is that the process of nutritional change in Bangladesh has been multidimensional. Economic development (as reflected by wealth accumulation at the household level) and rapid gains in education (maternal and paternal) typically emerge as the two most important factors. Both factors have been heavily influenced by policies and investments, particularly the secondary school stipend for girls in the case of education.

But the fact that health, sanitation, and demographic variables are highly significant after controlling for wealth and parental education might suggest that supply-side factors in these sectors have played an important role too (especially if the asset index is a strong enough predictor of household economic status). From very low bases, utilization of antenatal and neonatal care has improved rapidly. Some of this change was led by the private sector, though expansion of NGO and government-sector maternal healthcare seems to have played an important role in reducing severe stunting.

The government and NGO sectors likely played an even more central role in reducing fertility rates and increasing birth spacing. Indeed, the speed of fertility decline was even more rapid prior to 1997 than afterward (when economic growth and educational gains were more limited), suggesting that family planning policies have played an important role in explaining the longer-term decline in child undernutrition in Bangladesh. To investigate what role the longer-term decline in fertility rates since the 1970s might have had on undernutrition rates we therefore conducted a simple *backcasting* exercise. Using fertility rates and birth spacing results for 1975 (reported in Cleland et al. 1994) and our baseline regression results, we estimate that improvements in demographic outcomes from 1975 to 2011 accounted for a 0.21 standard deviation increase in child growth HAZ scores and a 6.7 point decline in stunting prevalence during this period.[4] Thus, Bangladesh's long-term emphasis on proactive family planning seems to have had sizeable benefits in reducing undernutrition in addition to other documented benefits in terms of maternal and child mortality outcomes (Joshi and Schultz 2013).

Finally, consistent with emerging evidence on its importance in explaining India's unusually high undernutrition rate (Spears 2013), it appears that major efforts to reduce open defecation have played an important role in improving child growth outcomes in Bangladesh, though more so in urban areas. Also of interest are the respective roles of traditional government-led investment in sanitation infrastructure as opposed to the largely behaviorally oriented Community-led Total Sanitation campaigns. Unfortunately, the DHS data are not able to shed light on this.

Finally, we offer some conjectures on an important limitation of our empirical results: namely, that they typically explain only slightly more than half of the actual change in child nutrition outcomes. One explanation may be that the nutrition-specific interventions referred to in our Introduction were more widespread and more effective than previous research has suggested. Consistent with this hypothesis, the DHS data suggest that the proportion of children aged 6 to 9 months who were introduced to solid foods rose from an appallingly low 21.9 percent in 1996/1997 to around 70 percent by 2004. Only a small portion of this change is accounted for by gains in wealth and paternal education, so it is possible that nutritional programs did play some role, especially in a country where a wide range of NGOs and international development agencies were implementing nutritional programs in a highly decentralized setting.

[4] Specifically, Cleland et al. (1994) report an average fertility rate of 7 children in 1975 and median birth spacing of 33 months, whereas the 2011 Bangladesh Demographic and Health Survey reports an average fertility rate of 2.30 children and median birth spacing of 47.40 months. We multiply these changes by the relevant coefficients reported in the previous section to obtain these estimates of the long-term contribution of demographic change to improved nutrition outcomes.

A second promising explanation of this residual nutritional enigma in Bangladesh is the country's rapid agricultural development, which certainly played a major role increasing basic household food security (World Bank 2005b). This growth was largely led by a 70 percent increase in rice production from 1997 to 2011. There are several pieces of circumstantial evidence pointing to a significant impact of rice productivity growth. First, nutritional improvement was much more rapid in rural (that is, agricultural) communities than in urban communities (Section 2). Second, agricultural growth could well have an impact on nutrition outcomes independent of asset accumulation, which is only an imperfect indicator of household economic status. Particularly important in Bangladesh has been the rise of the once secondary rice crop, the irrigated *boro* crop. In 1996/1997 the *boro* crop accounted for only 40 percent of total rice production, but by 2011 it accounted for 58 percent. The rise of such a productive second-season crop may have substantially reduced seasonal deprivation of nutrients and reduced any intrahousehold rationing of food for mothers and young children. Finally, the coefficients on the time dummies in Table 4.1 suggest that our model performs particularly poorly in the 1996/1997 to 2000 period when *boro*-led growth in rice production was particularly rapid, growing by 60 percent in just four years.

These hypotheses remain entirely conjectural, but exploring them further should be a priority objective of future research.

## APPENDIX A: SUPPLEMENTARY TABLES AND FIGURES

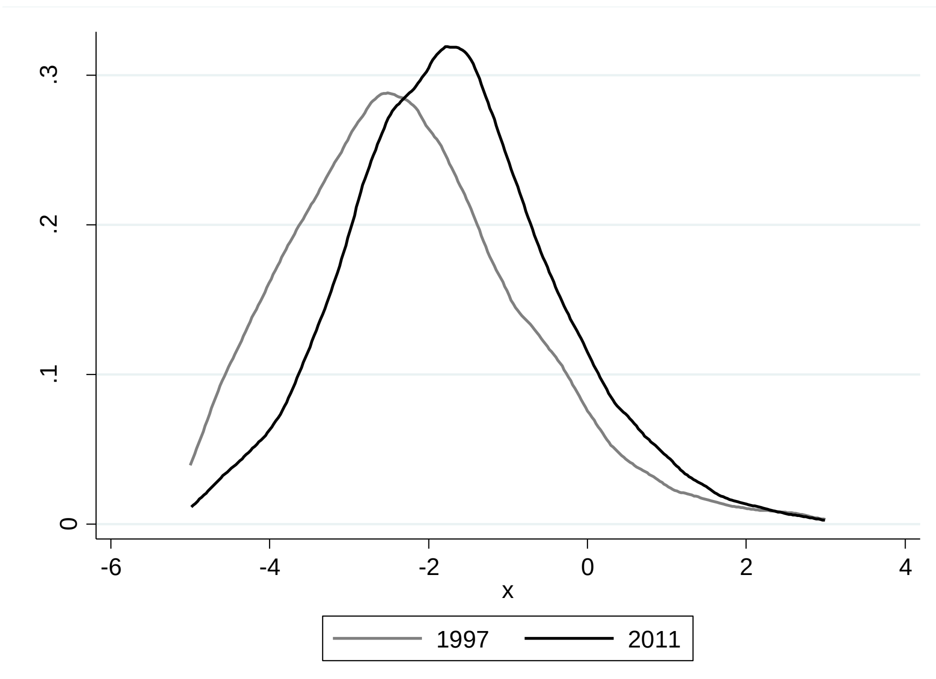
**Table A.1 Trends in HAZ scores and stunting, boys and girls**

| | Boys | | Girls | |
|---|---|---|---|---|
| Year | HAZ | Stunting | HAZ | Stunting |
| 1997 | -2.21 | 59.0% | -2.18 | 58.1% |
| 2000 | -1.92 | 49.4% | -1.91 | 49.1% |
| 2004 | -1.90 | 49.0% | -1.86 | 48.4% |
| 2007 | -1.71 | 42.9% | -1.73 | 42.6% |
| 2011 | -1.58 | 39.1% | -1.65 | 40.5% |

Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).

Note: HAZ = height-for-age z score.

