I Z A Institute of Labor Economics
Initiated by Deutsche Post Foundation

DISCUSSION PAPER SERIES

IZA DP No. 12288

Neonatal Death in India: Birth Order in a Context of Maternal Undernutrition

Diane Coffey
Dean Spears

APRIL 2019

DISCUSSION PAPER SERIES

IZA DP No. 12288

Neonatal Death in India: Birth Order in a Context of Maternal Undernutrition

Diane Coffey
University of of Texas at Austin and Indian Statistical Institute

Dean Spears
University of of Texas at Austin, Indian Statistical Institute and IZA

APRIL 2019

ISSN: 2365-9793

IZA – Institute of Labor Economics

Schaumburg-Lippe-Straße 5–9
53113 Bonn, Germany

Phone: +49-228-3894-0
Email: publications@iza.org

www.iza.org

ABSTRACT

Neonatal Death in India: Birth Order in a Context of Maternal Undernutrition*

We document a novel fact about neonatal death, or death in the first month of life. Globally, neonatal mortality is disproportionately concentrated in India. We identify a large effect of birth order on neonatal mortality that is unique to India: later-born siblings have a steep survival advantage relative to the birth order gradient in other developing countries. We show that India's high prevalence of maternal undernutrition and its correlation with age and childbearing can explain this pattern. We find that Indian mothers exit the underweight body mass range at an internationally comparatively high rate as they progress through childbearing careers.

JEL Classification: O15, I15

Keywords: neonatal mortality, infant mortality, birth order, maternal nutrition, India

Corresponding author:
Dean Spears
Department of Economics
University of Texas at Austin
305 E. 23rd Street
Mail Stop G1800
Austin, Texas 78712
USA

E-mail: dspears@utexas.edu

* We are grateful to Melissa LoPalo and Aashish Gupta for outstanding research assistance and for comments from seminar audiences at the Penn Population Studies Centre & CASI; Princeton; UT-Austin; the Université du Québec à Montréal; Stockholm University; and the Austin-Bergen conference. We are grateful for comments from and discussion with Farzana Afridi, Jere Behrman, Sandra Black, Anne Case, Joe Cummins, Janet Currie, Angus Deaton, Irma Elo, Andrew Foster, Michael Geruso, Michel Guillot, Martin Kolk, Ilyana Kuziemko, Nicholas Lawson, Will Masters, Grant Miller, Gerald Oettinger, Steve Trejo, and Tom Vogl.

1 Introduction

The rapid human development of the past decades is reflected in a steep fall in infant mortality. In 1960, 12% of babies worldwide died in their first year of life compared to only 3% in 2015.[1] Over three-fifths of the infant deaths that still occur are neonatal deaths, meaning deaths in the first month of life. Although progress in reducing both neonatal and infant deaths has been rapid, it has also been uneven. Twenty-seven percent of neonatal deaths now occur in India. India has a large population, but its share of neonatal mortality is disproportionately large: it is home to 19% of worldwide births.

Why is neonatal mortality in India so disproportionately large? Investigating neonatal mortality (NNM)[2] in India, we document a novel fact. We identify a unique later-born NNM advantage in India. We exploit data on over 6 million births in the developing world to describe the relationship between birth order and mortality, following the econometric methods of Blake (1989) and Black et al. (2005). This empirical strategy allows us to separate birth order from other correlates of fertility in India that differ from other developing countries (Vogl, 2015). The gradient that we estimate is quantitatively large and is specific to NNM in India: there is no similarly large later-born advantage for NNM in the rest of the developing world, nor is there an internationally unusual later-born advantage for postneonatal mortality (death between months 2-11) in India. This poses a puzzle: why is NNM in India higher for early-born siblings than for later-born siblings? This result, as we show, is not explained by differences in medical care at birth.

We provide evidence that India's later-born NNM advantage reflects a pernicious intersection of maternal nutrition and women's social status in India (Das Gupta, 1995). Neonatal death is substantially influenced by birth weight and intrauterine growth. Moth-

[1]Sources and computations for these motivating demographic facts are fully detailed in section A of the online Supplementary Appendix.

[2]We use the abbreviation NNM for the neonatal mortality rate: neonatal deaths per 1,000 live births.

ers in India are especially likely to be underweight: as Coffey (2015b) showed, over 40% of women in India are underweight at the beginning of pregnancy (in the sense of low body mass relative to height). Moreover, as we document, the prevalence of underweight in India — in contrast with other developing populations — is particularly concentrated among young women at the beginning of their childbearing careers. As women in India age, have children, and gain social status, they become less likely to be underweight.

To explain India's unique later-born NNM advantage, we document these facts about maternal underweight for India, and show that they differ compared with the rest of the developing world. We use two strategies to show that the fraction of a cohort of mothers who are underweight declines as they age more steeply in India than elsewhere: first, by matching cohorts across repeated cross-sectional survey waves, and second, in a specialized longitudinal survey that tracked a sample of mothers in four developing countries.

The effects that we document are large. In fact, the pattern we document is large enough to be an important component of worldwide average NNM. This is in part because the effects that we find are large, and in part because India contributes a large fraction of global NNM. In the final part of the paper, we compute a projection of how different India's overall neonatal mortality rate would be, in the absence of its unique birth-order pattern (but with other correlations held equal). To do this, we ask how many Indian neonates would die if India's earlier-born disadvantage were only as large as the earlier-born disadvantage in other developing countries. Changing India in this hypothetical way would eliminate, in an accounting sense, about eight percent of all neonatal deaths worldwide. So, the links among maternal undernutrition, women's social status, and neonatal death in India should be a priority for human development policy.

1.1 Contributions to the literature

The facts presented in this paper make several contributions throughout empirical economics. First, correlates of birth order have received continued attention in labor economics and economic demography (Behrman and Taubman, 1986). Because of binding requirements for complete data that can separate sibsize from birth order, this literature has generally focused on developed countries where population-level administrative and vital records are available. No prior study has examined birth order in the developing world with such a large dataset, with so many mothers who have completed fertility.

In the developed-country literature on birth order and child outcomes, a common result is that later-born siblings are at a disadvantage. For example, Black et al. (2005) use a rich dataset that contains information on the entire population of Norway to show that later-born siblings attain less education.[3] In contrast, we find that later-born siblings are at an especially large neonatal mortality *advantage* in India because (unlike in other contexts) mothers' nutrition is a sharply restricted input to child health that improves over a childbearing career, reflecting improvements in social status. In particular, although we show that later-birth-order children are somewhat more likely to survive infancy throughout the developing world,[4] they are quantitatively even more likely to survive infancy in India. Further, we document an unusually large average disadvantage of children born to higher-fertility mothers in India relative to children born to higher-fertility mothers in other countries. In India, a large *disadvantage* to high *sibsize* coexists with a large *advantage* to later *birth order*. This finding reinforces a methodological literature that

[3]Other studies from developed countries that document later-born disadvantages include Conley and Glauber (2006) and Price (2008). A smaller literature has studied developing countries. Studying rural India, Behrman (1988) finds an earlier-born advantage in intrahousehold allocation — the opposite of the direction of our result. Studying educational outcomes in households in Ecuador where all children of the mother are alive, De Haan et al. (2014) find a later-born advantage in poorer households and an earlier-born advantage in richer households.

[4]Some recent studies also note later-born advantages in early-life health and related variables in Scandinavian data (Lundberg and Svaleryd, 2017; Brenøe and Molitor, 2018); see also Modin (2002).

emphasizes the endogeneity of sibsize for estimating effects of birth order (Blake, 1989).

Second, the large and economically important puzzles of early-life health in India have received sustained attention at the frontiers of development economics (Deaton, 2013). This large literature includes both studies of differences between India and other parts of the world (Drèze and Sen, 2013; Bhagwati and Panagariya, 2012; Tarozzi, 2008; Headey et al., 2015; Jayachandran and Pande, 2017) as well as puzzling differences within India in health or nutrition between demographic groups or across time (Deaton and Drèze, 2009; Bhalotra et al., 2010; Eli and Li, 2013).

Third, perhaps most broadly, we advance a literature documenting the continuing relevance of family structures for outcomes in developing countries (Strauss and Thomas, 1995), where state safety nets are less developed and incomplete markets make families an important unit of economic and social organization. Some of this research documents effects on demographic and health outcomes (Vogl, 2013; Barcellos et al., 2014) while other research studies labor market and economic consequences (Foster and Rosenzweig, 2002; Bertrand et al., 2003; Field and Ambrus, 2008; Ardington et al., 2009).

Fourth, maternal nutrition is of policy importance (Alderman and Behrman, 2006; World Health Organization, 1995). Economists increasingly recognize that what happens in very early life matters for later-life health and human capital (Maluccio et al., 2009; Almond et al., 2017). This is especially true in developing countries, where early-life insults are severe and varied, and fewer opportunities exist for remediation (Currie and Vogl, 2013; Spears, 2012).

Finally, the descriptive facts we document about NNM and birth order are of such quantitative magnitude to themselves be an important contribution to understanding patterns of infant death globally. Thus, our results join other recent studies in economics that have documented important novel facts about mortality (Case and Deaton, 2015; Chetty et al., 2016). For comparison, Chen et al. (2016) have recently studied the large

IMR difference between the U.S. and Europe. Combining their estimates with standard quantification of the value of a statistical life, they compute that "reducing the US IMR to that of Scandinavian countries would be worth on the order of US$84 billion annually. By this metric, it would be 'worth it' to spend up to $21,000 on each live birth to lower the infant mortality risk to the level in Scandinavia." Mortality rates are much higher in developing countries, where many more babies are born. The excess NNM that we newly document between India and the rest of the developing world is about three times as large as the important IMR gap that they study between the U.S. and Europe, expressed as a rate, and applies to many more births.[5]

1.2 Outline

Section 2 presents background: India is a country with very high neonatal mortality, despite the fact that a large and increasing fraction of births take place in hospitals rather than at home. India's is also a population where maternal nutrition is very poor on average, but improves as women gain status over a childbearing career. A large literature in labor economics, especially in developed countries, has identified human capital disadvantages of being a later-birth-order child. However, India's pattern of maternal nutrition gives reason to expect an opposite result in the Indian context. Motivated by these facts, we estimate an effect of birth order on neonatal mortality, using Demographic and Health Survey data introduced in section 3 and an empirical strategy described in section 4.

[5]Chen et al. (2016) summarize: "in the unrestricted samples, the US excess mortality ranges from 1.4 to 3.6 deaths per 1000." They study Austria, Belgium, Finland, the UK, and the United States, which UN World Population Prospects data compute have slightly more than 5 million births per year combined, compared with about 26 million in India. Chen et al. (2016) cite Viscusi and Aldy (2003) as reporting that the value of a statistical life in the U.S. is $7 million; applying the $1 million for India reported in that review article would suggest that the approximately 200,000 annual excess neonatal deaths that we compute (see section 7) are worth about a 200 billion dollars, assuming that eliminating these deaths would not increase post-neonatal mortality. Replicating the Chen et al. (2016) calculation, that suggests India should be willing to spend about $7,500 per live birth to eliminate its effect of birth order on NNM. Although these computations are necessarily approximate, what is clear is that the effects in question are large.

Section 5 presents our main results, first as descriptive summaries of early-life mortality by birth order and sibsize, and then as a series of regression results that highlight the value of our empirical strategy. The association between birth order on neonatal mortality in India is not reversed by an opposite association with post-neonatal mortality (as might have happened if the effect merely accelerated a set of deaths which were otherwise likely to occur). We also verify that our results are not driven by medical care: birth in a hospital, rather than at home, is a weak predictor of neonatal mortality in India (Coffey, 2019). Although high-quality intensive medical care of low-birth-weight infants has been shown to reduce neonatal mortality (Paneth et al., 1982), the average quality of medical care that births in our Indian sample would have received is very low (Chaudhury et al., 2006; Das et al., 2008; Coffey, 2014).

Section 6 presents a collage of evidence that maternal nutrition can account for our main result. We estimate longitudinal weight gain of cohorts of women by matching cohorts at different ages across successive DHS surveys. We find that more mothers exit the dangerously underweight range of body mass as they age in India than in other places. This is in part because more women in India are underweight to begin with. We then turn to a separate panel data source to verify that these facts hold longitudinally for individual mothers. Finally, in a comparison across DHS surveys in various countries, we find that those survey rounds where there is a steeper negative age gradient between weight and underage are those where later birth order has a less positive (or more negative) association with NNM, on average.

Section 7 considers the magnitude of our estimates in international comparison. We use a hypothetical demographic decomposition to summarize and scale our estimates. This computation projects that global NNM would be substantially lower if India shared the rest of the developing world's birth order pattern.

2 Background on maternal nutrition, birth order, and early-life health in India and the developing world

Compared with other developing countries, neonatal mortality in India is unusually common. Our estimates from 2015 data find that 27% of neonatal deaths happen in India, which is essentially identical to what Lawn et al. (2005) find for 2000. A large fraction of India's NNM occurs in the state of Uttar Pradesh, which has a population as large as Brazil's (over 200 million people) and a neonatal mortality rate far greater than the rest of India.[6] In general, variation in NNM across places and times can be largely explained by poor healthcare at birth and by low birth weight (Bhutta et al., 2008).

Improving rates of institutional delivery – meaning, causing births to happen in medical facilities rather than in homes – is typically presented in policy and epidemiological literatures as the solution for neonatal death in the developing world.[7] However, over the past decade, the rapid expansion of institutional delivery in India due to a government conditional cash transfer program has not had a large effect on neonatal survival. Between 2005-6 and 2015-6, institutional delivery increased from 39% to 79%, but neonatal mortality fell only from 37 in 2003 to 28 in 2013.[8] Section 5.3 finds that children who are born in hospitals are not less likely to die neonatal deaths than those born at home. Although these outcomes may surprise policy-makers, they are consistent with theories and evidence in

[6]The Annual Health Survey 2011 estimated an NNM of 50 for Uttar Pradesh; in 2015 the globally greatest country-level NNM reported in the World Bank World Development Indicators was 49.

[7]Consider the Million Death Study (Million Death Collaborators, 2010), which writes of India in 2005: "three causes accounted for 78% (0.79 million of 1.01 million) of all neonatal deaths: prematurity and low birthweight (0.33 million, 99% CI 0.31 million to 0.35 million), neonatal infections (0.27 million, 0.25 million to 0.29 million), and birth asphyxia and birth trauma (0.19 million, 0.18 million to 0.21 million)." Despite emphasizing size at birth as the leading cause, it does not emphasize policies to improve maternal nutrition: "Expanded neonatal and intrapartum care, case management of diarrhoea and pneumonia, and addition of new vaccines to immunisation programmes could substantially reduce child deaths in India."

[8]See also section 5.3. Institutional delivery figures are from the 2015-6 National Family Health Survey fact sheet. 34 percentage points of this 40 percentage point difference are from births at public, rather than private, facilities. NNM is from India's Sample Registration System.

the economics literature about poorly-monitored public spending programs (Hanushek, 2003; Banerjee et al., 2008; Pritchett, 2009). Health care facilities in this context do not have much incentive to promote health (Coffey, 2014).

Unfortunately, there are no reliable national statistics on birthweight in India. However, national estimates of maternal undernutrition suggest that the prevalence of low birthweight is very high (Coffey, 2015b). Maternal nutrition is important for birth weight and babies' outcomes (Hytten and Leitch, 1964; Yaktine and Rasmussen, 2009). Low weight gain in pregnancy by mothers causes low birth weight (Ludwig and Currie, 2010), and low-birth-weight babies are less likely to survive early infancy (Almond et al., 2005). Maternal nutrition is especially bad in India due the low social status of young women (Palriwala, 1993; Jeffery et al., 1988). But, as the demography literature implies (Das Gupta, 1995), and as we document in section 6, women's social and nutritional statuses improve over a childbearing career, on average.[9]

To learn about the implications of these patterns of maternal status and nutrition, we turn to identifying an effect of birth order, building upon an accomplished literature in labor economics and economic demography. We employ a standard empirical strategy that isolates birth order by controlling flexibly for each count and combination of siblings. As this literature has shown, this strategy requires large, complete data sources that allow researchers to separate birth order from sibsize, cohort, and age (Blake, 1989). As a result, much of this literature has focused on developed countries, where in some cases administrative demographic records are available (*e.g.* Black et al., 2005). A smaller set of papers has investigated birth order in developing countries (Behrman, 1988; Horton, 1988; Emerson and Souza, 2008; De Haan et al., 2014).

A typical conclusion in the birth order literature is that earlier-birth-order children are

[9]Coffey (2015b) first noted the cross-sectional age gradient of undernutrition among women in India in the demographic literature, but did not study longitudinal weight gain or children's mortality outcomes.

better off. As Lehmann et al. (2016) summarize: "A growing number of studies find that birth order affects educational attainment and labor market outcomes: younger siblings within the same family have consistently worse adult economic outcomes than their elder siblings." Many of these papers are motivated by a theory of parental or household allocation of resources among siblings, such as in a quantity-quality tradeoff decision. We find the opposite birth order effect: later-born siblings in India are more likely to survive the neonatal period than earlier-born siblings. However, our finding is compatible with the prior literature, because a different mechanism is likely to be at work in the context we study: a pattern of maternal undernutrition that is unusual both in its structure and magnitude. Because this determinant of mortality reflects factors operating before birth, we propose that our results are due not to unequal treatment of *children* who are siblings, but rather are due to decreasing severity of neglect of *mothers* at different points in their childbearing careers.

3 Demographic and Health Survey data

As Chen et al. (2016) write in the introduction to their study on infant mortality in the US and Europe, "a key constraint on past research has been the lack of comparable micro-datasets across countries. Cross-country comparisons of aggregate infant mortality rates provide very limited insight." This constraint is even more binding in the study of developing countries, where credible vital registration systems have often been absent and where census and other official data sources can be limited by both state capacity and incentives (Mehta, 1969; Setel et al., 2007).

We overcome this constraint by using birth histories from 169 Demographic and Health Surveys (DHS). DHS are cross-sectional surveys in developing and middle-income countries, organized and funded by USAID. For almost three decades, the DHS have asked a comparable set of questions to representative samples of adult women of reproductive age. Each DHS round is a cross-sectional survey, but the survey includes a retrospective birth history that collects information on each child ever born alive to the mother. The survey module records the month of birth of the child, whether it died, and the age in months at death. These questions are uniform across survey rounds and countries.

Applying DHS data to our question has several advantages. First, the retrospective nature of the birth histories allows us to use empirical strategies for studying longitudinal data, such as mother fixed effects that focus on variation across siblings. Second, because DHS rounds are repeated cross-sections, we can separate birth order and sibsize from the passage of historical time and from the cohort of the mother's and child's birth. Third, the richness of our large child-level data, observing all births to the mother by the time of the survey, permits us to meet the data requirements necessary to separate birth order from sibsize (Blake, 1989), as well as to link anthropometry and other observables at a much finer level than would be possible with aggregate data.

Our "main DHS sample of births," used to generate the results in section 5, includes over 6 million births. Because we are particularly interested in understanding early-life mortality in India, we compare children in India with children elsewhere in the developing world. For the "rest of the developing world," we use an inclusive set of all available DHS rounds in which maternal anthropometry is measured.[10] We also include births from all three DHS surveys conducted in India, even though the 1992-1993 Indian DHS lacks maternal anthropometry data and is therefore absent from the analyses in section 6. Table A.1 in the Supplementary Appendix lists the country and year of all of the 169 DHS survey rounds used in our paper. 12% of our observations (about 800,000) are from India.

In robustness checks of our main results, we replicate our findings using a restricted

[10]By design, many DHS rounds do not measure the height and weight of mothers. We exclude these surveys because these variables are critical to our analysis in section 6.

sample of almost 3 million births to mothers whose last birth was at least five years before the survey.[11] As an additional robustness check, and because the other countries in the DHS likely contain no single proper "counterfactual India" that corresponds exactly with how mortality in India would progress in the absence of the forces we document, we replicate our results comparing India to a sample of DHS rounds from sub-Saharan Africa that has been studied in the economics literature.[12] DHS survey rounds in the sub-Saharan African comparison sample are identified in table A.1.

For the most of the analyses in section 6, we use a "women's anthropometry sample" that includes all women whose heights and weights were measured by the surveys listed in appendix table A.1.[13] Most of the women in this sample are the mothers of children in the "main DHS sample of births" described above, but some are women who have not yet had children. We discuss these data in greater detail in section 6.

4 Empirical strategy for an effect of birth order

We build upon prior literatures in labor economics and demography that have both (i) documented a set of specific, intersecting, and often prohibitive challenges and data requirements for identifying an effect of birth order, and (ii) established a standard identification strategy for birth order, which we implement here. Blake (1989) describes the

[11]This approach is common in the demography literature, although it is subject to both exclusion errors (women who have completed their last birth more recently than five years ago) and inclusion errors (women whose last birth was over 5 years ago, but who will give birth again) (see Bhalotra and Van Soest (2008)). In our sample, 82% of 2nd-6th borns were born after an interval of less than 5 years from the prior reported birth. As we will show, our results are qualitatively and quantitatively robust to using this restricted sample instead of our main sample.

[12]Comparing India with sub-Saharan Africa is an enduring focus in the literature (*e.g.* Drèze and Sen, 2013; Nisbett, 2017). Our alternative comparison sample is the same sample of African DHS rounds used to study the India-Africa height gap by Jayachandran and Pande (2017) and Spears (2018). Coffey (2015b) compared maternal nutrition in India and Africa using a slightly different sample of African survey rounds.

[13]Where the DHS measures women's anthropometry, it either measures all women ages 15-49 in the full sample of households, or all of the women ages 15-49 in a randomly selected subsample of households. In both types of surveys, DHS data on women's anthropometry is nationally representative of women of childbearing age in the country-year in which the survey was done.

requirements to identify an effect of birth order: complete data on siblings born in different time periods is needed, such that birth order can be separated from sibsize (or mother's fertility) and from the child's and mother's cohort of birth.

One challenge of identifying effects of birth order is that birth order and sibsize are correlated, in part mechanically: children of high birth order must come from large sibsizes. Another challenge is that later birth order children are born to later cohorts, on average. Overcoming these endogeneity concerns requires complete, detailed data on siblings born to mothers of different ages in different cohorts.

Our main data source for infant mortality – the birth histories in the DHS – offer such longitudinal data, which is collected retrospectively from the mother's report. The mother's birth history offers a longitudinal account of *all* of her births by the time of the survey. This allows us to separately account for birth order and sibsize (meaning, the total count of births to the mother). This is important to our empirical strategy, because higher sibsize is negatively selective in India to a greater extent than in the rest of the DHS (Spears et al., 2019). For example, mothers' height and BMI are *increasing* in sibsize for the average child measured in the rest of the DHS, meaning children of higher-fertility mothers are relatively advantaged, on average, in these ways. Mothers' height and BMI are *decreasing* in sibsize for the average child measured in India.

Our empirical strategy allows sibsize and cohort to have correlations with early-life mortality that are different in India than they are in the rest of the DHS. This would not be possible for variables that are only measured once per mother at the time of the survey (such as her BMI, or whether her home is in a rural area) or only for a mother's most recent birth (such as reported indicators of pre-natal and peri-natal health care for the last birth, or anthropometric measures restricted to the youngest children).

We follow Black et al. (2005) in identifying effects of birth order by controlling flexibly for fixed effects by sibsize, and also by showing that results are robust to instead using mother fixed effects. We build upon their method by estimating a *difference*[14] between the effect of birth order in India and the effect in the rest of the DHS: we allow each independent variable to be fully interacted with an indicator that the child is from India, rather than the rest of the developing world. Our coefficients of interest, therefore, are the interactions between the India indicator and indicators for birth order:

$$\begin{aligned} NNM_{ims} = & \sum_b \beta_1^b birth\ order_{ims} \times India_s + \sum_b \beta_2^b birth\ order_{ims} + \\ & \sum_b \beta_3^b sibsize_{ms} \times India_s + \sum_b \beta_4^b sibsize_{ms} + \\ & f\left(CMC_{ims}^{child}, India_s\right) + g\left(CMC_{ms}^{moth.}, India_s\right) + \\ & \gamma_1 sex_{ims} \times India_s + \gamma_2 sex_{ims}\ [+\alpha_{ms}] + \alpha_s + \varepsilon_{ims}. \end{aligned} \tag{1}$$

i	children	f	cubic of child's CMC[15] birth cohort
m	mothers	g	cubic of mother's CMC birth cohort
s	DHS survey rounds	α_{ms}	mother fixed effect
b	birth orders/sibsizes	α_s	survey round fixed effect

Mother fixed effects (α_{ms}) are in brackets in equation 1 because we include specifications with and without them. We expect our results to be quantitatively robust and stable when mother fixed effects are added, because their principal anticipated role would be to control for sibsize, which is already controlled for. We will find that our estimates are indeed quantitatively robust to the inclusion or exclusion of mother fixed effects, which suggests that our identification strategy has successfully accounted for potentially biasing heterogeneity across children's households.

Our main dependent variable is neonatal mortality, NNM. We also estimate effects

[14] In a robustness check that is available in the replication files, we instead use logistic regression, which effectively estimates the *ratio* of the birth order effect in India to that elsewhere. This finds the same qualitative pattern, which is an important verification of the fact that our results are not driven by the zero lower bound on mortality. We thank Irma Elo and Michel Guillot for this suggestion.

on postneonatal mortality (PNM) and infant mortality (IMR). IMR, which is the fraction of children who die in the first year of life, is simply the sum of NNM (death in the first month) and PNM (death in months 2-11). In particular, we compare effects on NNM with effects on PNM because PNM typically has different causes than NNM. In India, and in other developing countries, levels of PNM are often determined by the disease environment and the timing and quality of the transition from breastfeeding to other foods (Coffey, 2015a). Because we study *age-specific* mortality rates that are held constant in any dependent variable, our regression equation need not (and cannot) control for child age.

5 Results

5.1 Summary mortality rates

In India and in the rest of the developing world, how does the mortality of later-born children compare to that of their earlier-born siblings, on average? We first answer that question with figure 1, which plots summary mortality rates by birth order and sibsize. These graphs, inspired by Blake (1989) and Black et al. (2005), connect mortality rates for successive birth orders with lines within sibsizes.

Two facts are visually apparent. First is the negative selectivity of sibsize, visible in the vertical distance among lines. Sibsize is more negatively selective in India than in the rest of the developing world. That is, children born to higher-fertility mothers are more likely to die than children born to lower-fertility mothers by considerably more in India than in the rest of the developing world. Second is the steep downward slope of the connected lines for NNM in India, indicating a later-born advantage within the same sibsize. Comparing panel (a) for NNM in India with panel (c) for PNM in India it is clear that India's later-born IMR advantage (shown in panel (e)) is driven by death in the first month of life. Panels (b), (d), and (f) show that, although there are downward slopes, in the rest of the DHS none of these mortality rates are similarly steeply decreasing in birth order. That is, the later-born NNM advantage in India appears unique compared with other developing countries. The neonatal timing of the effect of birth order is strongly suggestive of the mechanisms of maternal nutrition, intrauterine growth restriction, and birth weight.

Combining these two conclusions, we see that NNM is highest in India among earlier-born children of mothers who will go on to have many births. Results in the Supplementary Appendix present two robustness checks for this finding. Figure A.1 uses a restricted sample that excludes births to mothers whose most recent birth was within five years of the survey interview. This exclusion is intended to ensure that results are not driven by mothers whose fertility is incomplete at the time of the survey. As a robustness check, and because of a focus in the development economics literature that compares India with sub-Saharan Africa, we further include appendix figure A.2, which uses the sample described in footnote 12. For both comparisons, the later-born NNM advantage in India is steeper than in other regions by a demographically significant amount.

5.2 Main results

This section estimates regression equation 1. This permits us to test the statistical significance and quantitative robustness of the patterns in figure 1.

Figure 2 plots the regression coefficients on $\textit{birth order}_{ims} \times \textit{India}_s$ from regression equation 1, comparing siblings using mother fixed effects. Panel (a) shows our main result: later birth order children in India are advantaged in NNM relative to the rest of the developing world. This interaction is specific to NNM; it does not apply to PNM. Moreover, there is no opposite, countervailing effect on PNM, which indicates that the neonatal deaths that we study are not merely an acceleration of infant deaths that would have otherwise happened at a post-neonatal age (that is, not a so-called “harvesting” effect). The effect on survival of the first year is almost the same as the effect on survival of the first month.

Panel (b) investigates the sensitivity of the NNM result to the functional form of equation 1. It explores the role of the sibsize controls by plotting coefficients on *birth order*$_{ims}$ $\times$ *India*$_s$ from a regression that omits them. We expect that omitting sibsize controls will produce qualitatively different results than the results from panel (a) because, as we show in figure 4 (discussed in section 6), high fertility is a marker of disadvantage in India by more than it is in the rest of the developing world. Panel (b) further explores whether the mother fixed effects specification yields a qualitatively different result than a specification which merely controls for sibsize. We expect that it will not, because, conditional on sibsize, birth order in a complete birth history is unlikely to be correlated with further properties of mothers or households. In these specifications, all controls, including for sibsize, are fully interacted with an indicator for the child living in India.

The results in panel (b) of figure 2 verify both of these expectations. Moving from the squares (without sibsize $\times$ India) to the circles (with sibsize $\times$ India) reverses the sign of the apparent effect of later birth order on NNM. This is consistent with the higher mortality of higher-sibsize children in India (visible in figure 1), and the mechanical correlation of birth order with sibsize.[16] Moving from the circles (with sibsize $\times$ India) to the triangles (with mother fixed effects, automatically controlling for sibsize) makes no further difference to the estimate of the effect of birth order.

[16]Using Demographic and Health Survey data, Jayachandran and Pande (2017) find that higher birth order children in India are shorter than lower birth order children in India, on average, and that this gradient between birth order and average height is steeper in India than in sub-Saharan Africa. Investigations into child height and family structure in India, described in Spears et al. (2019), suggest that this result is sensitive to specification choice: it reverses when controls for sibsize are introduced. That is, at the same sibsize, later-born Indian children are taller than earlier-born Indian children. This is because sibsize is mechanically correlated with birth order, especially in DHS data which only observes height for the youngest children. This finding is consistent with figure 4 of this paper, which finds that larger sibsize (or higher mother’s fertility) is a marker of disadvantage in India but not in the rest of the DHS.

Sex composition of siblings. One important property of mother fixed effects is to control for the *sex composition and pattern* of a child's siblings.[17] India is a country where son preference has many demographic consequences (Das Gupta, 1987; Arnold et al., 1998; Kishore and Spears, 2014). One implication is that fertility stopping depends on realized child sex (Clark, 2000). As a result, smaller sibsizes in India contain more boys, on average, than larger sibsizes; moreover, the earlier-born children in a larger sibsize are more likely to be female than male.[18] Also, sex patterns are correlated with other household properties: families which have a girl and then a boy may be more socially conservative, on average, than families which have a boy and then a girl. Mother fixed effects control for the full realization of this pattern and make no quantitative difference to our results.

The Supplementary Appendix includes two further investigations of heterogeneity by sex and composition of sibships. The first is to allow sibsize to have different correlations with NNM for boys and girls. Supplementary Appendix table A.4 shows the results of a regression that adds to equation 1 sibsize indicators, interacted with an India indicator, interacted with an indicator for the child's sex. These additional controls makes no difference to our main result. This result provides an informative contrast with evidence of boys and girls receiving different treatment after birth, when child sex is known (*e.g.* Barcellos et al., 2014). This therefore points towards a mechanism that operates during pregnancy, before the sex of a child is revealed. The second, in table A.7 splits the sample by whether the first child born to a mother is female or male. Our main result is present for sibships with both first boys and first girls but is larger for first boys: the later-born neonatal survival relative advantage in India is steeper among sibships with first boys. This is consistent with the interpretation that we will introduce in section 6: a life-course pattern

[17]For example, sibsizes of three could include, among other possibilities, (boy, then girl, then boy) or (girl, then boy, then boy).

[18]This is because mothers whose earlier-born children are girls are more likely to go on to have more children.

in maternal undernutrition. Kishore and Spears (2014) have shown that women in India who have a first son (rather than daughter) experience relative increases in subsequent social status that is reflected, among other ways, in greater subsequent body mass.

Robustness checks in alternative samples. Table A.2 in the Supplementary Appendix presents regression results with standard errors for each of the six specifications shown in panel (b) of figure 2. Table A.3 shows results of the same specifications using IMR, rather than NNM, as the dependent variable. Figure A.3 replicates panel (a) for a restricted sample that omits births to mothers whose last birth was within 5 years, to ensure that fertility is completed. Figure A.4 replicates this result with the sub-Saharan African comparison sample described in footnote 12. These supplementary analyses confirm the robustness of our main result.

Later-childhood survival. A further question is whether India's pattern of NNM merely accelerates deaths of infants who would otherwise be likely to die later in childhood. We have already seen evidence against this possibility in the finding that the effect of birth order on IMR is similar to the effect of birth order on NNM. In the Supplementary Appendix, figure A.5 extends these results using mortality up to two years of age as the dependent variable. Results are very similar to those which use NNM and IMR as dependent variables, indicating that the neonatal deaths documented here are not offset by countervailing effects on later-childhood mortality.

Fertility response to infant death. Any study of effects of birth order must consider the possibility that fertility endogenously responds to child outcomes, such as neonatal death. If parents replace children who die in early life with additional children who would not otherwise have been born, then late-birth-order children will tend to be born to parents whose children are more likely to die. This is one reason why our mother fixed effects robustness check is important, because it accounts for sibship-level heterogeneity in frailty. In our case, this possibility could only be an important omitted variable in our regressions if the fertility response to neonatal death were large and *different* between India and the rest of the DHS. In particular, to account for our large interaction-coefficient estimates, the difference between India and the rest of the developing world in this effect would have to be quantitatively very large relative to the variation in fertility rates, because even where neonatal mortality is relatively high, most babies do not die.

In our data, we can observe descriptive statistics that quantify the scope for such a possibility. In particular, we investigate the difference in the probability of having a further birth after births that do and do not survive the neonatal period. The difference between India and sub-Saharan Africa is small and its sign depends on the window studied for subsequent births, suggesting that an important confound is unlikely.[19]

Although these quantities suggest that such an endogenous-fertility threat is implausible in our case, we additionally implement a regression-based robustness check from the birth order literature. In the Supplementary Appendix, table A.6 presents results of a robustness test that rules out the possibility that later-born children who are conceived in response to sibling deaths are responsible for our finding. We follow a robustness strategy used by Lundberg and Svaleryd (2017), who study birth order in Sweden: we exclude any last-born child born after a prior sibling neonatal death. As we show and discuss further in the appendix, our result is robust to this change of the sample.

[19]For example, a mother who experiences a neonatal death is 18.8 percentage points more likely to go onto have a subsequent birth in the next 36 months in Africa and 18.9 percentage points more likely in India. This small difference is not statistically significant, and the sign of the India-Africa difference is different for births within the next 24 months. Comparing our effect sizes with these results, which are available in detail in the replication files, (as well as considering the similarity of our results when controlling for sibsize, sibsize structures, or mother fixed effects) suggests that this issue is not a problem in our case. We thank Andrew Foster for suggesting this analysis.

5.3 Medical care at birth does not explain India's birth order effect on NNM

Variation in medical care at birth often explains differences across populations in neonatal mortality (Paneth et al., 1982). In India's most recent DHS, from 2005-6, 45% of births in the prior five years are recorded to have taken place in a medical facility, rather than at the home of the child's parents or relatives. Institutional delivery, that is, birth in a medical facility, has been increasing over time in India. Could differences in institutional delivery by birth order account for the birth order gradient observed in India?

Figure 3 shows that institutional delivery does not explain the effect of birth order. The pattern of neonatal mortality by birth order and sibsize is essentially identical among Indian children born in a health facility (solid markers) and among Indian children born in a home (hollow markers). Indeed, institutional delivery is not even consistently associated with reduced mortality. This result is consistent with evidence in the literature that rapidly increasing institutional delivery in India has not lead to improvements in health outcomes,[20] because much of the care in health facilities is low-quality (Chaudhury et al., 2006; Das et al., 2008), or is even rent-seeking rather than health-promoting (Coffey, 2014). Of course, our results are not intended to estimate any causal effect of institutional delivery – for example, they do not consider that women may give birth in hospitals because a pregnancy appears risky or a labor has been prolonged – they merely demonstrate that our birth order results do not reflect medical care as a mechanism or as an omitted variable.

In the Supplementary Appendix, table A.5 shows these results in a regression framework. Controlling for an indicator for institutional delivery does not change the estimated

[20] Lim et al. (2010) study the recent rapid expansion of institutional delivery in India as part of a conditional cash transfer program. Although institutional delivery is correlated with neonatal survival in the sample that they study, they show that when a difference-in-differences empirical strategy that considers the extent of within-district implementation is used to identify a causal effect, there is no apparent effect on NNM (Web Table 3).

effect of birth order on NNM. Moreover, it shows that, conditional on birth cohort, later birth order children are not more likely to have institutional deliveries. In table A.5, results are presented with controls for sibsize indicators. The birth order gradients in table A.5 and figure 3 must be interpreted with care because the sample of children for whom institutional delivery was collected differs from the main birth history sample: whereas the main result uses a mother's complete birth history up until the time of the survey, data on institutional delivery are only collected for children under 60 months old. The note to table A.5 in the Supplementary Appendix further discusses the importance of this sample restriction.

6 Mechanism: Maternal nutrition and anthropometry

Women in India gain social status as they progress through a childbearing career (Jeffery et al., 1988; Das Gupta, 1995). Because this process has consequences for food consumption and for work expectations, it has consequences for the net nutrition of mothers, and therefore also for the children they nurture during pregnancy and while breastfeeding (Palriwala, 1993; Das Gupta, 1995). Improvement in women's social status occurs in part due to having children, in part due to increasing autonomy of the nuclear family from the joint family, sometimes in part due to death of the husband's parents, and finally in part due to the passage of time and the social rank associated with age itself.