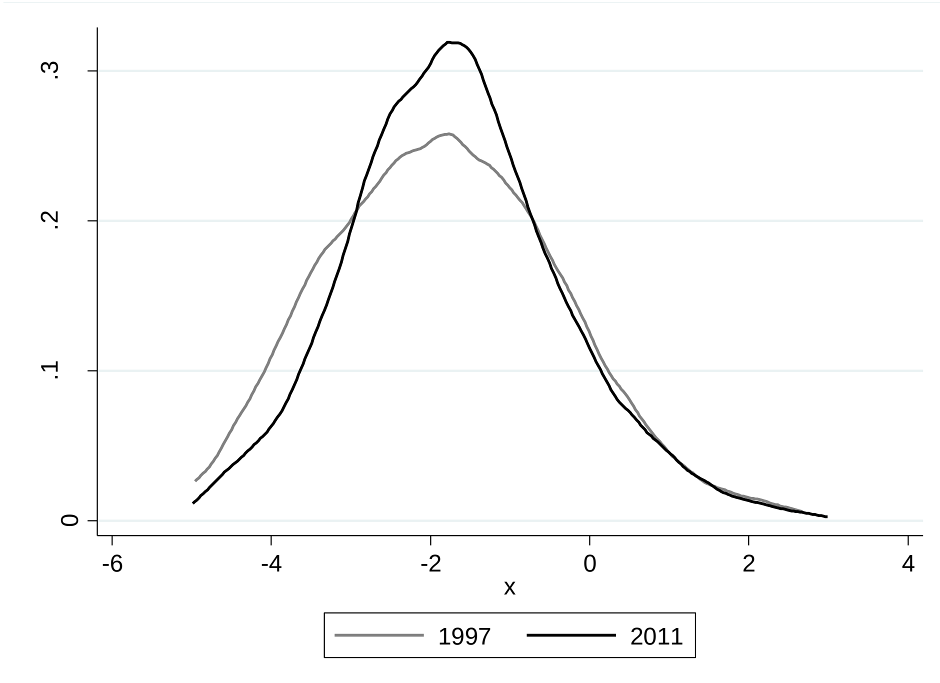
**Figure A.1 Changes in the distribution of HAZ scores 1997-2011, rural areas**




Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).

Note: HAZ = height-for-age z score.

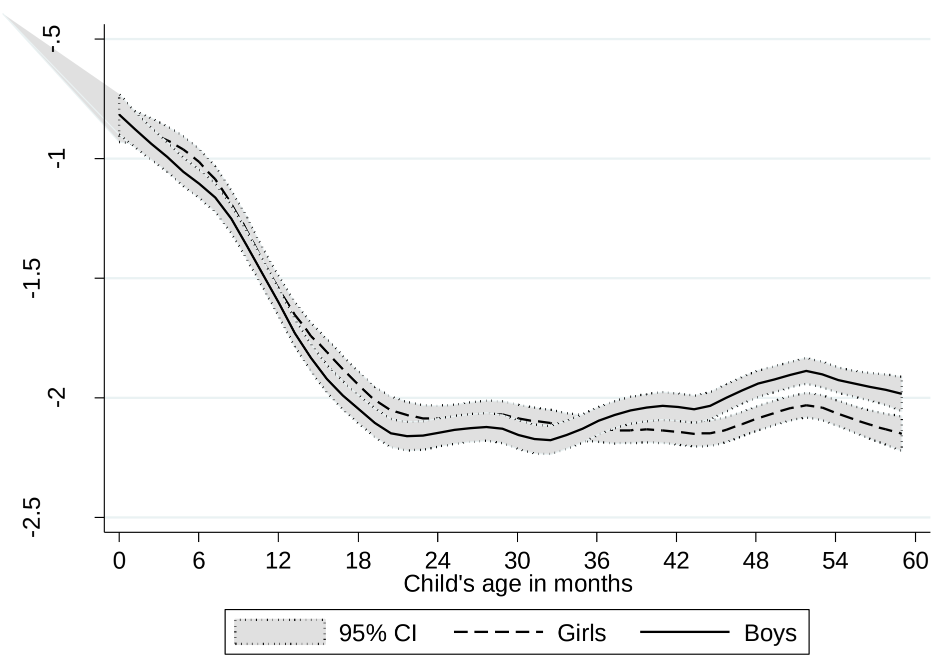
**Figure A.2 Changes in the distribution of HAZ scores 1997-2011, urban areas**




Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).

Note: HAZ = height-for-age z score.

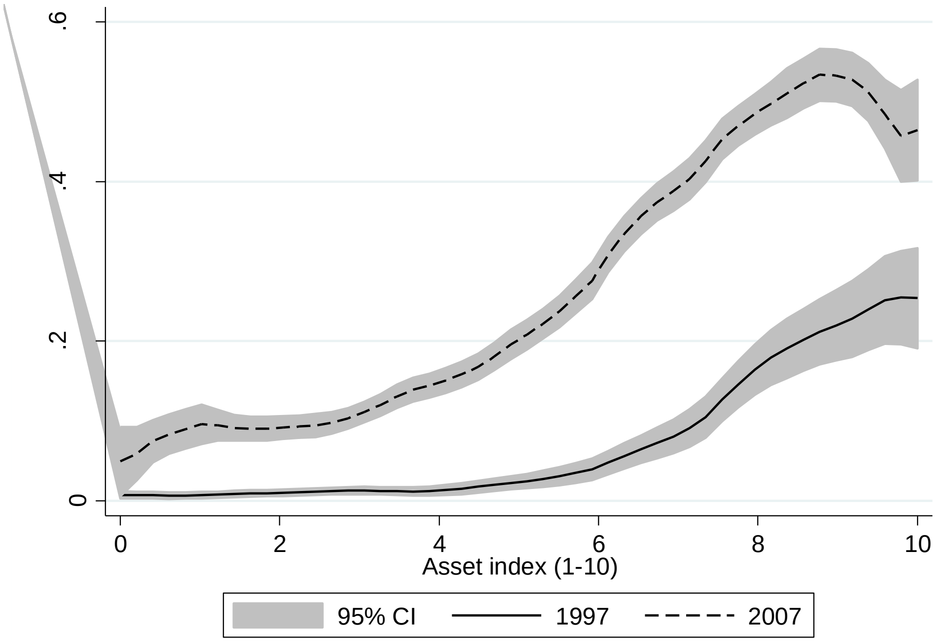
**Figure A.3 Growth faltering by child's age, boys and girls, pooled sample**




Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).

Note: HAZ = height-for-age z score; CI = confidence interval. These are local polynomial estimates of the predicted relationships between the two variables, with 95 percent confidence.

**Figure A.4 The relationship between the proportion of births in medical facilities and the wealth index, 1997 and 2007**




Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; NIPORT, Mitra and Associates and ICF International 2013).

Note: CI = confidence interval.