We have seen that the effect of birth order on NNM cannot be explained by medical care. We propose that our NNM results can be explained by India's exceptionally poor maternal nutrition combined with weight gain and improvements in social status over her childbearing career.[21] We show that young women in India are highly likely to be

[21] We cannot separate social status as a root cause from other causes of a steep trajectory out of underweight by parity progression in India: it is consistent with our findings and interpretation, for example, that low-status young mothers in India are very likely to begin childbearing careers while underweight, and that the biological processes of pregnancy cause them to gain weight which they otherwise would not gain and do

underweight, but the prevalence of underweight falls at a steep rate as women age and bear children. This is consistent with our main results: many babies in India would be born to undernourished mothers, and therefore would suffer from low birth weight. However, some babies — born later in their mothers' childbearing careers — would have better outcomes, less different from those of children in the rest of the developing world because their mothers would be more nearly as likely to be underweight as mothers in the rest of the developing world.

This section provides a collage of evidence for our interpretation. Ideally, we would have data that would allow us to see how much of India's NNM–birth order patterns can be accounted for by controlling for a mother's pre-pregnancy BMI and weight gain in pregnancy, for each of her pregnancies (Thomson and Billewicz, 1957; Siega-Riz et al., 1994; Abrams and Selvin, 1995; Yaktine and Rasmussen, 2009). Alternatively, we might control for a child's birth weight, an important summary measure of her growth *in utero* and a predictor of her subsequent health (Behrman and Rosenzweig, 2004; Alderman and Behrman, 2006). Either of these strategies would require temporally precise anthropometric measurements from the time of the pregnancy or birth. Instead, the DHS measures the weight and height of adult women and some of their children only once, at the time of the survey. Therefore, we use cohort-tracking methods from the demography literature as well as an alternative source of mother-level panel data to document India's pattern of maternal underweight and compare it to the rest of the developing world.

First, section 6.1 discusses what can be learned from cross-sectional measurements in the DHS. Next, section 6.2 matches cohorts of adult women across successive cross-sectional DHS survey rounds to compare the mean consequences of cohort aging for body mass in India to consequences of cohort aging elsewhere. Then, section 6.3 notes that an alternative, longitudinal data set also shows a unique pattern of maternal nutrition in

not fully lose after giving birth.

India. Section 6.4 studies geographic heterogeneity beyond the India-other comparison, including by comparing states within India where maternal undernutrition is more and less common. Finally, section 6.5 documents that the effect of birth order on NNM in India is consistent with the correlation of the birth order–NNM gradient in a DHS survey round with that DHS survey round's age gradient of women's undernutrition. We show that in DHS survey rounds where a woman's age does not predict her chances of being undernourished, there is no protective effect of later birth on NNM.

6.1 Anthropometry in the DHS cross-sections

6.1.1 The effect of parity progression on maternal anthropometry is difficult to study in the DHS cross-section

The fact that DHS anthropometric data on the body sizes of mothers is collected cross-sectionally presents two challenges for demonstrating that maternal nutrition is the mechanism behind India's NNM–birth order gradient. First, it is *incomplete*, in that there is not a measurement for each studied birth; rather mothers are measured only once, however many children they have. Second, it is *mistimed*, in that we know the size of mothers at the time of the survey, when we would ideally like know their sizes at the time of pregnancy and birth. Infant mortality data, which we have studied up to this point in the paper, has neither problem: in the DHS, mothers report all children ever born and the time of a child's death.

Because a mother's anthropometry in the DHS is only observed after her most recent birth, any cross-sectional correlation between BMI and parity at last birth would reflect a combination of the effects of (1) parity progression, meaning the longitudinal process that we wish to study, and (2) fertility selection, meaning any correlation between the number of children ever born to a mother and her anthropometry.[22] Unlike in other developing countries on average, in India, these two effects have opposite signs and large magnitudes.

Figure 4 illustrates that high fertility is differently selective for mother's health in India and in the rest of the DHS. It uses height and body mass index as outcomes, and shows that higher fertility tends to be correlated with anthropometric *advantage* in the rest of the DHS, but with anthropometric *disadvantage* in India. The results for height are the same whether or not age is controlled for because adult height does not substantially change as a person ages. For BMI, the differences between India and the rest of the developing world are sharper once the woman's age is controlled for (the solid lines and markers) because otherwise the shape of the relationship between BMI and parity reflects the combination of the selectivity of high fertility with the effect of progression through the life course.

The evidence of figure 4 is consistent with the pattern we saw for NNM in figure 1: the vertical distance between lines showed that, although within a sibsize later-borns are advantaged, children born to larger sibsizes are substantially disadvantaged relative to children born to smaller sibsizes. Misinterpreting the correlations in figure 4 simply as a longitudinal effect of parity progression would be misleading, similar to how it would be misleading to compare NNM between earlier and later birth order children without accounting for sibsize.

We also note that figure 4 shows large level differences in women's health between India and the rest of the developing world: mothers in India are substanially shorter and have less body mass, on average, than mothers elsewhere. Although it is not shown in the figure, we note that average fertility is lower in India than in the other countries in these data.

[22]Parity could also be correlated with age, cohort, SES, or education, all of which could be correlated with anthropometry.

6.1.2 What can we learn from age patterns in the DHS?

We have seen that it would be difficult to learn about the average pattern of maternal nutrition over a child-bearing career by studying the cross-sectional correlation of women's BMI with parity progression in the DHS. In this section, we study cross-sectional correlates of age: although comparing women of different ages in a cross-section does not cleanly isolate a longitudinal process, it provides useful suggestive evidence. Because adult mortality is low at childbearing ages, age is not inherently selective in the way that parity is: almost every 20-year-old woman eventually becomes a 30- and a 40-year-old woman, but not every woman with one or two children eventually has three or four.

Figure 5 documents two facts about underweight (meaning a body mass index (BMI) below 18.5) among women in India, relative to the rest of the DHS: (1) underweight is far more common in India, and (2) the cross-sectional age gradient of underweight is far steeper. That is, young women in India are especially likely to be underweight. Women at the end of their reproductive careers are less likely than younger women to be underweight, although still more likely than women in the rest of the developing world.[23] These figures visually resemble the NNM–birth order gradients shown in figure 1.[24]

[23]Coffey (2015b) notes that working-age adult men in India are also more likely to be underweight than men in the rest of the developing world. The fact that high-status men and women have low body mass in India is consistent with evidence that social status is not the only determinant of poor nutrition in India: shared contextual causes also matter, such as disease externalities from open defecation (see Duh and Spears, 2017).

[24]Figure 5 focuses on one cut-point in the BMI distribution: the division between being underweight or not. In the Supplementary Appendix, Figure A.7 extends this analysis by examining the cross-sectional association between adult women's ages and the linear probability of being above a range of BMI scores. The figure shows that in India's cross-section, age predicts whether a woman has *normal, rather than low, BMI*, while in the rest of the DHS age predicts whether a woman has *high, rather than normal, BMI*. See appendix section B for more details.

6.2 Evidence from tracking cohorts across repeated DHS cross-sections

We have seen cross-sectional evidence that age is strongly associated with being underweight among mothers in India. For this pattern to account for the effect of birth order, however, it must reflect a longitudinal process that occurs as women progress through childbearing careers. Although DHS surveys are not individual-level panels, it is possible to track age-cohorts through successive cross-sectional survey rounds. In other words, we can compute the average BMI among 20 year old women in the 1998 Indian DHS, and compare this sample mean with the average BMI in the 2005 DHS, among women who *were* 20 years old at the time of the 1998 survey. Then, because adult mortality at these ages is low, and because the DHS is a representative survey of women at these ages, the average cohort-level longitudinal rate of change in mean BMI for that cohort is the difference between these averages divided by the length of the time interval.

This section reports these cohort-level computations. We use data on all measured adult women from women's anthropometry sample described in section 3, except that a woman can only be included if she is in a country that has had more than one DHS survey round that measures women's anthropometry. Cohorts are matched across each successive pair of survey rounds within the same country. The DHS data have detailed information on age; so we are able to define cohorts by age in months at the time of the earlier survey round.

Figure 6 presents the results of a computation of cohort rate of change in BMI. Each woman is matched to the mean property of the cohort of which she is a member from the immediately prior survey round. Therefore, the figure plots sample means of cohort velocity v_{ct} for cohort c, over the time interval from survey round $t-1$ to round t, computed as:

$$v_{ct} = \frac{\overline{underweight_{ict}} - \overline{underweight_{ict-1}}}{\overline{m_{ict}} - \overline{m_{ict-1}}}, \tag{2}$$

where i is an individual woman in a survey round, $underweight$ is an indicator for being underweight, m is the century-month-code of the month of the interview in historical time (so the denominator is time between surveys measured in months), $\overline{underweight_{ict}}$ is the average of underweight in survey round t. In panel (a), cohort level changes that occurred between the 1998 and 2005 Indian DHS are compared to all other available pairs of DHS surveys. In panel (b), changes between the 2 Indian DHS are compared to changes in those places for which the first of two surveys in the same country was within 2.5 years before or after the 1998 Indian DHS.

It is clear in the figure that the longitudinal change in cohort anthropometry is different in India from the rest of the DHS: underweight velocity is more negative in India, indicating that on average a larger fraction of the cohort is moving out of the underweight range each year in India than elsewhere. This is in part because more women in India are originally underweight to begin with. Figure A.8 in the Supplementary Appendix replicates figure 6 using BMI, rather than an indicator for underweight, as the dependent variable and finds similar results.

6.3 Anthropometry in Young Lives longitudinal data

Because the DHS is a cross-section, one strategy is to turn to other data. In order to study longitudinal weight gain of individual mothers, this section draws upon a panel data source which tracked the anthropometry of mothers in developing countries over time. The Young Lives[25] data longitudinally measured the weight of mothers of young children in four developing countries: India, Vietnam, Ethiopia, and Peru. The survey is principally designed to follow 12,000 children (3,000 at each country site) through childhood (Wilson et al., 2006). Data are not nationally representative; for example, the Indian data are from seven districts in the states of Andhra Pradesh and Telangana.

[25]Data are available online at www.younglives.org.uk.

Supplementary Appendix Figure A.9 plots the distribution of starting weights (panel (a)) and weight gain (panel (b)), separately for each of the four samples from different developing countries. The results are qualitatively consistent with our nationally-representative cohort estimates from the DHS: women in India begin weighing the least among the four countries in 2009, and experience the largest longitudinal weight gain over the four years studied. In both cases the difference between India and other countries is statistically significant ($p < 0.001$) as a test of means or as a Kolmogorov-Smirnov test. Therefore, panel data are consistent with our life-course interpretation of the DHS cross-section.

6.4 Geographic heterogeneity in the effect of birth order

The main analysis of this paper compares India with the rest of the developing world, and interprets the differences as due to India's distinctive pattern of maternal undernutrition. However, other heterogeneity also correlates with maternal undernutrition, and can be used to assess our interpretation. In the Supplementary Appendix, figures A.10 and A.11 report two such investigations.

Within India, there exists a broad set of cultural differences and differences in maternal nutrition between northern and southern states. Figure A.10 focuses only on the Indian data, and compares the birth order pattern in the north Indian states of Uttar Pradesh and Bihar (where 33% of women are underweight) with the birth order pattern in the south Indian states of Goa, Kerala, and Tamil Nadu (where women's social status is higher and 19% of women are underweight). At all birth orders, the effect on NNM of a later-order birth, relative to a first-birth, is more negative in the northern states than in the southern states. Although the sample is much smaller here than in our main international sample, this interaction is statistically significant for the comparison of second with first births; unlike in the rest of the DHS, these two birth orders are a majority of births in India, because India has lower average fertility than the rest of the DHS.

Across the developing world, some localities outside of India have high rates of maternal undernutrition; some localities within India have relatively low undernutrition. Figure A.11 uses the main DHS sample, and substitutes an interaction between birth order and the local prevalence of underweight among adult women, instead of an interaction between birth order and India. Consistent with our interpretation that maternal nutrition drives our main results, the larger the fraction of adult women in a locality (PSU) who are underweight, the more negative the effect of later birth order on BMI. This interaction is statistically significant at all birth orders. Because underweight is much more common among adult women in India than in the rest of the DHS, this interaction projects a more negative effect of later birth on NNM in India than in the rest of the DHS — which matches what we find in our main results.

6.5 Connecting maternal underweight with the effect of birth order

Figure 7 presents results at the DHS-survey-round level that integrate the mortality results with the results on women's anthropometry. In particular, this figure shows that India's exceptional effect of birth order is consistent with its exceptional age profile of maternal underweight. Each point in the figure reflects two separately-estimated regressions, both estimated using data from one of the survey rounds in the main DHS sample of births. The vertical axes plot the coefficient on birth order linearly predicting NNM, in a regression with mother fixed effects.[26] The horizontal axis plots the coefficient on adult women's age in years linearly predicting an indicator for being underweight.

Because this scatter-plot is an international comparison of country-years at different stages of development, a reader might wonder whether the pattern in figure 7 merely reflects socioeconomic development. Therefore, panel (b) adds to panel (a) a control for

[26]This is different from equation 1 in which birth order is entered as dummy variables. We use a linear term for birth order here in order to be able to plot a single parameter estimate for each DHS survey round.

GDP per capita. The same DHS-survey-round-level coefficients are used in panel (b) as in panel (a), but now the coefficients on the horizontal and vertical axes are residualized after regressing the set of coefficients from each axis on GDP per capita.[27] The control for economic development does not change the conclusion: panel (b) resembles panel (a). This is consistent with our basic observation that India's early-life health differs from other countries at similar levels of economic development, because its patterns of maternal undernutrition do, too.

The fact that the association between these two gradients is positive means that the places and times in which the age-underweight gradient among adult women is more negative are those in which being later-born confers more of a neonatal survival advantage. The fact that the trend passes through the origin means that in DHS rounds where there is no age-underweight gradient among mothers, there is also no effect of birth order on NNM. Finally, we note that the large blue circles, which represent India, are at the far left of the graph, meaning that both of the relationships we study are exceptionally negative compared to other countries. However, the data points for India are also consistent with the international trend, which is shown in the figure.[28] Of course, these computations should be interpreted with the same care as is required for interpreting figure 5: the horizontal axis of these graphs reflects a regression on age in a cross section, not longitudinal parity progression. We therefore emphasize merely that, across independently computed regressions on separate samples, India's protective effect of later birth on NNM is linked with its age pattern of maternal nutrition; one does not appear without the other.

Figure A.12 in the Supplementary Appendix verifies that these results are similar if,

[27] A DHS-survey-round-level GDP per capita variable is constructed by: (1) matching GDP per capita in the year of birth (from the Penn World Tables) to each birth in the main DHS sample of births that is used as an observation to produce the coefficient on the vertical axis, (2) taking the sample mean of these matched per capita GDPs, and (3) taking the log of the mean.

[28] Figure 7 also highlights Bangladesh, India's South Asian neighbor and a notable case in need of further study, in which there is relatively little underweight-age gradient but a relatively large birth order gradient.

instead of looking at the association of the magnitude of regression coefficients, we instead plot the association of test statistics for the coefficients of interest from the regressions described above. In figure A.12, panels (a) and (b) plot the t-statistics for the same linear regression coefficients plotted in figure 7. t-statistics have the advantage over regression coefficients of not giving importance to noisy estimates. Panels (c) and (d) replace the vertical axis with F-statistics (multiplied by the sign of the linear coefficient) from a regression of NNM on birth order indicators, rather than birth order entered linearly.

7 Magnitude: How different would NNM in India be without the effect of birth order?

How large of a total impact on India's aggregate NNM does its unique effect of birth order amount to? One version of this question is to ask: by how much would NNM in India be reduced if it matched the rest of the developing world's birth-order effect, keeping the effect of sibsize unchanged? This is a counterfactual question, for which we can use our estimates to compute a projection in the spirit of a demographic reweighting that weights subsample-specific changes by their frequency in the population. It is also, we emphasize, a *hypothetical* accounting question: although this is an informative way of scaling our effect estimates, no actual policy could change the correlation between birth order and mortality without also changing, for example, the correlation between sibsize and mortality.

We ask by how much India's average NNM would change, if each combination of birth order and sibsize switched from the NNM it actually experiences to the NNM it would counterfactually experience if its disadvantage relative to the NNM of the last-born of its sibsize matched the earlier-born disadvantage experienced by that birth order and sibsize combination in the rest of the developing world. This computation leaves mortality among last births unchanged. Because, on average, being earlier-born carries an larger average

NNM penalty in India, this counterfactual change would reduce NNM in India.

To construct a projected NNM, we compute a counterfactual change in India's NNM with the following weighted sum, where b continues to index birth orders and j indexes sibsizes, both running from 1 to a category for 6 or greater:

$$\text{counterfactual } \Delta\text{NNM}_{\text{India}} = \frac{\sum_{1\leq j\leq 6+}\sum_{1\leq b\leq j} w_{bj} d_{bj}}{\sum_{1\leq j\leq 6+}\sum_{1\leq b\leq j} w_{bj}}, \tag{3}$$

where w_{bj} is the weight of the combination of birth order b and sibsize j in the Indian sample, and d_{bj} is the difference that our counterfactual change in mortality rates would make to that partition of the births. Our computations of $\Delta\text{NNM}_{\text{India}}$ differ in three ways:

- *sample*: We use either (i) the full sample (as in figures 1 and 2), or (ii) the restricted sample intended to focus on completed fertility (as in figures A.1 and A.3).
- *weights* w_{bj}: We weight our sample to reflect the observed distribution of births in India's 2005-6 DHS, its most recent. Our two approaches to weights w_{bj} either (i) sum the DHS sampling weights[29] across all births of birth order b and sibsize j, or (ii) alternatively ignore the sampling weights and set w_{bj} equal to the count of births.
- *differences* d_{bj}: Our first approach to constructing a counterfactual difference is to (i) use the summary NNM statistics plotted in figures 1 and A.1. We ask how NNM for birth order b in sibsize j compares to birth order for the last-borns j of sibsize j, and how this difference in India compares with that elsewhere:

$$d_{bj} = \left(\overline{NNM}_{bj}^{\text{India}} - \overline{NNM}_{jj}^{\text{India}}\right) - \left(\overline{NNM}_{bj}^{\text{rest of DHS}} - \overline{NNM}_{jj}^{\text{rest of DHS}}\right). \tag{4}$$

Our second approach (ii) uses the regression coefficients on the interaction between

[29]This is our only use of sampling weights in this paper, as we are intending to produce a summary statistic comparable to the published population-level demographic rates released in the DHS manual (Solon et al., 2015).

India and birth order from equation 1, plotted in figure 2:

$$d_{bj} = \hat{\beta}_1^b - \hat{\beta}_1^j, \tag{5}$$

with $\hat{\beta}_1^1$, the omitted category in the regression, set to zero.

The regression approach has the advantage of controlling for the full set of regression controls, including mother fixed effects, sex, and cohort, but has the disadvantage of restricting the birth order gradient to be constant across sibsizes. Note that either definition of d_{bj} sets $d_{jj} = 0$ for all last-borns of a sibsize. This is because the counterfactual exercise is to match the rest of the world's NNM disadvantage of earlier-born siblings relative to last-born siblings, leaving unchanged fertility selectivity, as reflected in the average NNM of the last-born of each sibsize.