**Table A.2. Tests of coefficient stability**

| Comparison | Asset index | Any sickness | Birth order |
|---|---|---|---|
| 1997-2000 | 0.46 | 0.89 | 0.77 |
| 1997-2004 | 0.50 | 0.99 | 0.81 |
| 1997-2007 | 0.13 | 0.70 | 0.71 |
| 1997-2011 | 0.21 | 0.86 | 0.71 |
| Comparison | Maternal education | Prenatal doctor visit | Preceding birth interval |
| 1997-2000 | 0.61 | 0.53 | 0.05** |
| 1997-2004 | 0.38 | 0.70 | 0.01*** |
| 1997-2007 | 0.17 | 0.68 | 0.31 |
| 1997-2011 | 0.34 | 0.38 | 0.86 |
| Comparison | Paternal education | Birth in medical facility | Maternal height |
| 1997-2000 | 0.60 | 0.44 | 0.54 |
| 1997-2004 | 0.13 | 0.08 | 0.08 |
| 1997-2007 | 0.70 | 0.05 | 0.02 |
| 1997-2011 | 0.64 | 0.13 | 0.12 |
| Comparison | All vaccinations | Open defecation | |
| 1997-2000 | 0.11 | 0.97 | |
| 1997-2004 | 0.04** | 0.26 | |
| 1997-2007 | 0.55 | 0.65 | |
| 1997-2011 | 0.01*** | 0.35 | |

Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).

**Table A.3 Correlations between key indicators**

| Indicator | HAZ | Assets | Mat. Educ. | Pat. Educ. | Vaccin-ations | Prenatal doctor | Prenatal other HP | Born private | Born public | No toilets | Water piped | Birth order | Birth interval | Clinic alone |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HAZ | 1.00 | | | | | | | | | | | | | |
| Asset index | 0.25 | 1.00 | | | | | | | | | | | | |
| Mat. educ | 0.26 | 0.59 | 1.00 | | | | | | | | | | | |
| Pat. educ | 0.25 | 0.58 | 0.69 | 1.00 | | | | | | | | | | |
| Vaccinations | -0.04 | 0.14 | 0.15 | 0.12 | 1.00 | | | | | | | | | |
| Prenatal- doc | 0.19 | 0.40 | 0.40 | 0.38 | 0.09 | 1.00 | | | | | | | | |
| Prenatal- HP | 0.02 | 0.03 | 0.08 | 0.01 | 0.05 | -0.32 | 1.00 | | | | | | | |
| Born private | 0.15 | 0.31 | 0.34 | 0.31 | 0.07 | 0.26 | -0.01 | 1.00 | | | | | | |
| Born public | 0.09 | 0.18 | 0.19 | 0.18 | 0.03 | 0.19 | 0.01 | -0.07 | 1.00 | | | | | |
| No toilet – village | -0.12 | -0.30 | -0.25 | -0.20 | -0.11 | -0.19 | -0.05 | -0.13 | -0.08 | 1.00 | | | | |
| Water – piped | 0.08 | 0.28 | 0.18 | 0.19 | 0.03 | 0.19 | 0.01 | 0.18 | 0.10 | -0.14 | 1.00 | | | |
| Birth order | -0.11 | -0.19 | -0.38 | -0.24 | -0.05 | -0.19 | -0.10 | -0.14 | -0.10 | 0.06 | -0.07 | 1.00 | | |
| Birth interval | 0.05 | 0.01 | -0.15 | -0.06 | 0.04 | -0.02 | 0.00 | -0.02 | -0.02 | -0.02 | 0.01 | 0.38 | 1.00 | |

Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).

Note: HAZ = height-for-age z score. Mat. Educ. = Maternal education level; Pat. Educ. = Paternal education level; HP = health professionals.

**Table A.4 Quantile regression results**

| Variable | OLS | Quantile - 25th | Quantile - 50th | Coefficient differences across 25th and 50th quantiles? (p-value) |
|---|---|---|---|---|
| Asset index, 1-10 | 0.046*** | 0.044*** | 0.044*** | 0.98 |
| | 0.004 | 0.005 | 0.007 | |
| Maternal education (years) | 0.016*** | 0.024*** | 0.014*** | 0.04 |
| | 0.003 | 0.006 | 0.004 | |
| Paternal education (years) | 0.021*** | 0.018*** | 0.023*** | 0.12 |
| | 0.002 | 0.003 | 0.003 | |
| All vaccinations[a] | 0.036* | 0.055** | 0.028 | 0.35 |
| | 0.020 | 0.028 | 0.028 | |
| Prenatal doctor visit | 0.175*** | 0.184*** | 0.186*** | 0.93 |
| | 0.022 | 0.025 | 0.029 | |
| Prenatal health professional visit | 0.025 | 0.058** | 0.025 | 0.05 |
| | 0.022 | 0.025 | 0.02 | |
| Born in medical facility | 0.116*** | 0.116*** | 0.136*** | 0.36 |
| | 0.027 | 0.031 | 0.033 | |
| Open defecation[b] | -0.027*** | -0.041*** | -0.037*** | 0.69 |
| | 0.007 | 0.009 | 0.008 | |
| Piped water | 0.001 | -0.047 | -0.003 | n.a. |
| | 0.034 | 0.05 | 0.047 | |
| Birth order | -0.039*** | -0.058*** | -0.043*** | 0.12 |
| | 0.007 | 0.009 | 0.007 | |
| Birth interval (years)[c] | 0.028*** | 0.033*** | 0.027*** | 0.09 |
| | 0.003 | 0.004 | 0.005 | |
| Health clinic alone | 0.005 | 0.001 | 0.001 | n.a. |
| | 0.017 | 0.021 | 0.019 | |
| Maternal height | 0.052*** | 0.054*** | 0.055*** | 0.72 |
| | 0.001 | 0.002 | 0.002 | |
| Male child | -0.008 | -0.025 | 0.009 | |
| | 0.016 | 0.017 | 0.015 | |
| | | | | |
| R-squared | 0.252 | 0.15 | 0.15 | |
| N | 23150 | 23150 | 23150 | |

Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).

Notes: OLS = Ordinary least squares. Standard errors are in parentheses. The regressions include a number of time-invariant controls, including regional fixed effects, month-specific child age dummy variables, and dummy variables for various categories of maternal age. Dashes indicate the variable was not included in the model. ***10 percent, **5 percent, and ***1 percent significance levels. [a.] Vaccinations are measured for children 6 months or older only. [b.] Open defecation is measured as a cubic fraction to capture the non-linear relationships observed in our non-parametric graphs. [c.] Birth intervals are measured for proceeding children only. Quantile regressions are estimated using STATA's system quantile regression command (sqreg), which allows tests of parameter equality across the two equations.

**Table A.5 The effect of excluding health and demographic variables on other coefficients in the model**

| **Dependent variable** | **HAZ** | **HAZ** | **Stunting** | **Stunting** | **Severe stunting** | **Severe stunting** |
|---|---|---|---|---|---|---|
| Model | Full model | Exclusions | Full model | Exclusions | Full model | Exclusions |
| Asset index, 1-10 | 0.046*** | 0.057*** | -0.014*** | -0.019*** | -0.010*** | -0.013*** |
| | 0.004 | 0.004 | 0.002 | 0.002 | 0.001 | 0.001 |
| Maternal education (years) | 0.016*** | 0.023*** | -0.005*** | -0.007*** | -0.004*** | -0.006*** |
| | 0.003 | 0.003 | 0.001 | 0.001 | 0.001 | 0.001 |
| Paternal education (years) | 0.021*** | 0.024*** | -0.007*** | -0.008*** | -0.003*** | -0.004*** |
| | 0.003 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 |
| Open defecation[a] | -0.027*** | -0.026*** | 0.009*** | 0.008*** | 0.009*** | 0.009*** |
| | 0.008 | 0.008 | 0.003 | 0.003 | 0.003 | 0.003 |
| Maternal Height (centimeters) | 0.052*** | 0.051*** | -0.017*** | -0.017*** | -0.011*** | -0.011*** |
| | 0.002 | 0.002 | 0.001 | 0.001 | 0.000 | 0.000 |
| R-squared | 0.252 | 0.239 | 0.182 | 0.172 | 0.121 | 0.111 |
| N | 23150 | 27130 | 23150 | 27130 | 23150 | 27130 |

Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).

Notes: HAZ = height-for-age z score. Village-clustered standard errors are in parentheses. The regressions include a number of time-invariant controls, including regional fixed effects, month-specific child age dummy variables, and dummy variables for various categories of maternal age. Dashes indicate the variable was not included in the model. ***10 percent, **5 percent, and ***1 percent significance levels. a. Open defecation is measured as a cubic fraction to capture the non-linear relationships observed in our non-parametric graphs.

## APPENDIX B: CONSTRUCTION OF AN ASSET INDEX

We identified 12 asset variables that could be measured consistently over the five rounds of the survey, covering dummy variables of household durables (radio, TV, motorcycles, *almirah*, and the number of chairs and tables), house and farm land ownership, household electricity access and housing characteristics (whether floors, walls and roofs are made out of "basic" materials such as earth, mud, dung, bamboo or thatch). Table B.1 shows trends in these 12 asset indicators over time. Notably, all 12 indicators show consistent improvement, except ownership of farm land, which declined marginally.

**Table B.1 Trends in various assets, 1997 to 2011**

| Year | Radio | Television | Bicycle | Motorcycle | House | Cropland |
|---|---|---|---|---|---|---|
| 1997 | 30.3% | 10.4% | 18.3% | 2.3% | 90.4% | 54.6% |
| 2000 | 31.4% | 17.8% | 18.8% | 2.8% | 90.1% | 46.5% |
| 2004 | 32.2% | 24.7% | 21.6% | 3.3% | 91.8% | 48.0% |
| 2007 | 22.6% | 31.7% | 21.1% | 4.1% | 92.6% | 44.4% |
| 2011 | 7.9% | 39.8% | 23.6% | 4.6% | 92.7% | 45.0% |
| **Year** | **Almirah** | **Tables, chairs (#)** | **Floor, basic** | **Roof, basic** | **Wall, basic** | **Electricity** |
| 1997 | 27.2% | 0.91 | 89.7% | 29.8% | 69.5% | 22.2% |
| 2000 | 26.6% | 0.97 | 83.3% | 22.4% | 60.1% | 33.8% |
| 2004 | 30.2% | 1.10 | 81.6% | 9.4% | 46.6% | 41.2% |
| 2007 | 45.2% | 1.23 | 70.7% | 6.1% | 18.9% | 47.1% |
| 2011 | 36.9% | 1.27 | 66.0% | 3.6% | 15.0% | 60.0% |

Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).

Next, we conducted a principal components analysis (PCA) to derive weights for these variables in a composite index, following Filmer and Pritchett (2001) and others. Table B.2 reports the factor loading (or weights) assigned to these 12 variables in the first four principal components. Following the literature on asset indices, particularly Filmer and Pritchett (2001), we take the first principal component as our asset index. This first principal component accounts for 40 percent of the total variation in all variables, suggesting the inter-correlation among assets is high (more on this below).

Table B.2 shows that this first component places relatively equal weights on electricity, TV ownership, motorcycle ownership, house ownership, furniture ownership and housing materials, and somewhat smaller weights on radio, bicycle and farm land ownership. Moreover, while it is sometimes recommended that rural and urban samples be given their own separate weighting schemes for asset indices, we find that running PCA separately for rural and urban areas derives very similar weighting schemes. We also tested sensitivity of the index to the inclusion of electricity, since this is largely a publicly provided service and an asset that might have non-wealth linkages to nutrition outcomes (by influencing cooking practices, hygiene or health and care practices). However, the exclusion of electricity of the index resulted in an index that was very highly correlated to the index that included electricity (0.99). Finally, we re-scale the first principal component such that it varies between a maximum of 100 and a minimum of zero.

**Table B.2 Loading (weights) on the first principal components for the total sample, rural and urban subsamples, and an asset list excluding electricity**

| Asset | Total | Rural | Urban | No electricity |
|---|---|---|---|---|
| Electricity | 0.29 | 0.28 | 0.27 | |
| Radio | 0.15 | 0.13 | 0.16 | 0.16 |
| Television | 0.32 | 0.34 | 0.29 | 0.32 |
| Bicycle | 0.17 | 0.15 | 0.20 | 0.18 |
| Motorcycle | 0.40 | 0.41 | 0.40 | 0.41 |
| House | 0.31 | 0.30 | 0.36 | 0.34 |
| Cropland | 0.19 | 0.22 | 0.24 | 0.22 |
| Almirah | 0.31 | 0.32 | 0.30 | 0.33 |
| Tables, chairs (#) | 0.42 | 0.42 | 0.43 | 0.44 |
| Floor, basic | -0.27 | -0.29 | -0.23 | -0.27 |
| Roof, basic | -0.22 | -0.17 | -0.22 | -0.23 |
| Wall, basic | -0.26 | -0.26 | -0.24 | -0.27 |

Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).

Figure B.1 shows trends in the distribution of asset scores in 1997, 2004 and 2011. Essentially the distribution of asset scores shifts in parallel to the right, with the spread of the distribution largely unchanged. Indeed, the standard deviation of wealth scores is essentially unchanged across years, at around 24 in each year.

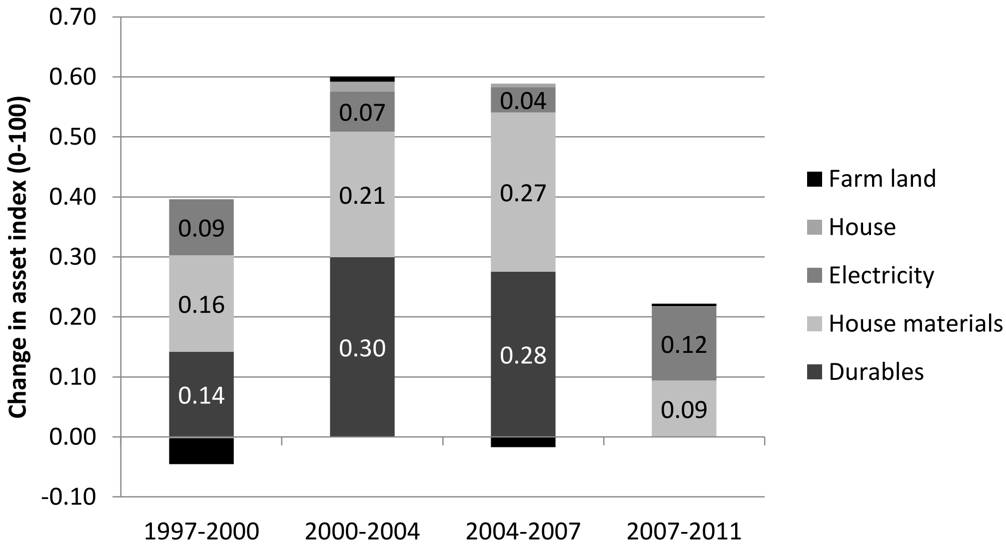
**Figure B.1 Trends in distribution of assets, 1997, 2004 and 2011**


Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).