Table 1 presents the results. NNM in India, it is projected, would be lower by 8 to 10 deaths per 1,000 births if it matched the rest of the world's birth order gradient. This is about the quantitative size of the gap between India's actual NNM and what is predicted by India's GDP per capita (Coffey and Hathi, 2016). Results are approximately quantitatively similar across the eight combinations of counterfactual strategy. To be sure, these comparisons must be considered with care: there is no reason to assume that the effect of birth order in India *would* precisely match the rest of the developing world in the absence of the particular social forces we study.[30]

A difference of 9 neonatal deaths per 1,000 births in India would be large. In 2015, 3.5 billion people lived in a country where the *total* NNM was less than 9 per 1,000. These countries include China, Brazil, Russia, Mexico, and Thailand. Such a reduction in India

[30]Note that, because mother fixed effects absorb household and village properties that are constant across siblings, this specification controls for any fixed properties of the mother such as her education, household or neighbors' religion (Geruso and Spears, 2017), local sanitation (Coffey and Spears, 2017), or the mother's birth order (Vogl, 2013) or that of of her husband.

would eliminate eight percent of all neonatal deaths that occur each year, worldwide.[31] Because there are about 13 million neonatal deaths each five-year period, this would account for an annual difference of a little over 200,000 infant deaths, if there were no countervailing increase in post-neonatal mortality.[32]

8 Conclusion

In this paper we examine birth order and early-life mortality in developing countries, using birth histories that allow us to separate effects of birth order from correlates of sibsize and maternal and child cohort of birth. We find a unique later-born neonatal mortality advantage in India that is much steeper than in the rest of the developing world. This later-born advantage contrasts with well-known findings from the developed world that later-birth-order children are disadvantaged in human capital (Black et al., 2005).

The effect of birth order on NNM in India is unusual, but it is explicable: it is consistent with the level and pattern of maternal undernutrition and social status among women in India (Jeffery et al., 1988). We show that high maternal undernutrition is concentrated among young women early in their childbearing careers. Steep differences in NNM by birth order are consistent with steep improvements in maternal nutrition that we document across childbearing careers. Moreover, comparing effect estimates across DHS survey rounds, we show that India's birth order effect on NNM is what the international trend predicts, given this pattern of maternal weight.

Our investigations of health outcomes have potential methodological implications as well as substantive implications: within India, the correlation of health outcomes with sibsize and with birth order have opposite signs. Researchers using cross-sectional data

[31] 27% of neonatal deaths are in India. A 9 per 1,000 reduction would reduce NNM from 31.7 to 22.7. $\frac{22.7}{31.7} \times 27 + 73 \approx 92$.

[32] Recall from figure 2 that there is no offsetting decrease in PNM in birth order: the effect on IMR is almost the same as the effect on NNM. Figure A.5 verifies this further for survival up to 24 months.

(such as the widely-used Demographic and Health Surveys) to study effects of birth order or parity progression on anthropometric outcomes (such as mothers' BMI or child height) may obtain biased estimates unless their empirical strategy can separate birth order or parity progression from sibsize and fertility (Spears et al., 2019).

Our estimates are of such quantitative magnitude as to constitute important facts about the overall composition of infant death in a world population in which more than a quarter of neonatal mortality occurs in India. Moreover, these findings demonstrate the continued relevance of woman's status, household structures, and demographic relationships to health outcomes in the developing world. Because early-life health is of enduring importance for economic and later-life health outcomes, the welfare consequences of these patterns for the Indian population are surely very large. They recommend policies to reduce maternal undernutrition; they also caution that social forces and household structures could perhaps form constraints that could prevent nutritional inputs intended for mothers from benefiting them and promoting neonatal survival.

References

Abrams, Barbara and Steve Selvin (1995) "Maternal weight gain pattern and birth weight," *Obstetrics & Gynecology*, Vol. 86, pp. 163–169.

Alderman, Harold and Jere R Behrman (2006) "Reducing the incidence of low birth weight in low-income countries has substantial economic benefits," *The World Bank Research Observer*, Vol. 21, pp. 25–48.

Almond, Douglas, Kenneth Y Chay, and David S Lee (2005) "The costs of low birth weight," *The Quarterly Journal of Economics*, Vol. 120, pp. 1031–1083.

Almond, Douglas, Janet Currie, and Valentina Duque (2017) "Childhood Circumstances and Adult Outcomes: Act II," working paper, NBER.

Ardington, Cally, Anne Case, and Victoria Hosegood (2009) "Labor supply responses to large social transfers: Longitudinal evidence from South Africa," *American Economic Journal: Applied Economics*, Vol. 1, pp. 22–48.

Arnold, Fred, Minja Kim Choe, and Tarun K Roy (1998) "Son preference, the family-building process and child mortality in India," *Population Studies*, Vol. 52, pp. 301–315.

Banerjee, Abhijit V, Esther Duflo, and Rachel Glennerster (2008) "Putting a band-aid on a corpse: incentives for nurses in the Indian public health care system," *Journal of the European Economic Association*, Vol. 6, pp. 487–500.

Barcellos, Silvia, Leandro Carvalho, and Adriana Lleras-Muney (2014) "Child gender and parental investments in India: Are boys and girls treated differently?" *American Economic Journal: Applied Economics*, Vol. 6, pp. 157–189.

Behrman, Jere R (1988) "Nutrition, health, birth order and seasonality: Intrahousehold allocation among children in rural India," *Journal of Development Economics*, Vol. 28, pp. 43–62.

Behrman, Jere R and Mark R Rosenzweig (2004) "Returns to birthweight," *Review of Economics and Statistics*, Vol. 86, pp. 586–601.

Behrman, Jere R and Paul Taubman (1986) "Birth order, schooling, and earnings," *Journal of Labor Economics*, Vol. 4, pp. S121–S145.

Bertrand, Marianne, Sendhil Mullainathan, and Douglas Miller (2003) "Public policy and extended families: Evidence from pensions in South Africa," *World Bank Economic Review*, Vol. 17, pp. 27–50.

Bhagwati, Jagdish and Arvind Panagariya (2012) *India's tryst with destiny: Debunking myths that undermine progress and addressing new challenges*: HarperCollins.

Bhalotra, Sonia, Christine Valente, and Arthur Van Soest (2010) "The puzzle of Muslim advantage in child survival in India," *Journal of Health Economics*, Vol. 29, pp. 191–204.

Bhalotra, Sonia and Arthur Van Soest (2008) "Birth-spacing, fertility and neonatal mortality in India: Dynamics, frailty, and fecundity," *Journal of Econometrics*, Vol. 143, pp. 274–290.

Bhutta, Zulfiqar A, Tahmeed Ahmed, Robert E Black, Simon Cousens, Kathryn Dewey, Elsa Giugliani, Batool A Haider, Betty Kirkwood, Saul S Morris, HPS Sachdev et al.

(2008) "What works? Interventions for maternal and child undernutrition and survival," *The Lancet*, Vol. 371, pp. 417–440.

Black, Sandra E, Paul J Devereux, and Kjell G Salvanes (2005) "The more the merrier? The effect of family size and birth order on children's education," *The Quarterly Journal of Economics*, Vol. 120, pp. 669–700.

Blake, Judith (1989) *Family size and achievement*: Univ of California Press.

Brenøe, Anne Ardila and Ramona Molitor (2018) "Birth order and health of newborns," *Journal of Population Economics*, Vol. 31, pp. 363–395.

Case, Anne and Angus Deaton (2015) "Rising morbidity and mortality in midlife among white non-Hispanic Americans in the 21st century," *Proceedings of the National Academy of Sciences*, Vol. 112, pp. 15078–15083.

Chaudhury, Nazmul, Jeffrey Hammer, Michael Kremer, Karthik Muralidharan, and F Halsey Rogers (2006) "Missing in action: teacher and health worker absence in developing countries," *The Journal of Economic Perspectives*, Vol. 20, pp. 91–116.

Chen, Alice, Emily Oster, and Heidi Williams (2016) "Why is infant mortality higher in the United States than in Europe?" *American Economic Journal: Economic Policy*, Vol. 8, p. 89.

Chetty, Raj, Michael Stepner, Sarah Abraham, Shelby Lin, Benjamin Scuderi, Nicholas Turner, Augustin Bergeron, and David Cutler (2016) "The association between income and life expectancy in the United States, 2001-2014," *JAMA*, Vol. 315, pp. 1750–1766.

Clark, Shelley (2000) "Son preference and sex composition of children: Evidence from India," *Demography*, Vol. 37, pp. 95–108.

Coffey, Diane (2014) "Costs and consequences of a cash transfer for hospital births in a rural district of Uttar Pradesh, India," *Social Science & Medicine*, Vol. 114, pp. 89–96.

——— (2015a) "Early life mortality and height in Indian states," *Economics & Human Biology*, Vol. 17, pp. 177–189.

——— (2015b) "Pre pregnancy body mass and weight gain during pregnancy in India & sub-Saharan Africa," *Proceedings of the National Academy of Sciences*, Vol. 112, pp. 3302–3307.

——— (2019) "The association between neonatal death and facility birth in regions of India," *Demographic Research*, Vol. 40, pp. 417–430.

Coffey, Diane and Payal Hathi (2016) "Underweight and Pregnant: Designing Universal Maternity Entitlements to Improve Health," *Indian Journal of Human Development*, Vol. 10, pp. 176–190.

Coffey, Diane and Dean Spears (2017) *Where India Goes: Abandoned Toilets, Stunted Development and the Costs of Caste*: Harper Collins.

Conley, Dalton and Rebecca Glauber (2006) "Parental educational investment and children's academic risk: Estimates of the impact of sibship size and birth order from exogenous variation in fertility," *Journal of Human Resources*, Vol. 41, pp. 722–737.

Currie, Janet and Tom Vogl (2013) "Early-life health and adult circumstance in developing countries," *Annual Review of Economics*, Vol. 5, pp. 1–36.

Das Gupta, Monica (1987) "Selective discrimination against female children in rural Punjab, India," *Population and Development Review*, pp. 77–100.

——— (1995) "Life course perspectives on women's autonomy and health outcomes," *American Anthropologist*, Vol. 97, pp. 481–491.

Das, Jishnu, Jeffrey Hammer, and Kenneth Leonard (2008) "The quality of medical advice in low-income countries," *The Journal of Economic Perspectives*, Vol. 22, pp. 93–114.

De Haan, Monique, Erik Plug, and José Rosero (2014) "Birth order and human capital development evidence from Ecuador," *Journal of Human Resources*, Vol. 49, pp. 359–392.

Deaton, Angus (2013) *The great escape: Health, wealth, and the origins of inequality*: Princeton University Press.

Deaton, Angus and Jean Drèze (2009) "Nutrition in India: Facts and Interpretations," *Economic & Political Weekely*, Vol. XLIV, pp. 42–65.

Drèze, Jean and Amartya Sen (2013) *An uncertain glory: India and its contradictions*: Princeton University Press.

Duh, Josephine and Dean Spears (2017) "Health and hunger: disease, energy needs, and the Indian calorie consumption puzzle," *The Economic Journal*.

Eli, Shari and Nicholas Li (2013) "Can caloric needs explain three food consumption puzzles? Evidence from India."

Emerson, Patrick M and Andre Portela Souza (2008) "Birth order, child labor, and school attendance in Brazil," *World Development*, Vol. 36, pp. 1647–1664.

Field, Erica and Attila Ambrus (2008) "Early marriage, age of menarche, and female schooling attainment in Bangladesh," *Journal of Political Economy*, Vol. 116, pp. 881–930.

Foster, Andrew D and Mark R Rosenzweig (2002) "Household division and rural economic growth," *The Review of Economic Studies*, Vol. 69, pp. 839–869.

Geruso, Michael and Dean Spears (2017) "Neighborhood sanitation and infant mortality," *American Economic Journal: Applied Economics*.

Hanushek, Eric A (2003) "The failure of input-based schooling policies," *The Economic Journal*, Vol. 113.

Headey, Derek, John Hoddinott, Disha Ali, Roman Tesfaye, and Mekdim Dereje (2015) "The other Asian enigma: explaining the rapid reduction of undernutrition in Bangladesh," *World Development*, Vol. 66, pp. 749–761.

Horton, Susan (1988) "Birth order and child nutritional status: evidence from the Philippines," *Economic Development and Cultural Change*, Vol. 36, pp. 341–354.

Hytten, Frank E and Isabella Leitch (1964) *The physiology of human pregnancy*: Blackwell.

Jayachandran, Seema and Rohini Pande (2017) "Why are Indian children so short?: The role of son preference and birth order," *American Economic Review*, Vol. 107.

Jeffery, Patricia, Roger Jeffery, and Andrew Lyon (1988) *Labour Pains and Labour Power: Women and Childbearing in India*: Zed Books.

Kishore, Avinash and Dean Spears (2014) "Having a son promotes clean cooking fuel use in urban India: Women's status and son preference," *Economic Development and Cultural Change*, Vol. 62, pp. 673–699.

Lawn, Joy E, Simon Cousens, Jelka Zupan, and Lancet Neonatal Survival Steering Team (2005) "4 million neonatal deaths: When? Where? Why?" *The Lancet*, Vol. 365, pp. 891–900.

Lehmann, Jee-Yeon K, Ana Nuevo-Chiquero, and Marian Vidal-Fernandez (2016) "The early origins of birth order differences in children's outcomes and parental behavior," *Journal of Human Resources*, pp. 0816–8177.

Lim, Stephen S, Lalit Dandona, Joseph A Hoisington, Spencer L James, Margaret C Hogan, and Emmanuela Gakidou (2010) "India's Janani Suraksha Yojana, a conditional cash transfer programme to increase births in health facilities: An impact evaluation," *The Lancet*, Vol. 375, pp. 2009–2023.

Ludwig, David S and Janet Currie (2010) "The association between pregnancy weight gain and birthweight: A within-family comparison," *The Lancet*, Vol. 376, pp. 984–990.

Lundberg, Evelina and Helena Svaleryd (2017) "Birth Order and Child Health," working paper, Uppsala University.

Maluccio, John A, John Hoddinott, Jere R Behrman, Reynaldo Martorell, Agnes R Quisumbing, and Aryeh D Stein (2009) "The impact of improving nutrition during early childhood on education among Guatemalan adults," *The Economic Journal*, Vol. 119, pp. 734–763.

Mehta, DC (1969) "Sample registration in Gujarat, India," *Demography*, Vol. 6, pp. 403–411.

Million Death Collaborators (2010) "Causes of neonatal and child mortality in India: A nationally representative mortality survey," *The Lancet*, Vol. 376, pp. 1853–1860.

Modin, Bitte (2002) "Birth order and mortality: a life-long follow-up of 14,200 boys and girls born in early 20th century Sweden," *Social science & medicine*, Vol. 54, pp. 1051–1064.

Nisbett, Nicholas (2017) "A Narrative Analysis of the Political Economy Shaping Policy on Child Undernutrition in India," *Development and Change*, Vol. 48, pp. 312–338.

Palriwala, Rajni (1993) "Economics and patriliny: Consumption and authority within the household," *Social Scientist*, Vol. 21, pp. 47–73.

Paneth, Nigel, John L Kiely, Sylvan Wallenstein, Michele Marcus, Jean Pakter, and Mervyn Susser (1982) "Newborn intensive care and neonatal mortality in low-birth-weight infants: A population study," *New England Journal of Medicine*, Vol. 307, pp. 149–155.

Price, Joseph (2008) "Parent-child quality time does birth order matter?" *Journal of Human Resources*, Vol. 43, pp. 240–265.

Pritchett, Lant (2009) "Is India a Flailing State? Detours on the Four Lane Highway to Modernization," working paper, Harvard.

Setel, Philip W, Sarah B Macfarlane, Simon Szreter, Lene Mikkelsen, Prabhat Jha, Susan Stout, Carla AbouZahr, Monitoring of Vital Events (MoVE) writing group et al. (2007) "A scandal of invisibility: making everyone count by counting everyone," *The Lancet*, Vol. 370, pp. 1569–1577.

Siega-Riz, Anna Maria, Linda S Adair, and Calvin J Hobel (1994) "Institute of Medicine maternal weight gain recommendations and pregnancy outcome in a predominantly Hispanic population," *Obstetrics & Gynecology*, Vol. 84, pp. 565–573.

Solon, Gary, Steven J Haider, and Jeffrey M Wooldridge (2015) "What are we weighting for?" *Journal of Human Resources*, Vol. 50, pp. 301–316.

Spears, Dean (2012) "Height and cognitive achievement among Indian children," *Economics & Human Biology*, Vol. 10, pp. 210–219.

——— (2018) "Exposure to open defecation can account for the Indian enigma of child height," *Journal of Development Economics*.

Spears, Dean, Diane Coffey, and Jere Behrman (2019) "Birth order, fertility, and child height in India and Africa," Discussion Paper, IZA.

Strauss, John and Duncan Thomas (1995) "Human resources: Empirical modeling of household and family decisions," *Handbook of Development Economics*, Vol. 3, pp. 1883–2023.

Tarozzi, Alessandro (2008) "Growth reference charts and the nutritional status of Indian children," *Economics & Human Biology*, Vol. 6, pp. 455–468.

Thomson, AM and WZ Billewicz (1957) "Clinical significance of weight trends during pregnancy," *British Medical Journal*, Vol. 1, pp. 243–247.

Viscusi, W Kip and Joseph E Aldy (2003) "The value of a statistical life: A critical review of market estimates throughout the world," *Journal of Risk and Uncertainty*, Vol. 27, pp. 5–76.

Vogl, Tom (2013) "Marriage institutions and sibling competition: Evidence from South Asia," *Quarterly Journal of Economics*, Vol. 128, p. 1017.

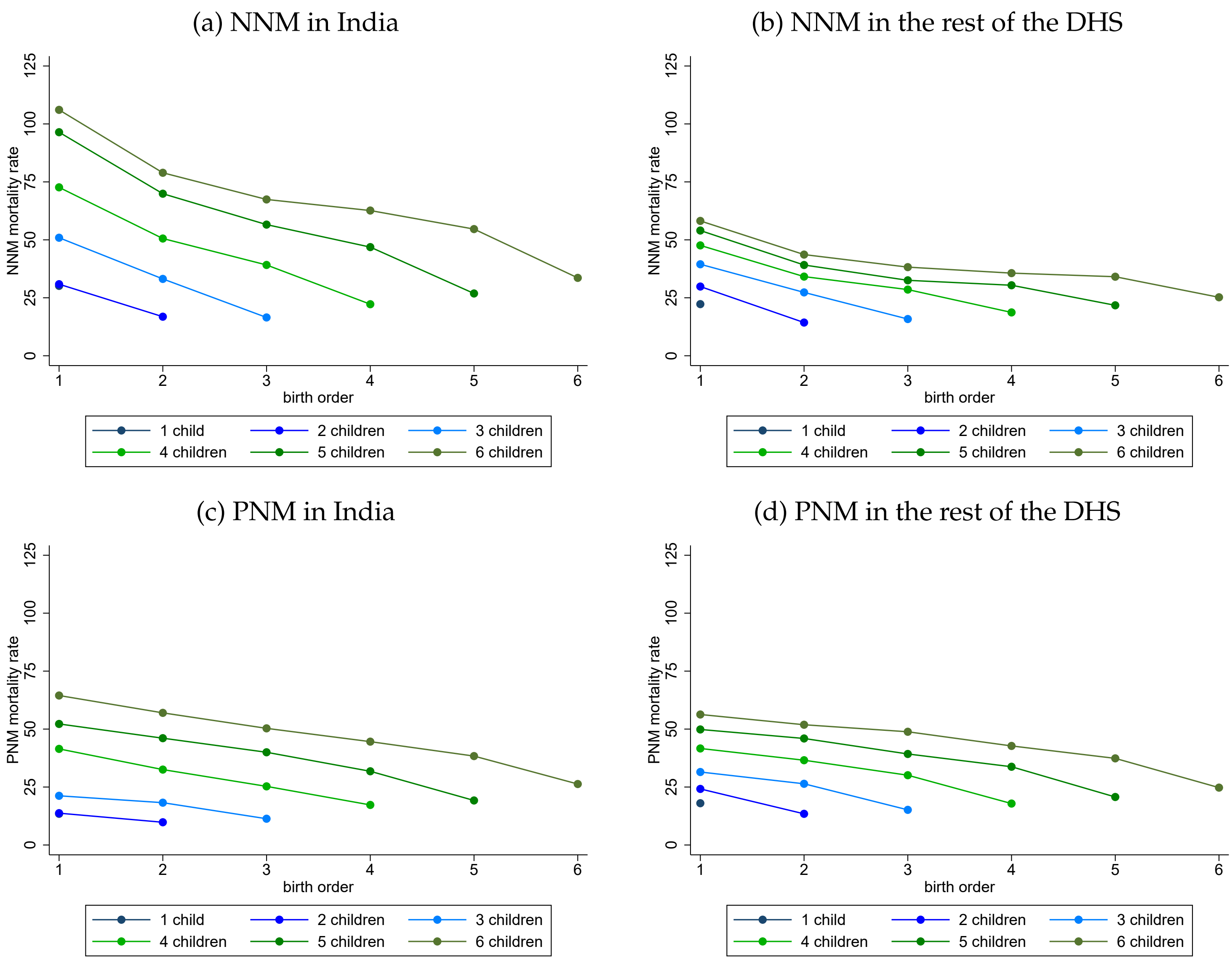
Vogl, Tom S (2015) "Differential Fertility, Human Capital, and Development," *The Review of Economic Studies*, p. rdv026.

Wilson, Ian, Sharon RA Huttly, and Bridget Fenn (2006) "A case study of sample design for longitudinal research: Young Lives," *International Journal of Social Research Methodology*, Vol. 9, pp. 351–365.

World Health Organization (1995) "Maternal anthropometry and birth outcomes: A WHO collaborative study," *Bulletin of the World Health Organization*, Vol. supplement to volume 73.

Yaktine, Ann L and Kathleen M Rasmussen (2009) *Weight Gain During Pregnancy: Reexamining the Guidelines*: National Academies Press.

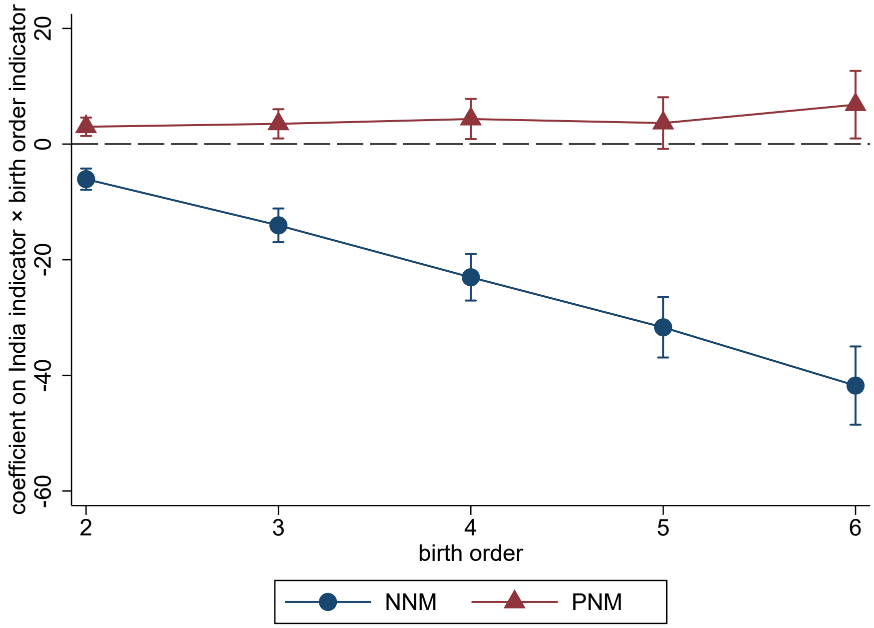
Figure 1: Early-life mortality by birth order and sibsize



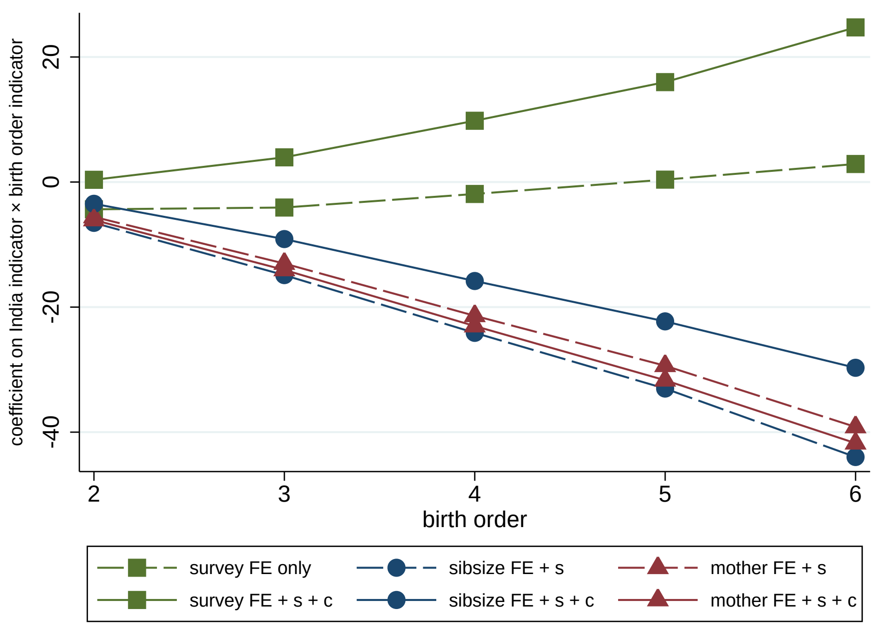
Main DHS birth sample of births, described in section 3. NNM = neonatal mortality. PNM = post-neonatal mortality. Mortality rates scaled to per 1,000. For a replication with a restricted sample that excludes mothers with incomplete fertility, see appendix figure A.1.

Figure 2: Main result: How the relationship between birth order and mortality in India differs from the rest of the developing world

(a) Coefficients on *birth order*$_{ims}$ × *India*$_s$ indicators from equation 1, all controls included: NNM and PNM are dependent variables



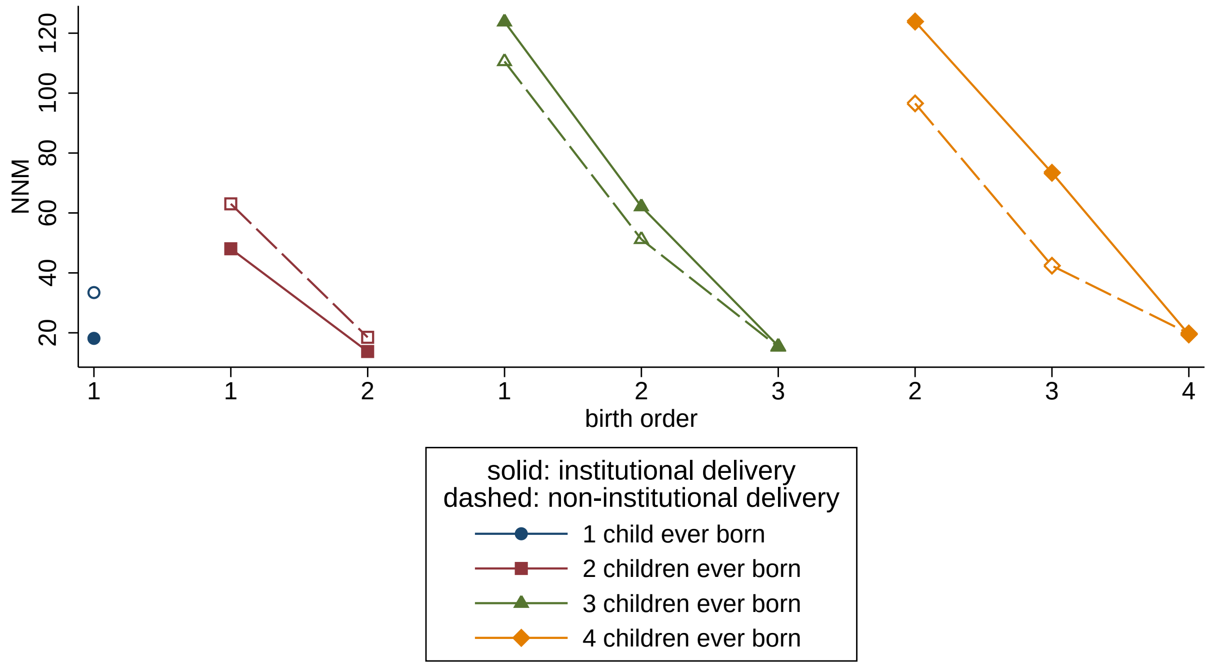
(b) Coefficients on *birth order*$_{ims}$ × *India*$_s$ indicators without sibsize controls, with sibsize controls, and with mother FEs: NNM is the dependent variable



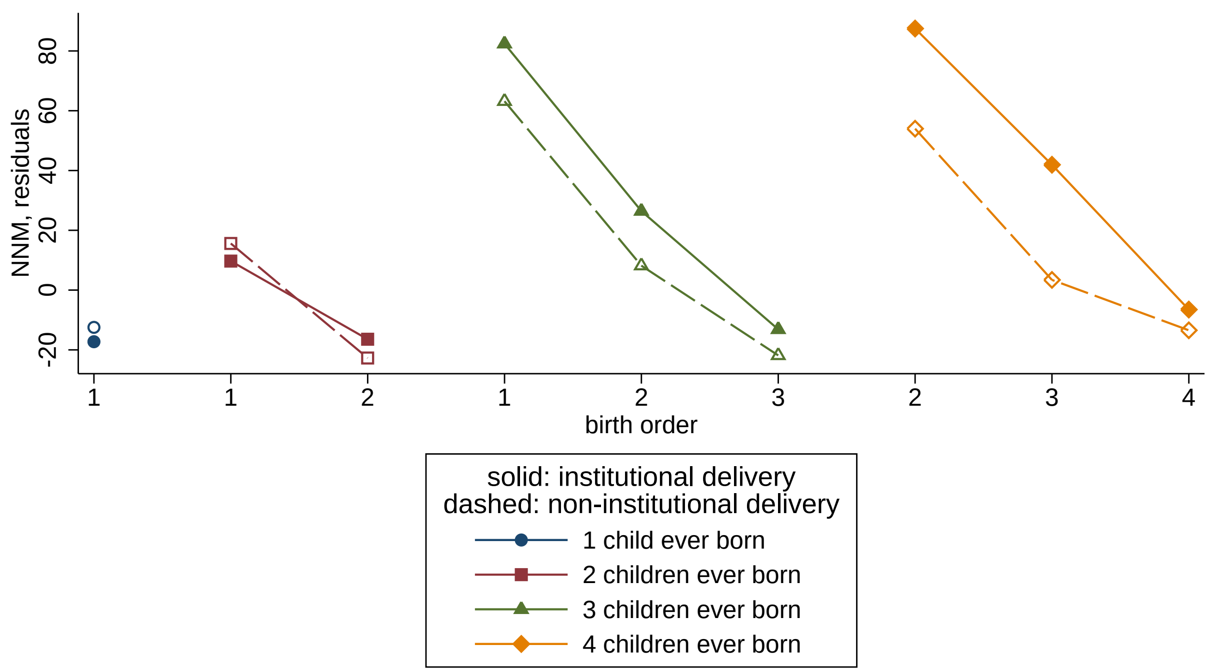
Main DHS sample of births, described in section 3. Each connected set of estimates is from a separate regression. 95% confidence intervals in panel (a) reflect standard errors clustered by survey PSU. Panel (a) uses the fully controlled specification from equation 1, including mother fixed effects. In panel (b) s = sex and c = birth cohort of mom and child. For a replication with a restricted sample that excludes mothers with incomplete fertility, see appendix figure A.3; for a robustness check comparing India with a sub-Saharan African sample, see appendix figure A.4.

Figure 3: Institutional delivery does not explain India's birth order pattern of NNM

(a) mean of NNM by institutional delivery



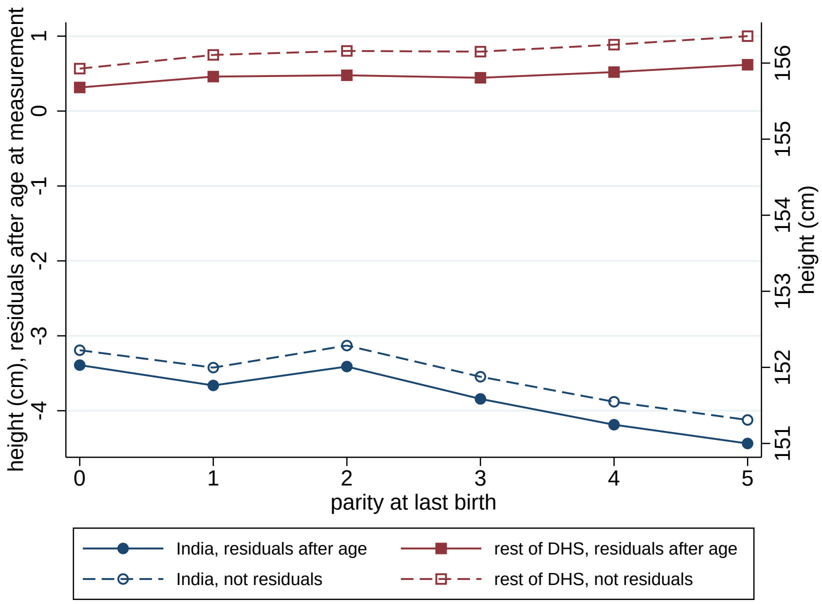
(b) mean of NNM by institutional delivery, residuals after cohort, sex, and location controls



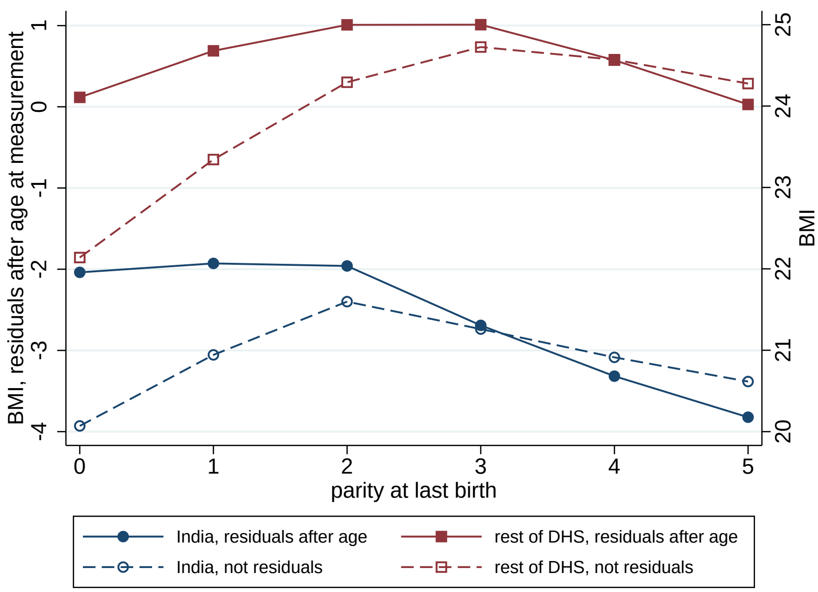
The sample is India's most recent DHS, from 2005-6. In the DHS institutional delivery is only recorded for children under 5 years old, so only these ages are included in our sample. Controls are for a quadratic of birth cohort of child and of mother (both as CMC codes), child sex, and whether the household is in a rural or urban location. Colors and marker shapes indicate the number of children ever born to mother by time of survey. For full regression results see appendix table A.5.

Figure 4: Differences in fertility selectivity between India and the rest of the DHS: Women's heights and women's BMIs, by parity at last birth

(a) height (cm)



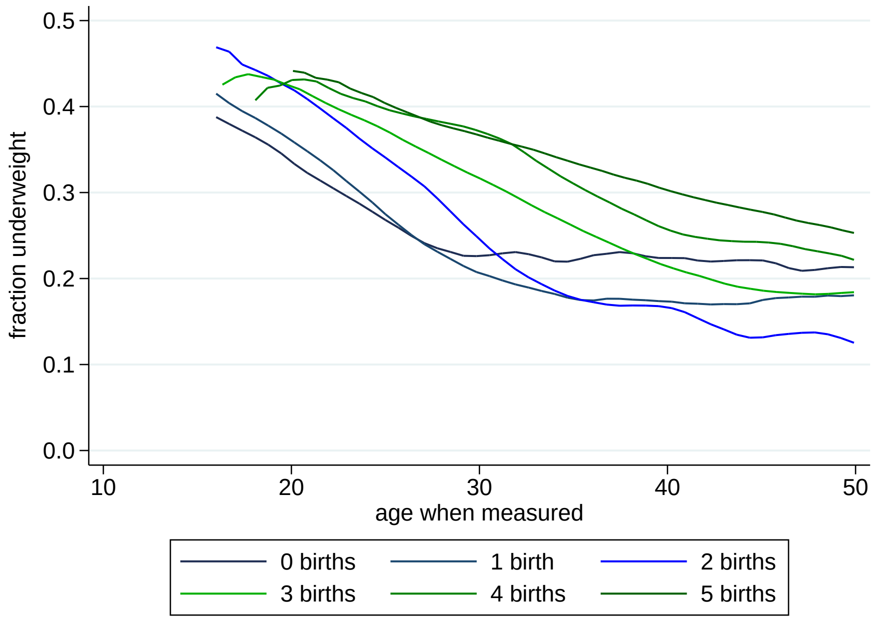
(b) body mass index (BMI)



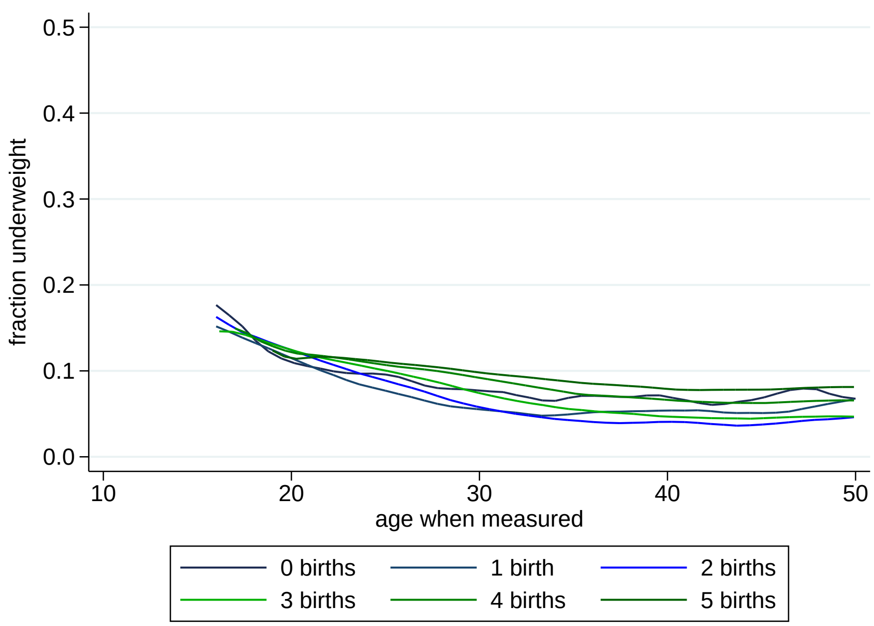
Women's anthropometry sample, described in sections 3 and 6. For a similar figure using the alternative sub-Saharan Africa comparison sample, see figure A.6 in the Supplementary Appendix.