Notes: These are kernel densities.

Figure B.2 shows the sources of change of asset scores across rounds, grouped under five broader heading: household durables, housing materials, electricity, house ownership and farm land ownership. Most of the change in asset scores over time is driven by household durables and housing materials, followed by electricity. However, the sources of change across rounds also varies somewhat, with household durables not contributing to any growth in the wealth index over 2007-2011.

**Figure B.2 Sources of change in the household asset index between BDHS rounds**

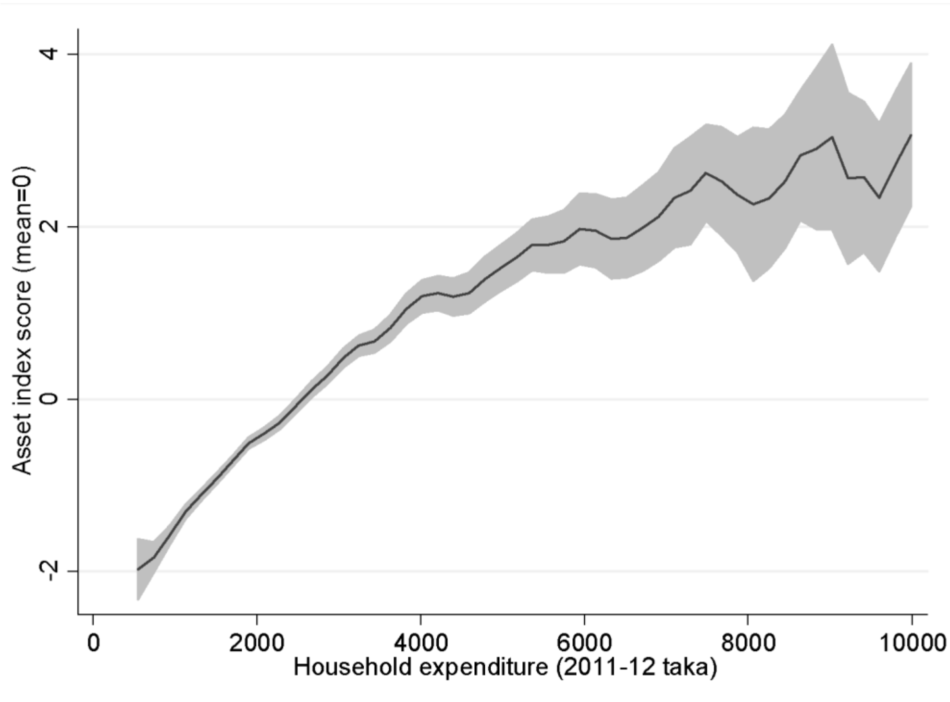



Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).
Notes: This is the change in the prevalence of each of the assets multiplied by its weights/loadings from the PCA.

Table B.3 shows correlations between the different indicators, and between child HAZ scores. The inter-correlations among assets is generally quite high, and many of the assets are significantly correlated with child HAZ scores, particularly motorcycle ownership, electricity, tables and chairs, TV ownership and electricity, and basic flooring. Conceivably some of these indicators may influence HAZ scores outside of wealth linkages. Radio and TV ownership could increase nutritional knowledge. Electricity could influence time use, cooking methods and sanitation outcomes, whilst housing materials might also influence sanitation and health outcomes. While we cannot rule out these linkages, we expect that they are quantitatively small linkages relative to the general effects of wealth on nutrition outcomes.

Finally, Figure B.3 utilizes a recent household survey from Bangladesh (the Bangladesh Integrated Household Survey, BIHS, of 2011–12), which is representative for rural areas only, to examine the relationship between the asset index and household expenditure, and to confirm that the asset index is a good proxy for household expenditure in Bangladesh. We first used the BIHS to first create a comparable asset index from the BIHS data (meaning, using the same variables), and then compared this to household expenditure from the same survey. As expected we find a strong but slightly curvilinear relationship. The asset index and expenditure share a tight, linear relationship up to expenditures of around 4,000 taka, but after that the gradient flattens out somewhat. This is unsurprising because the assets listed in this axis are typically dummy variables, meaning that their ability to distinguish among higher income groups is limited. For example, we record ownership of 1 television, but not of multiple televisions. This may also explain why we observe a linear relationship between the asset index and child HAZ scores, rather than a convex relationship. It also suggests the asset index is not ideal for examining inequality, since the scope for very rich households to improve the asset scores is inherently limited by the indicators available to us. Overall, though, these results strongly confirm those of the existing literature, which suggest that asset indices are very useful indicators of household economic status. Indeed, with the BIHS data we find that the asset index has an equally strong correlation with HAZ scores (0.15) as household expenditures (0.14), suggesting that there is no loss of explanatory power in our model from relying on asset scores rather than household expenditure.

**Figure B.3 Associations between the asset index and household expenditure from the 2011 Bangladesh Integrated Household Survey**




Source: Authors' estimates from the Bangladesh Integrated Household Survey (BIHS) implemented by The International Food Policy Research Institute (IFPRI).
Notes: This is a local polynomial prediction with 95% confidence intervals.