Figure 5: Women's underweight is predicted by age in India, but not in the rest of the DHS

(a) India



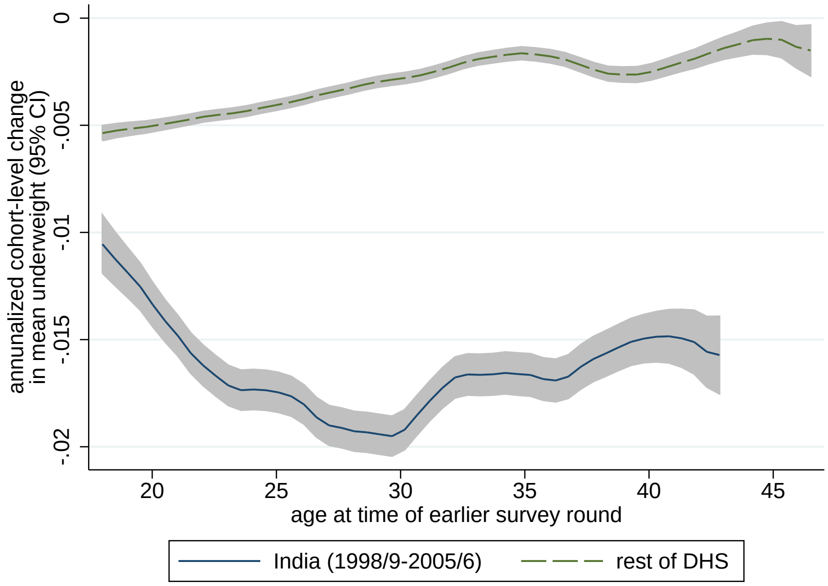
(b) rest of the DHS



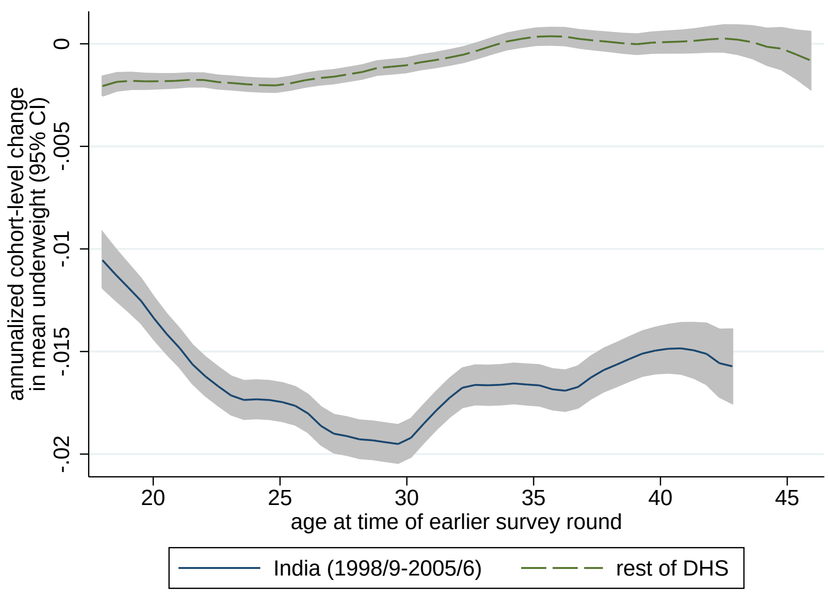
Women's anthropometry sample, described in sections 3 and 6. Vertical axes plot the fraction of women who are underweight, meaning they have a body mass index below 18.5. Age, underweight, and parity are all measured at the time of the DHS survey.

Figure 6: The rate of change in underweight of month-of-birth cohorts of women differs between India and the rest of the DHS

(a) India 1998/9 – 2005/6 is compared to all available DHS



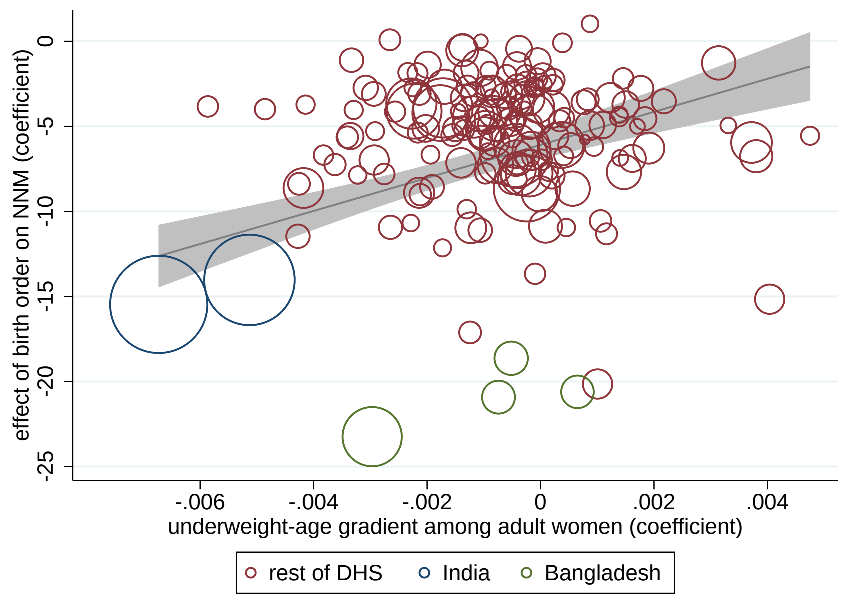
(b) India 1998/9 – 2005/6 is compared to those surveys collected during a similar time period



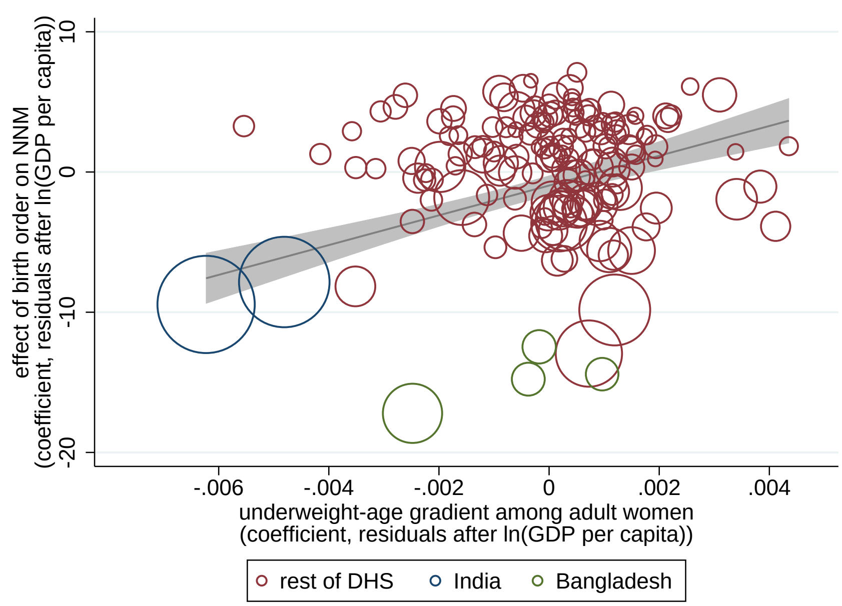
Panel (a) restricts the women's anthropometry sample described in sections 3 and 6 to those surveys for which there is more than one DHS survey round in the same country. Panel (b) restricts the women's anthropometry sample to those DHS surveys for which the first of two surveys in the same country was within 2.5 years before or after the 1998/9 Indian DHS. In both panels, cohort mean changes are annualized by dividing by the time interval in months between DHS rounds.

Figure 7: Across DHS survey rounds, a larger negative effect of birth order on NNM is associated with a steeper negative gradient between age and underweight among adult women

(a) linear birth order coefficient, no controls



(b) linear birth order coefficient, ln(GDP) control



The sample is DHS survey rounds used to construct the main DHS sample of births discussed in section 3. In both panels, each point plots regression results from two separate regressions, each estimated for one DHS survey round at a time. The vertical axes plot the coefficient on birth order linearly predicting NNM, in a regression with mother fixed effects. The horizontal axis plots the coefficient on adult women's age in years linearly predicting an indicator for being underweight. The results in panel (b) additionally control (by residualizing the variables in the horizontal and vertical axes in two separate regressions) for a DHS-survey-round-level mean of GDP per capita; for more detail see section 6.5.

Table 1: Counterfactual projected decrease in Indian NNM, if it were to match the birth order gradient in the rest of the developing world

method	note	equal weights	sample weights
mean differences	full sample	8.1	8.6
mean differences	restricted sample	9.8	10.0
regression	mother FE & controls	10.6	10.9
regression	sibsize controls only	11.1	11.2

The table presents eight alternative estimates of the counterfactual decrease in India's NNM from matching the rest of the world's NNM gradient in birth order, while holding constant the average NNM among the last-born children of each sibsize. The purpose is to summarize the magnitude of the effect tht we document (not to evaluate any actual policy proposal). For full details on the computation, see section 7. The second row uses the restricted sample (described in section 3), which excludes births to mothers whose last birth is within five years of the survey. The estimates in the third and fourth rows use the main DHS sample of births.

A Introductory demographic summary statistics

- “Twenty-seven percent of neonatal deaths now occur in India."
  - Births per five-year period in thousands, from UN World Population Prospects (2010-2015): World: 699,214; India: 129,729. Thus 19% of births each year are in India.
  - Neonatal mortality rates (2015), from World Bank World Development Indicators (WDI), expressed per 1,000: World: 19.2; India 28.
  - These imply 3,632 neonatal deaths per five-years in India and 13,425 globally, both in thousands.
- Decline in IMR: World Bank WDI show 121.9 in 1960 to 31.7 in 2015, both per 1,000 births.
- “Over three-fifths of infant deaths are neonatal deaths: deaths in the first month of life.”: World Bank WDI NNM in 2015 is 19.2 for the world, compared with 31.7 for IMR. 19.2 ÷ 31.7 is 61%.

B How age predicts alternative BMI cutpoints

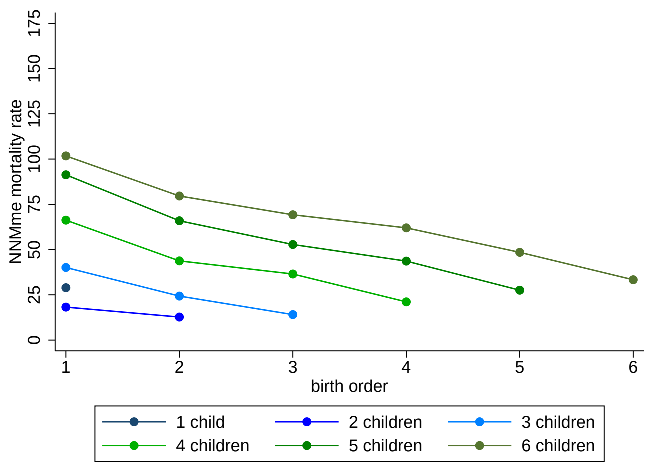
Figure 5 focuses on one cut-point in the BMI distribution: the division between being underweight or not. In the Supplementary Appendix, Figure A.7 extends this analysis by examining the cross-sectional association between adult women’s ages and the linear probability of being above a range of BMI scores. The figure shows that in India’s cross-section, age predicts whether a woman has *normal, rather than low, BMI*, while in the rest of the DHS age predicts whether a woman has *high, rather than normal, BMI*. A low BMI is one that is less than 18.5, a normal BMI is one that is between 18.5 and 25, and a high BMI is one that is greater than 25. For each BMI cutpoint, c, in half-point increments, for each sample s (India or the rest of the DHS), the figure plots the coefficients $\beta^s_{1,c}$ from the following linear probability model, with and without controls for children ever born:

$$\mathbf{1}\left[BMI_{ms} > c\right] = \beta^s_0 + \beta^s_{1,c}\text{age}_{ms} + \theta\text{children ever born}_{ms} + \varepsilon_{ms} \quad (6)$$

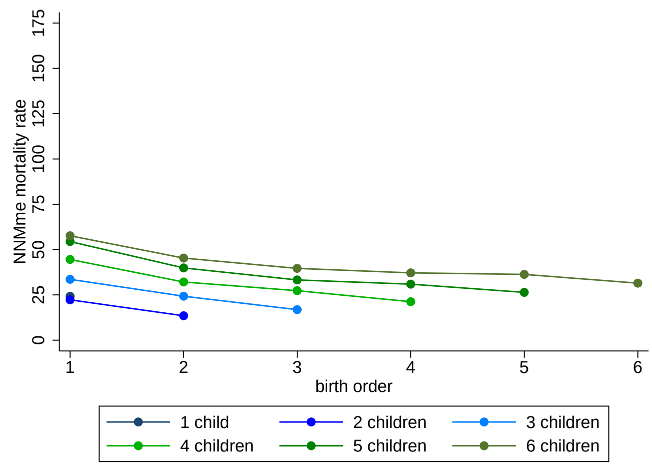
Thus, figure A.7 plots regression coefficients from separate regression estimations. All of the coefficients are positive because older adults tend to weigh more than younger adults in populations worldwide. The coefficients are larger for Indian women than for the rest of the DHS, meaning that age is especially predictive of BMI, and are especially large around the low BMI cutpoints, which is where maternal undernutrition poses a threat to children. In other words, in India, the distribution of BMI for older women is different from the distribution for younger women around the *underweight* side of the distribution; in the rest of the developing world, age is associated with a shift of the distribution through normal BMIs to overweight. Controlling for the number children ever born (results shown with dashed lines) makes the age-BMI gradients more steeply positive because age, parity progression, and BMI are all positively correlated with one another, but higher-fertility women weigh less, on average, because they are poorer.

Figure A.1: Early-life mortality by birth order and sibsize, restricted sample

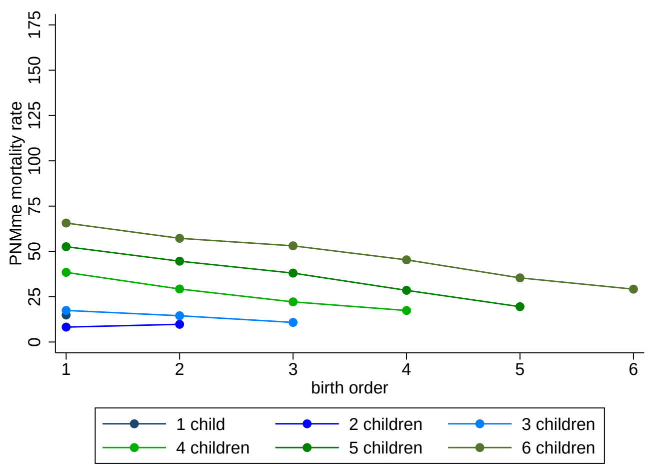
(a) NNM in India



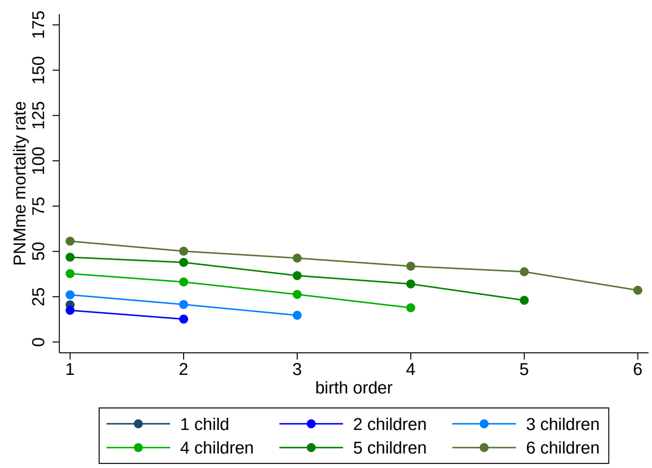
(b) NNM in the rest of the DHS



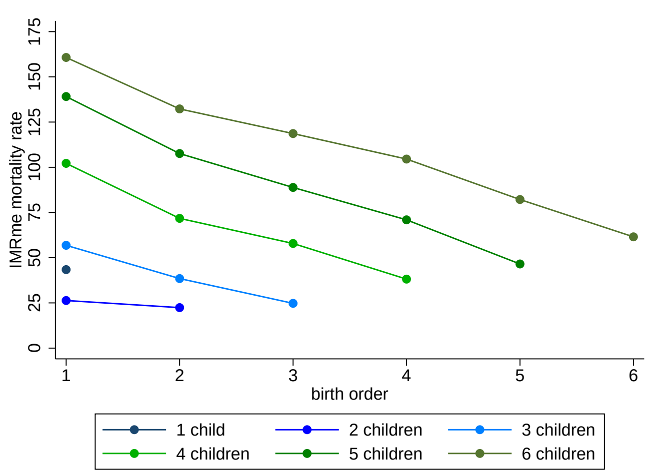
(c) PNM in India



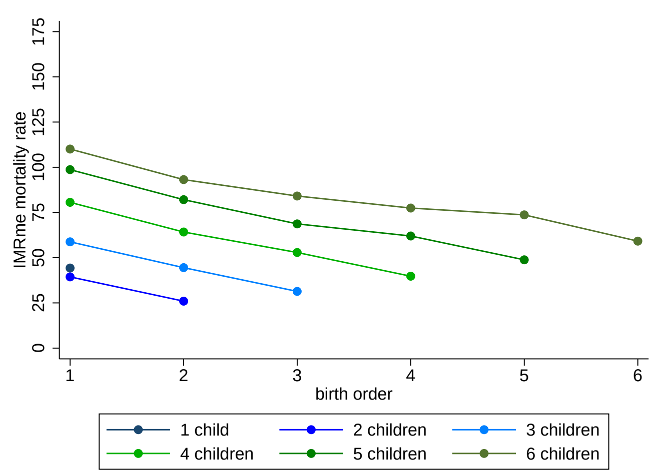
(d) PNM in the rest of the DHS



(e) IMR in India



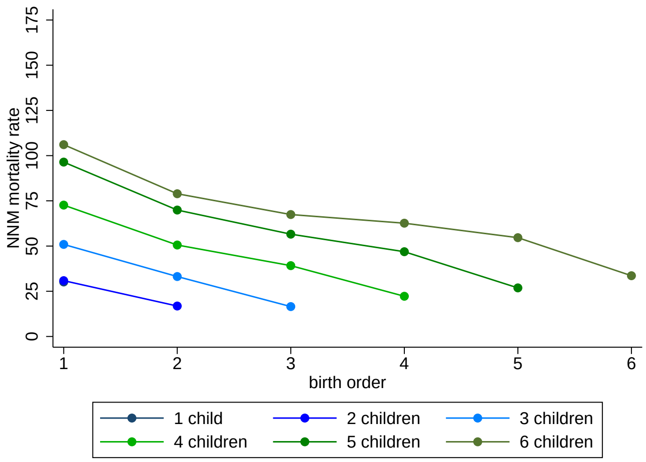
(f) IMR in the rest of the DHS



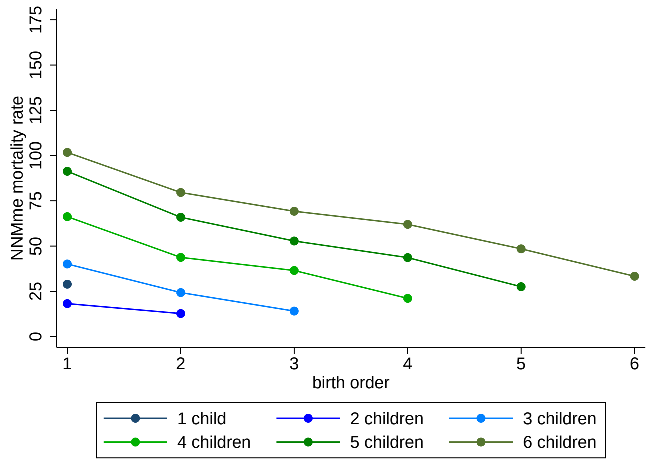
Restricted sample: Starting from the main DHS sample of births described in section 3, this sample excludes all births to mothers who have had a birth in the past five years to avoid confounding by incomplete fertility. Mortality rates are scaled to per 1,000.

Figure A.2: NNM by birth order and sibsize, replication with African sample

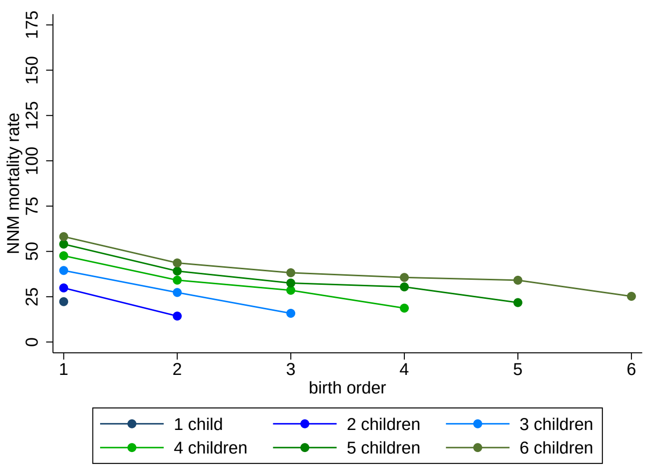
(a) NNM in India, full



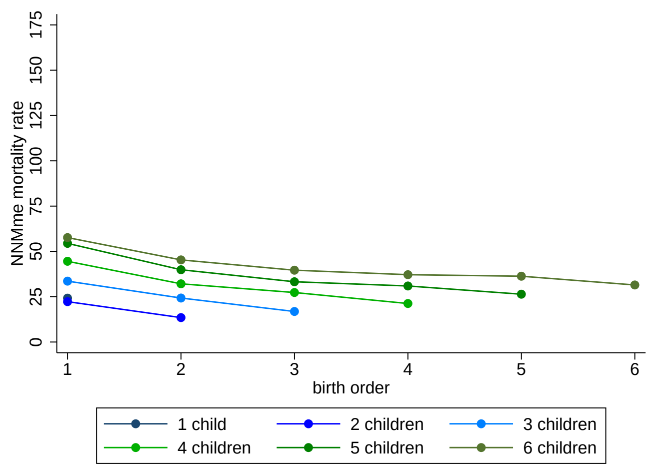
(b) NNM in India, restricted



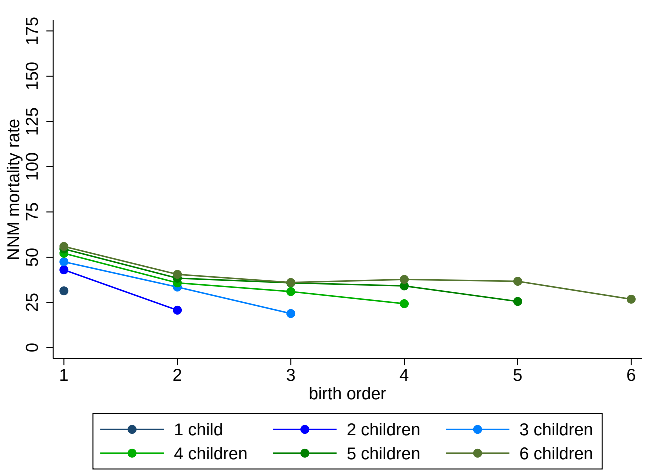
(c) NNM in the rest of the DHS, full



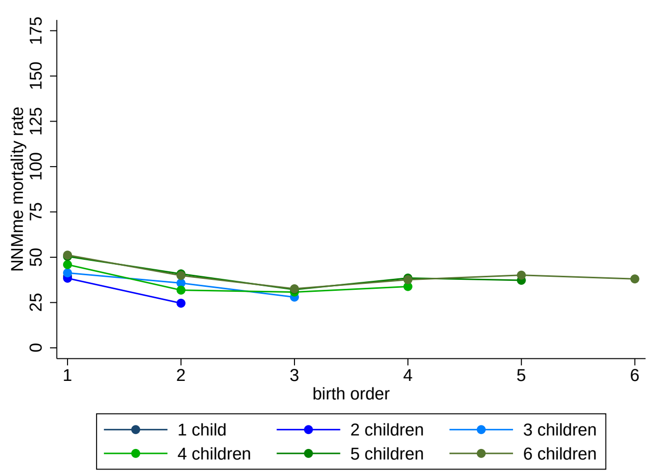
(d) NNM in the rest of the DHS, restricted



(e) NNM in Africa, full



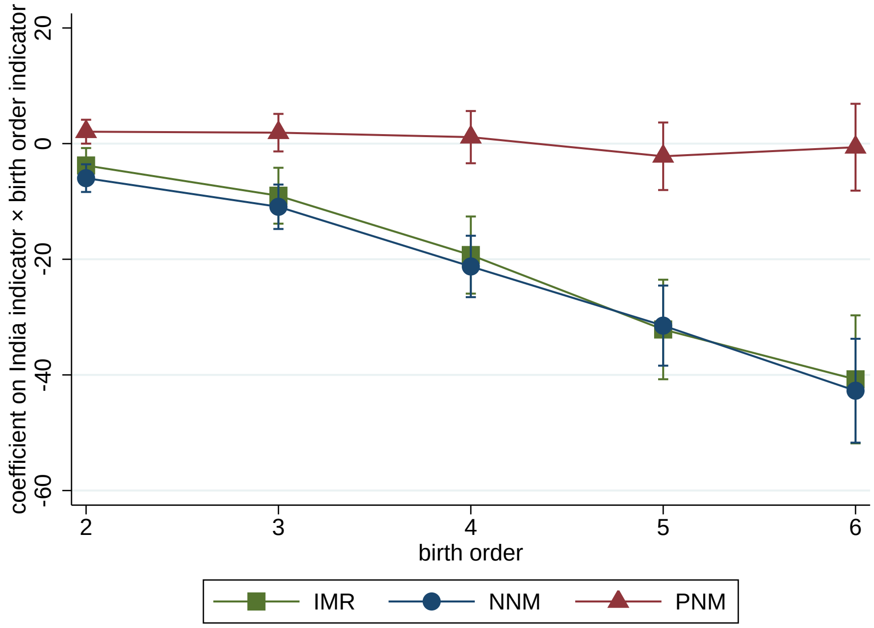
(f) NNM in Africa, restricted



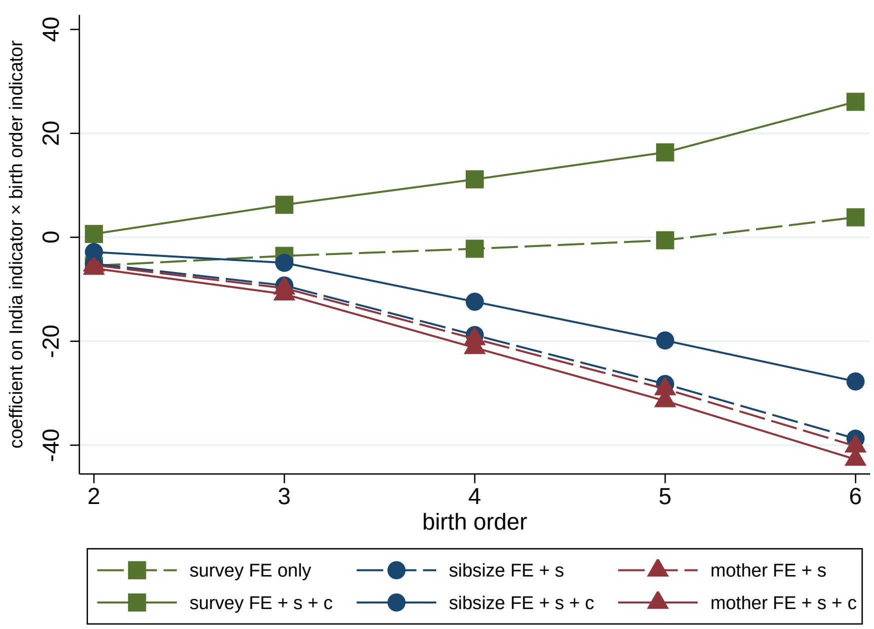
Restricted sample: Starting from the main DHS sample of births described in section 3, this sample excludes all births to mothers who have had a birth in the past five years to avoid confounding by incomplete fertility. African sample: This sample includes a set of DHS survey rounds used by Jayachandran and Pande (2017) to study height. They are listed in table A.1. Mortality rates are scaled to per 1,000.

Figure A.3: Robustness: How the relationship between birth order and mortality in India differs from the rest of the developing world, restricted sample

(a) Coefficients on *birth order*$_{ims}$ × *India*$_s$ indicators from equation 1, all controls included: NNM, PNM, and IMR are dependent variables



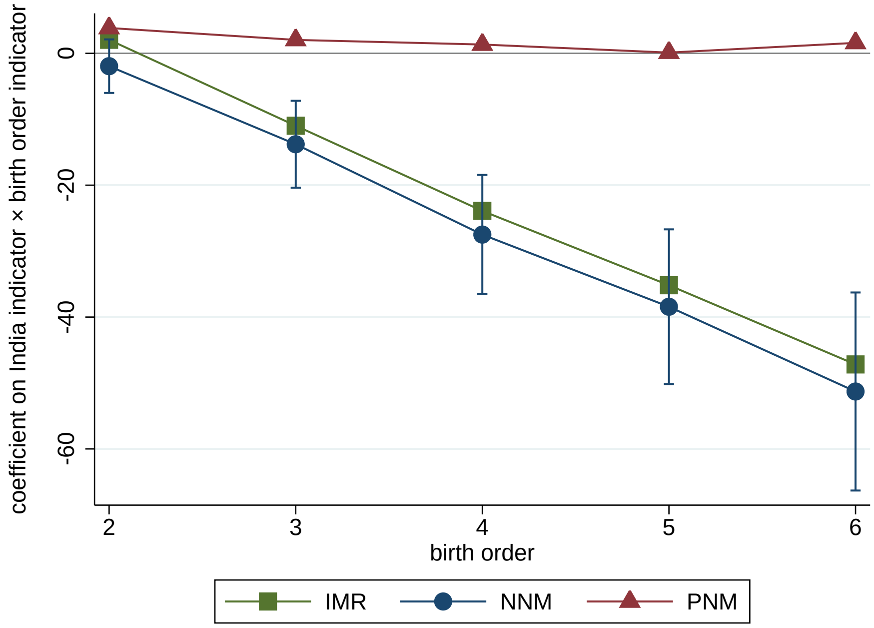
(b) Coefficients on *birth order*$_{ims}$ × *India*$_s$ indicators without sibsize controls, with sibsize controls, and with mother FEs: NNM is the dependent variable



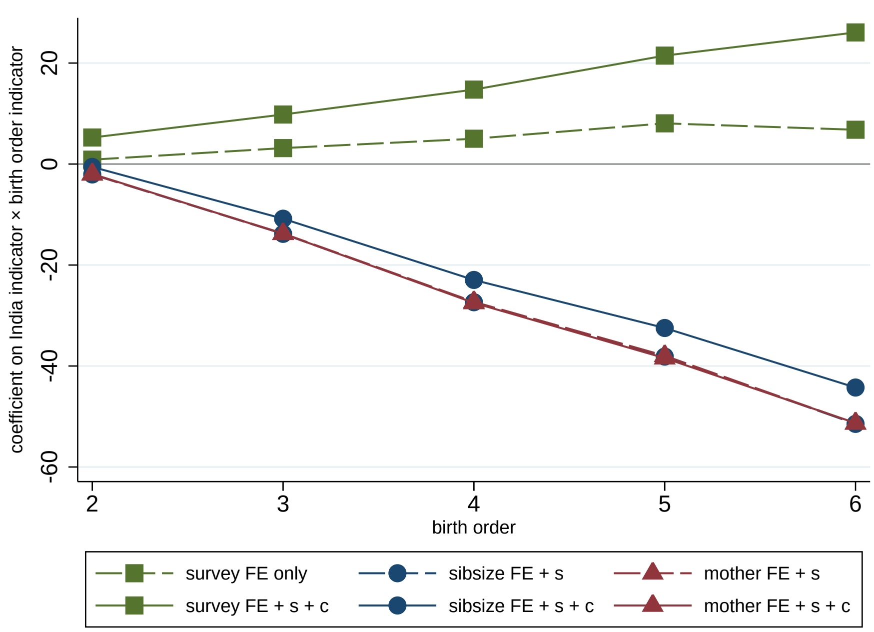
Restricted sample: Starting from the main DHS sample of births described in section 3, this sample excludes all births to mothers who have had a birth in the past five years to avoid confounding by incomplete fertility. Each connected set of estimates is from a separate regression. 95% confidence intervals in panel (a) reflect standard errors clustered by survey PSU. Panel (a) uses the fully controlled specification from equation 1, including mother fixed effects. In panel (b) s = sex and c = birth cohort of mom and child.

Figure A.4: Robustness: How the relationship between birth order and mortality in India differs from an alternative sub-Saharan African comparison sample

(a) Coefficients on $\textit{birth order}_{ims} \times \textit{India}_s$ indicators from equation 1, all controls included: NNM, PNM, and IMR are dependent variables

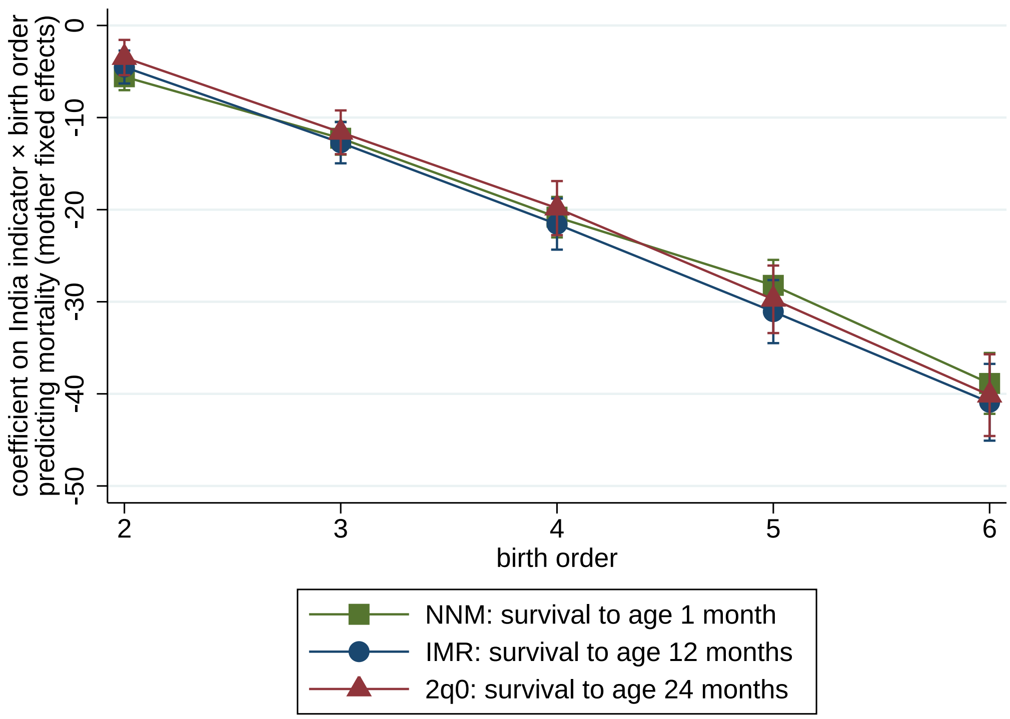


(b) Coefficients on $\textit{birth order}_{ims} \times \textit{India}_s$ indicators without sibsize controls, with sibsize controls, and with mother FEs: NNM is the dependent variable



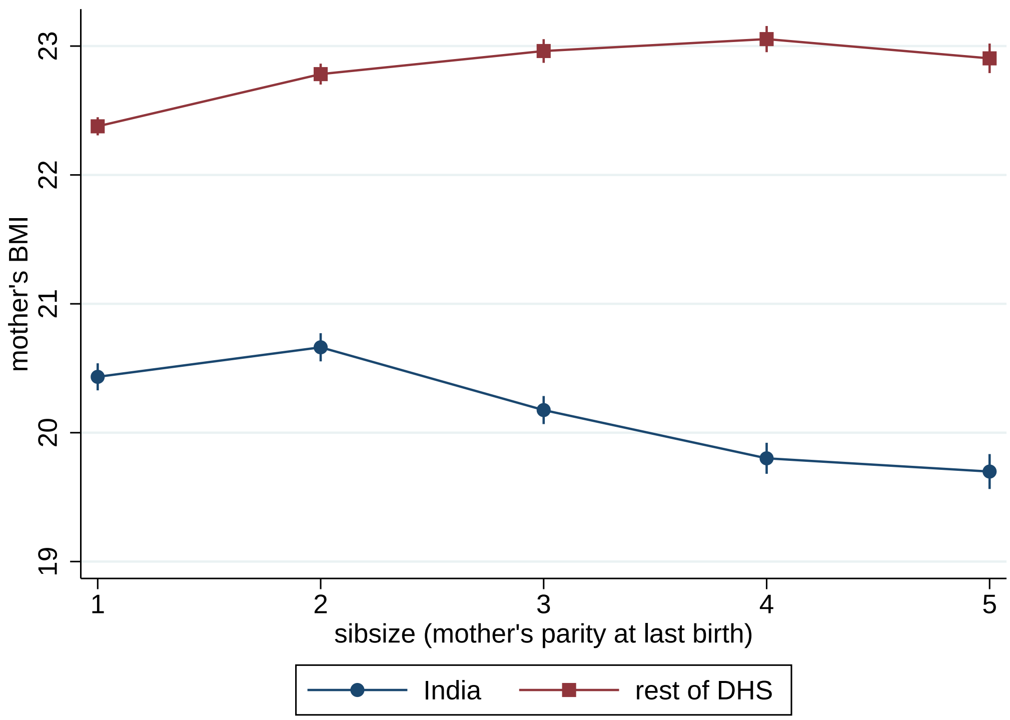
India's 2005-6 DHS is compared with the set of African DHS rounds used by Jayachandran and Pande (2017) to study height and listed in table A.1. Each connected set of estimates is from a separate regression. 95% confidence intervals in panel (a) reflect standard errors clustered by survey PSU. Panel (a) uses the fully controlled specification from equation 1, including mother fixed effects. In panel (b) s = sex and c = birth cohort of mom and child.