**Table B.3 Correlations between HAZ scores and various assets**

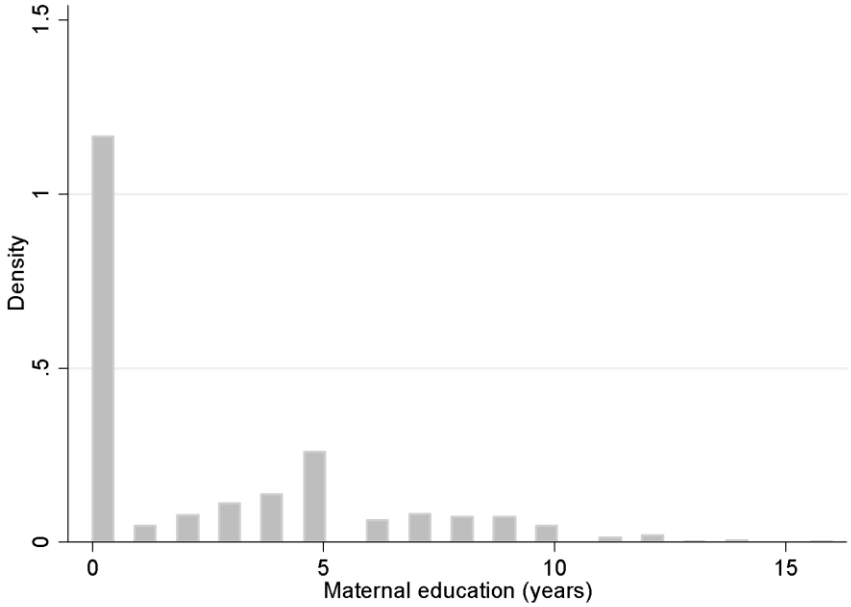
| Asset | HAZ | Electricity | Radio | Television | Bike | Motor-cycle | House | Farm-land | Almirah | Tables, chairs | Floor, basic | Roof, basic | Wall, basic |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HAZ | 1.00 | | | | | | | | | | | | |
| Electricity | 0.19 | 1.00 | | | | | | | | | | | |
| Radio | 0.07 | 0.15 | 1.00 | | | | | | | | | | |
| Television | 0.20 | 0.59 | 0.19 | 1.00 | | | | | | | | | |
| Bicycle | 0.07 | 0.11 | 0.16 | 0.17 | 1.00 | | | | | | | | |
| Motorcycle | 0.23 | 0.59 | 0.26 | 0.78 | 0.35 | 1.00 | | | | | | | |
| House | 0.16 | 0.41 | 0.23 | 0.45 | 0.13 | 0.69 | 1.00 | | | | | | |
| Farm land | 0.22 | 0.60 | 0.27 | 0.67 | 0.47 | 0.80 | 0.71 | 1.00 | | | | | |
| Almirah | 0.12 | 0.21 | 0.21 | 0.28 | 0.35 | 0.47 | 0.40 | 0.77 | 1.00 | | | | |
| Tables, chairs | 0.07 | 0.05 | 0.15 | 0.09 | 0.19 | 0.37 | 0.17 | 0.42 | 0.83 | 1.00 | | | |
| Floor, basic | -0.18 | -0.50 | -0.14 | -0.52 | -0.06 | -0.80 | -0.40 | -0.41 | -0.05 | -0.07 | 1.00 | | |
| Roof, basic | -0.10 | -0.27 | -0.09 | -0.21 | -0.11 | -0.23 | -0.22 | -0.56 | -0.52 | -0.11 | 0.19 | 1.00 | |
| Wall, basic | -0.14 | -0.36 | -0.07 | -0.33 | -0.06 | -0.41 | -0.31 | -0.59 | -0.40 | -0.10 | 0.39 | 0.36 | 1.00 |

Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).

Note: HAZ = height-for-age z score.

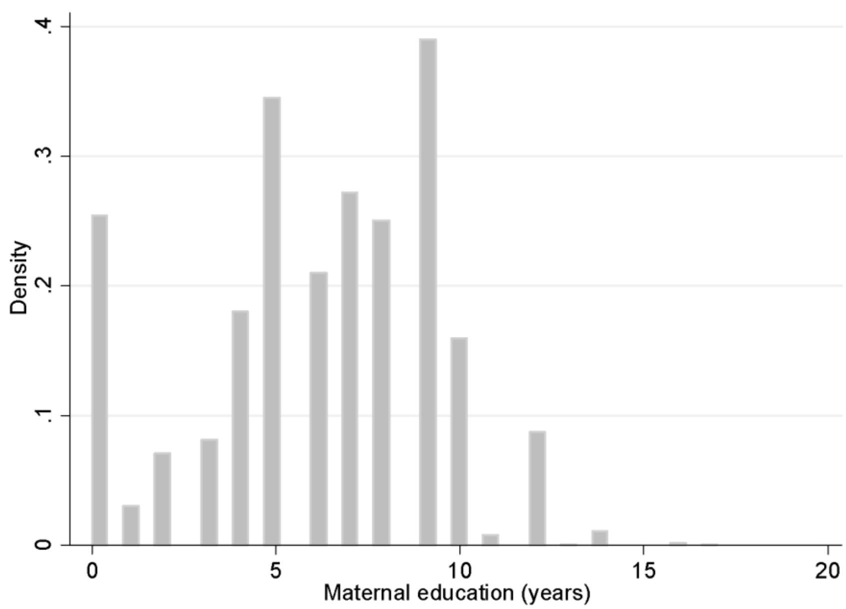
## APPENDIX C: ADDITIONAL RESULTS ON MATERNAL AND PATERNAL EDUCATION AND NUTRITION

**Figure C.1 The distribution of maternal educational attainment (years) in 1997 for women less than 26 years old**



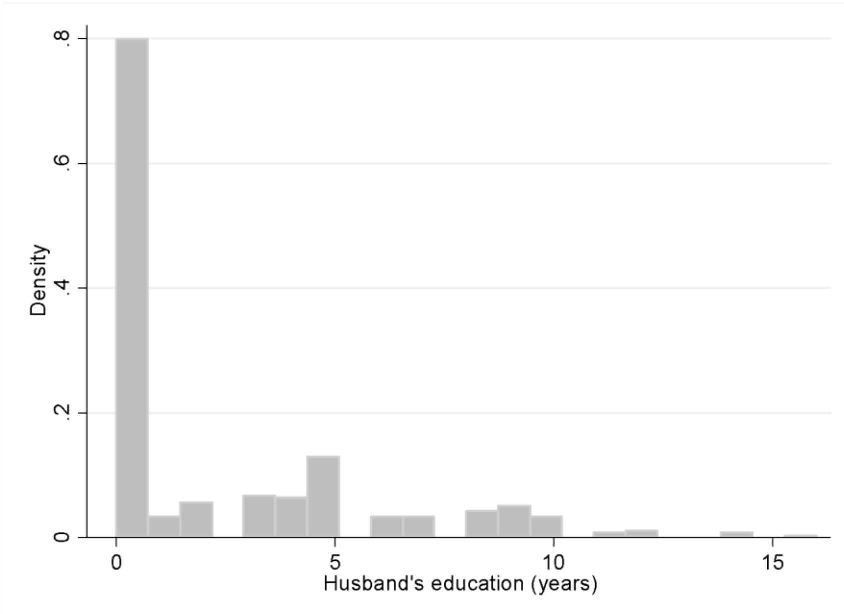

Source: Authors' estimates from the 1997 round of the DHS (NIPORT, Mitra and Associates and ORCM 1998).

**Figure C.2 The distribution of maternal educational attainment (years) in 2011 for women less than 26 years old**



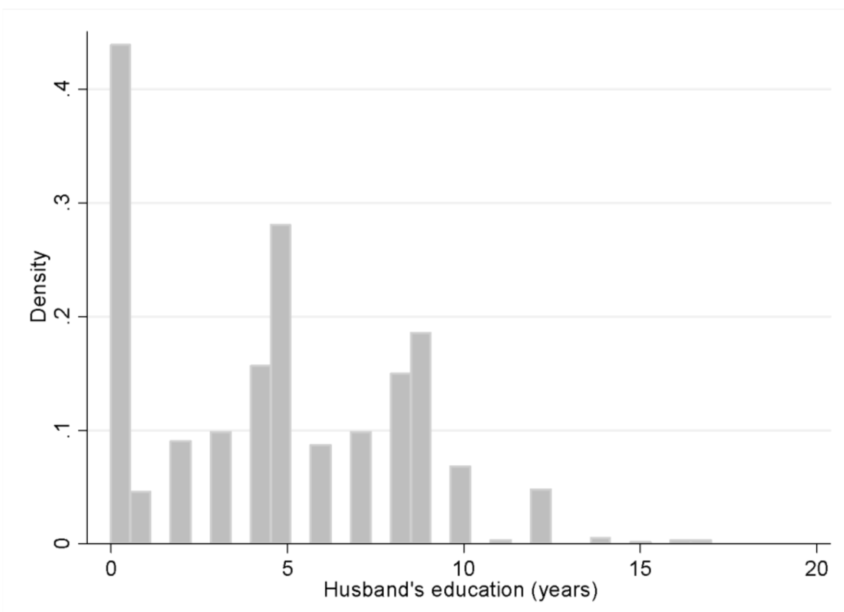

Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ICF International 2013).

**Figure C.3 The distribution of paternal educational attainment (years) in 1997 for men less than 26 years old**



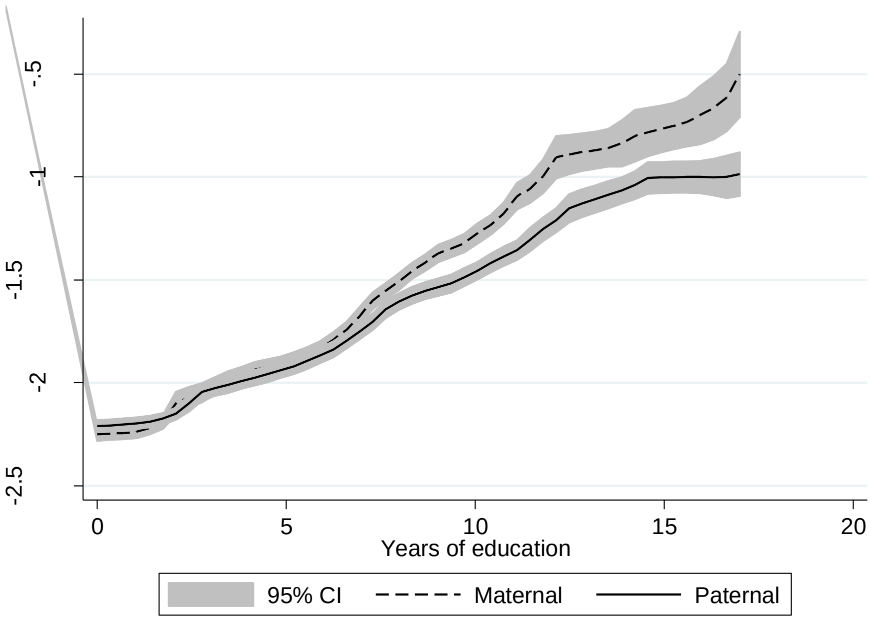

Source: Authors' estimates from the 1997 round of the BDHS (NIPORT, Mitra and Associates and ORCM 1998).

**Figure C.4 The distribution of paternal educational attainment (years) in 2011 for men less than 26 years old**




Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ICF International 2013).

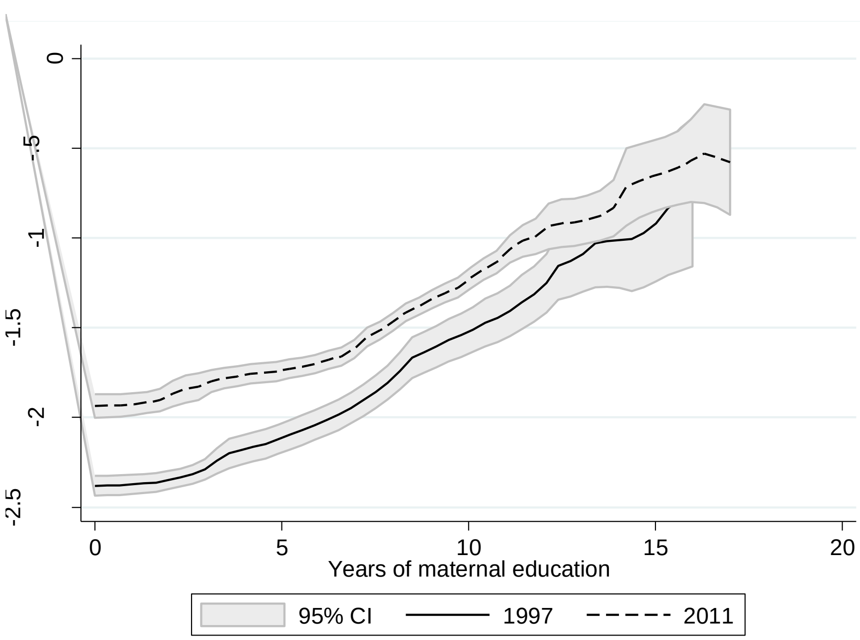
**Figure C.5 Maternal and paternal education as predictors of child HAZ scores**




Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).

Note: HAZ = height-for-age z score; CI = confidence intervals.

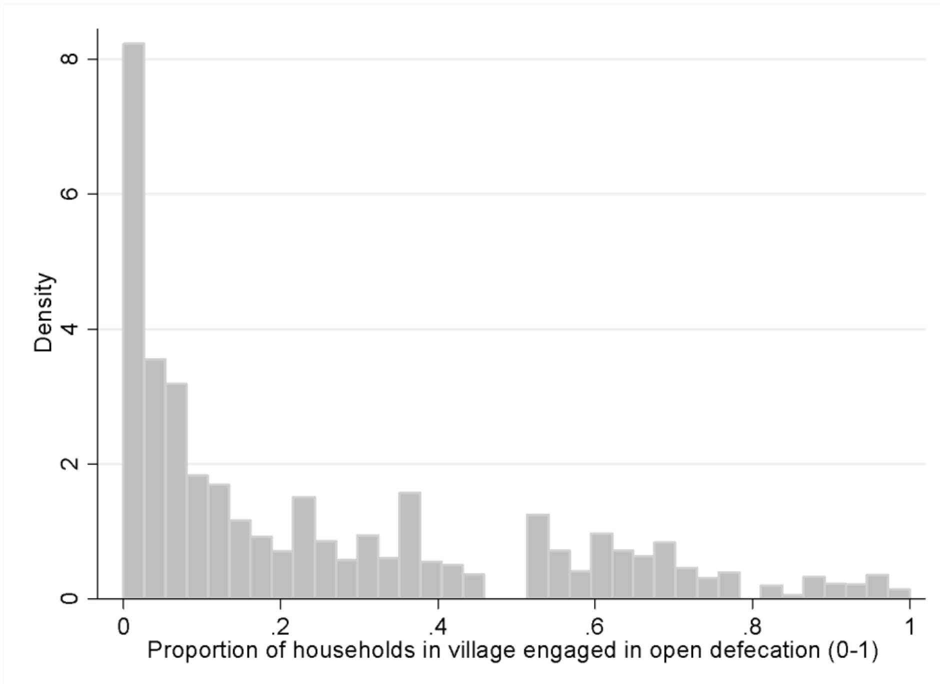
**Figure C.6 Maternal education and child HAZ scores, 1997 and 2011**




Source: Authors' estimates from the 1997 and 2011 rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; NIPORT, Mitra and Associates and ICF International 2005).

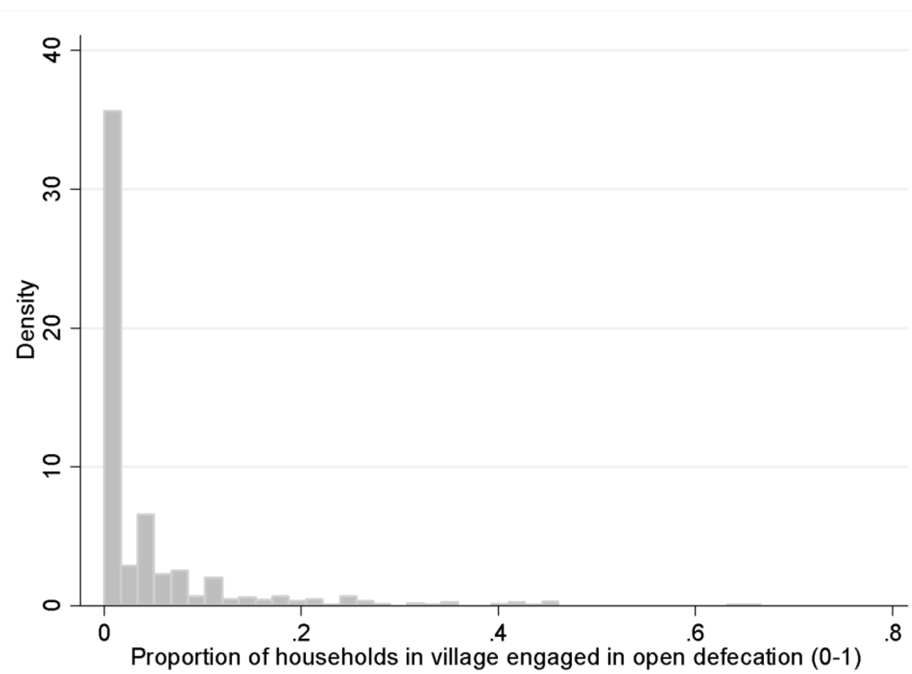
## APPENDIX D: ADDITIONAL RESULTS ON OPEN DEFECATION AND NUTRITION

**Figure D.1 Prevalence of open defecation in Bangladesh villages, 1997**



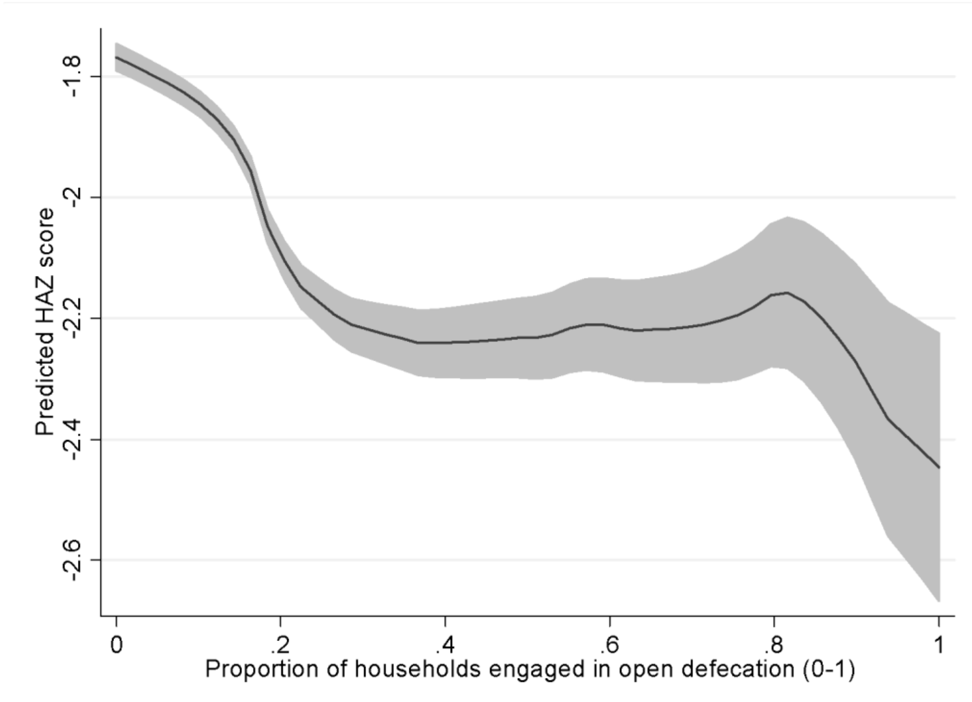

Source: Authors' estimates from the 1997 round of the DHS (NIPORT, Mitra and Associates and ORCM 1998).

**Figure D.2 Prevalence of open defecation in Bangladesh villages, 2011**



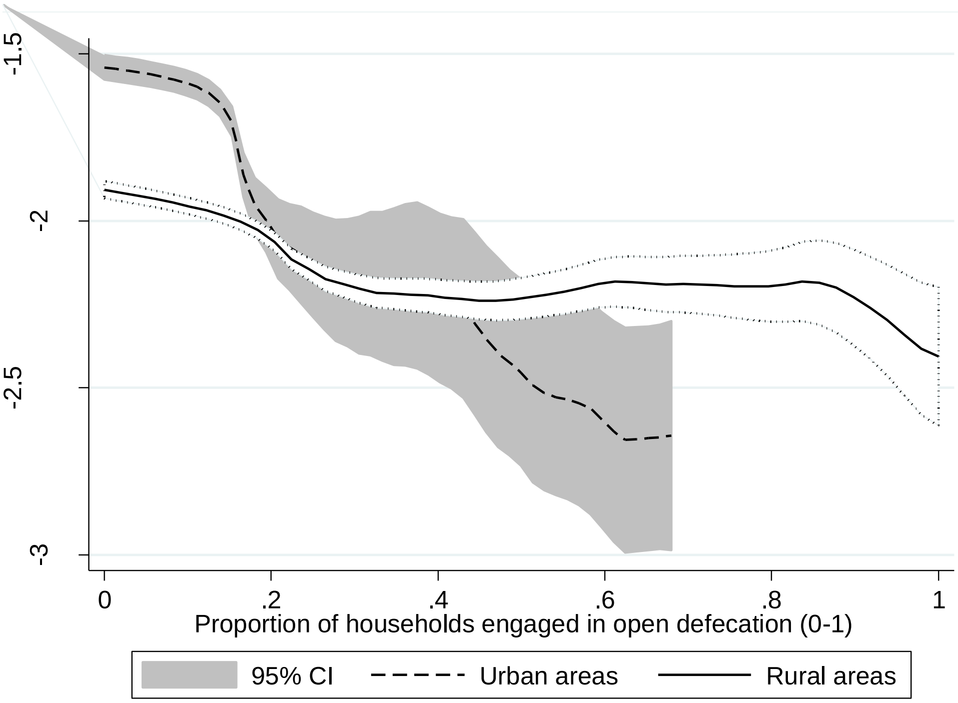

Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ICF International 2013).

**Figure D.3 Open defecation in Bangladeshi villages and HAZ scores, total sample**




Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).

**Figure D.4 Open defecation in Bangladeshi villages and HAZ scores, rural and urban subsamples**




Source: Authors' estimates from various rounds of the DHS (NIPORT, Mitra and Associates and ORCM 1998; 2001; NIPORT, Mitra and Associates and ICF International 2005; 2009; 2013).

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