Figure A.5: India's birth order pattern of NNM is not reversed by deaths at later ages



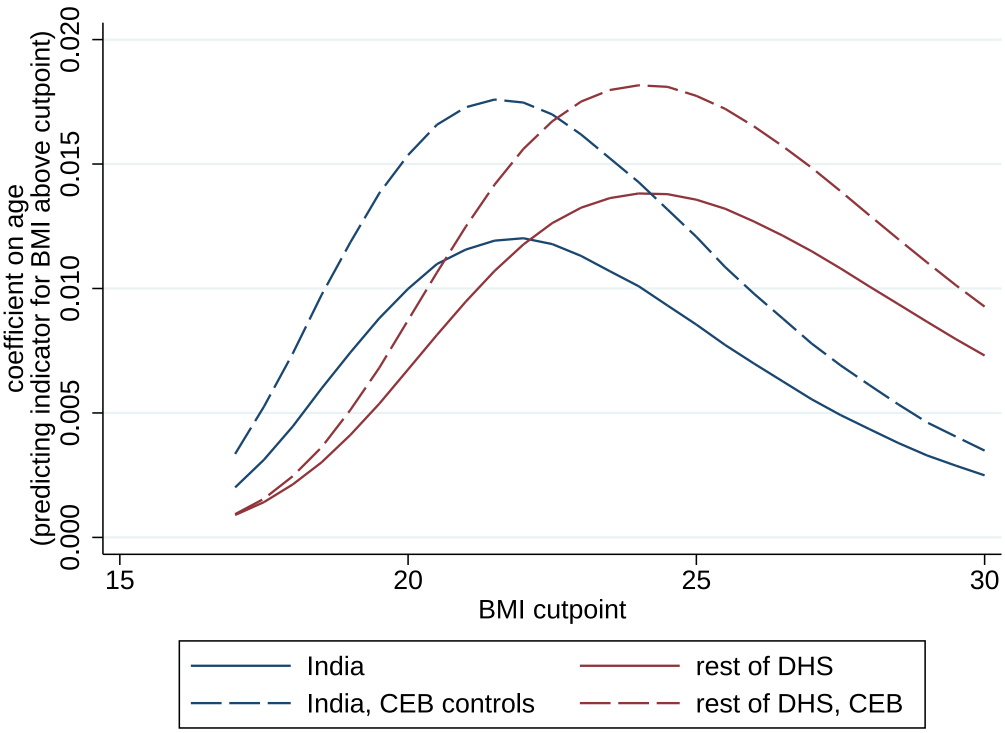
Main DHS sample of births, described in section 3. This figure is a robustness check and extension of panel (a) of figure 2, but with survival to age 2 ($_2q_0$) as a dependent variable. Each mortality rate (NNM, IMR, $_2q_0$) is a dependent variable in a separate regression. The results are slightly quantitatively different from the main result because only children born at least two years before their mother's interview date are included, so that the sample is comparable across the three mortality rates. 95% confidence intervals for the effect on NNM are clustered by survey PSU and overlap with the other coefficients.

Figure A.6: Mothers' BMI in India and in sub-Saharan Africa, by sibsize



Computations are identical to figure 4 in the main text, but here "rest of DHS" refers to the African comparison sample. We use the same set of DHS surveys used by Jayachandran and Pande (2017) to study height, which is listed in table A.1. Vertical lines are 95% CIs, with standard errors clustered to reflect survey design.

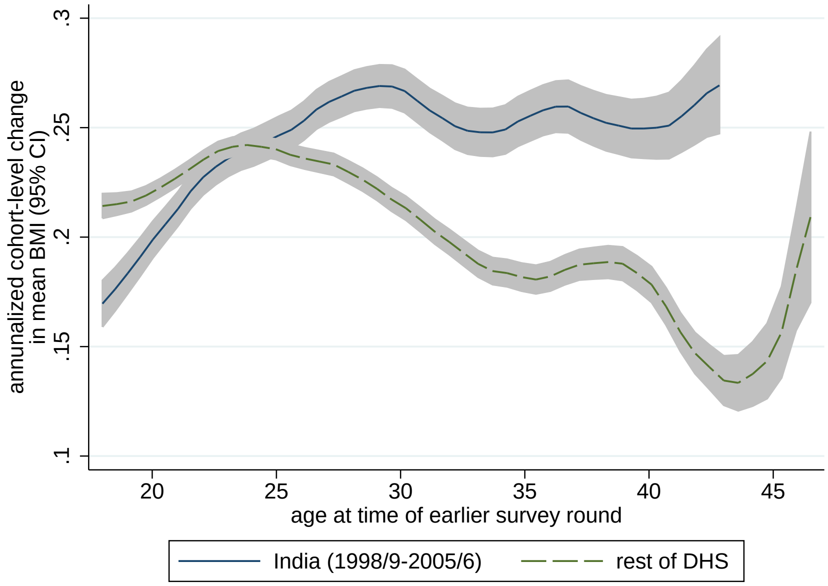
Figure A.7: How age predicts women's BMI, at dichotomized BMI cut-points: India compared with the rest of the DHS



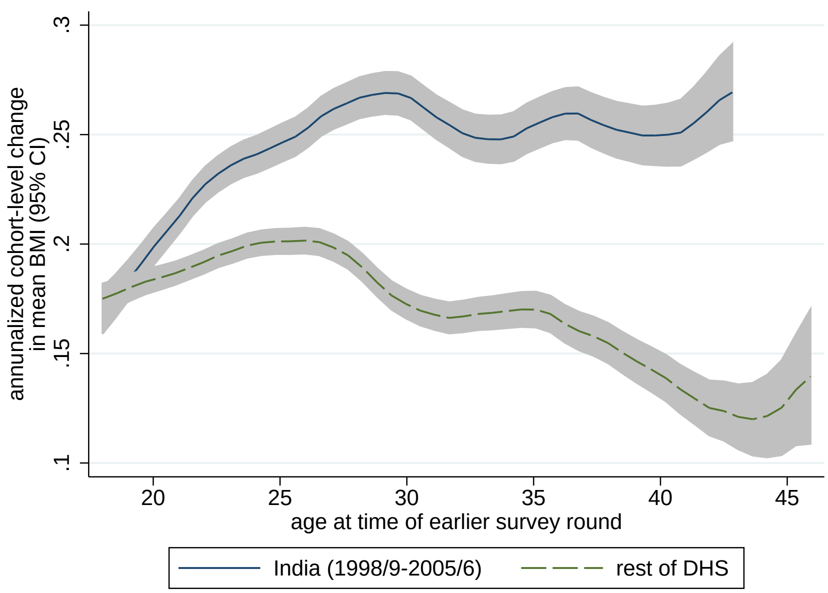
Women's anthropometry sample, described in sections 3 and 6. CEB stands for "children ever born" and indicates that controls for indicators of children ever born at the time of the survey are included. The figure plots and connects coefficients on age estimated from the following linear probability model:
$\mathbf{1}\left[BMI_{ms} > c\right] = \beta_0^s + \beta_1^s \text{age}_{ms} + \theta \text{children ever born}_{ms} + \varepsilon_{ms}$.

Figure A.8: The rate of change in BMI of month-of-birth cohorts of women differs between India and the rest of the DHS

(a) India 1998/9 – 2005/6 is compared to all available DHS



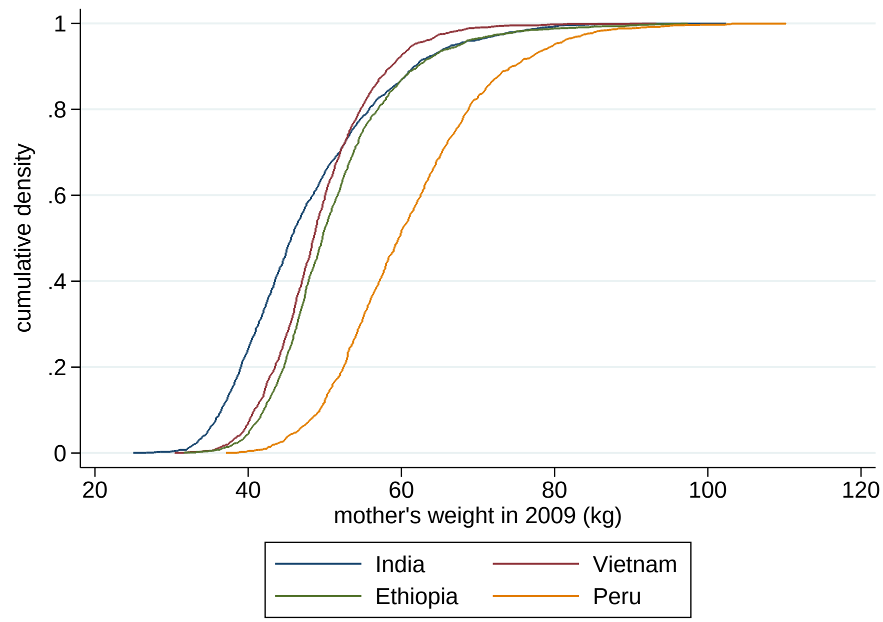
(b) India 1998/9 – 2005/6 is compared to those surveys collected during a similar time period



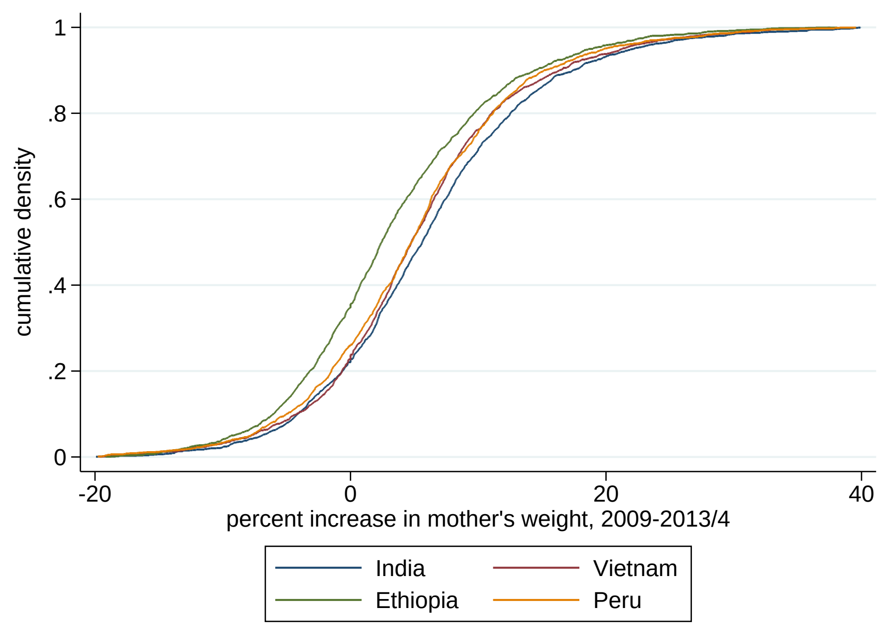
Panel (a) restricts the women's anthropometry sample described in sections 3 and 6 to include those surveys for which there is more than one DHS survey round in the same country. Panel (b) restricts the women's anthropometry sample to those DHS surveys for which the first of two surveys in the same country was within 2.5 years before or after the 1998/9 Indian DHS. In both panels, cohort mean changes are annualized by dividing by the time interval in months between DHS rounds.

Figure A.9: Longitudinal change in women's weight in four developing countries

(a) CDF of mothers' weight (kg) in 2009



(b) CDF of % change in weight, 2009 to 2013/4

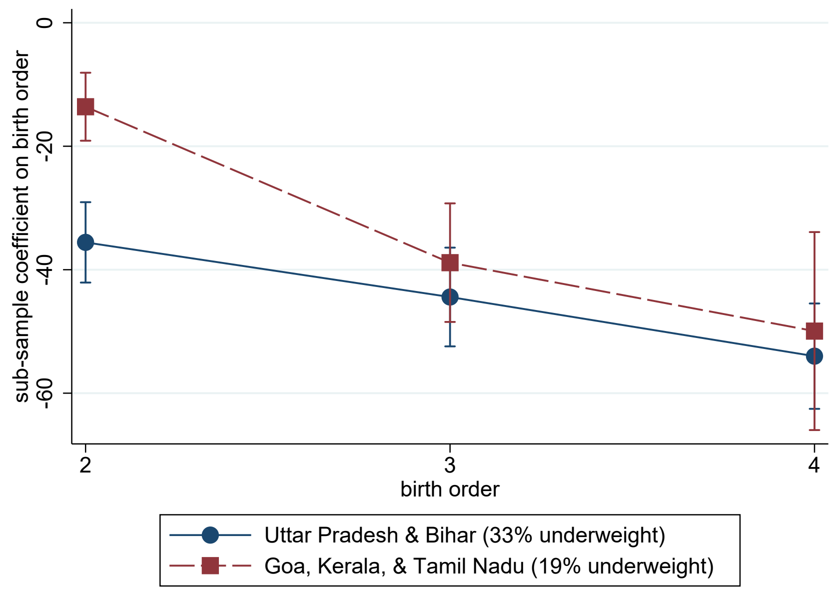


Young Lives data, described in section 6.3. Observations are mothers of young children whose weights were measured in each of two successive survey rounds.

Figure A.10: Geographic effect heterogeneity is suggestive of the role of maternal underweight 1: Comparisons within India

Conclusion: The birth order gradient is steeper in north India, where undernutrition is more severe and women's social status is more constrained, than in south India

$$NNM_{im} = \sum_b \beta^b \text{birth order}_{im} + \gamma \text{sex}_{im} + \alpha_m + \varepsilon_{im}.$$

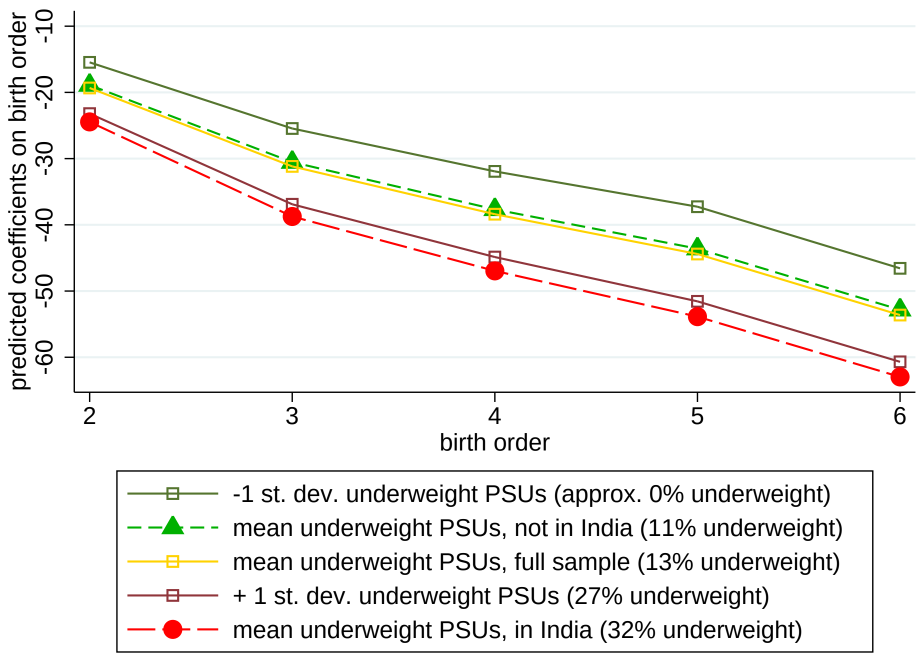


The figure reports two separate mother fixed effects regressions, using data from the listed states from India's 2005-6 DHS.

Figure A.11: Geographic effect heterogeneity is suggestive of the role of maternal underweight 2: Comparisons across full DHS sample

Conclusion: The local fraction of mothers underweight interacts with birth order

$$NNM_{imps} = \sum_b \beta_3^b birth\ order_{imps}^b \times PSU\ underweight_{ps} + \sum_b \beta_2^b birth\ order_{imps}^b + f\left(CMC_{imps}^{child}, India_s\right) + \gamma_1 sex_{imps} \times India_s + \gamma_2 sex_{imps} + \alpha_{mps} + \varepsilon_{imps}.$$

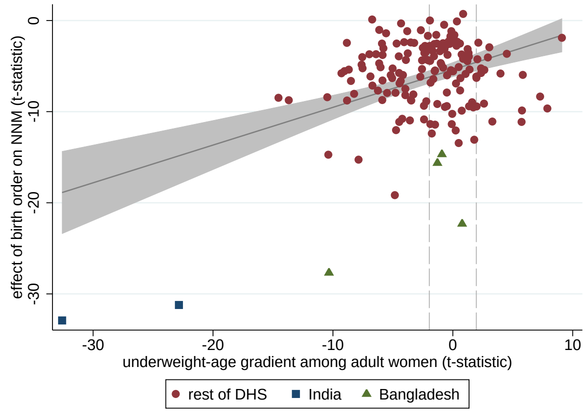


This figure plots predicted effects of being the birth order on the horizontal axis, rather than first-born, at various hypothetical levels of the fraction of women who are underweight in a PSU. This is a way of visualizing the magnitude of the interaction estimated with the equation above. In particular, each dot in the figure is computed as: $\left(\hat{\beta}_3^b \times PSU\ underweight + \hat{\beta}_2^b\right)$ at each birth order b, for a specified example levels of *PSU underweight*.

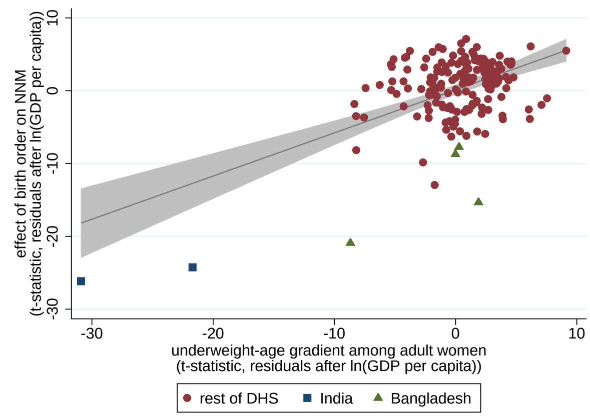
The data with which the regression equation is computed for the main DHS sample. Note that birth order is not interacted with India in the regression equation. Instead, the figure includes among the example hypothetical levels of *PSU underweight* the mean within India and the mean for our data outside of India; comparing these two lines would offer a linear post-diction of the interaction between India and birth order. PSU underweight is the fraction, in a local area, of all women of childbearing age measured by the DHS who have a BMI below 18.5; women are included whether or not they have given birth, and each woman is equally weighted in the mean, regardless of how many times she has given birth. PSU = primary sampling unit.

Figure A.12: Across DHS survey rounds, a larger negative effect of birth order on NNM is associated with a steeper negative gradient between age and underweight among adult women (plots of t-statistics and F-statistics)

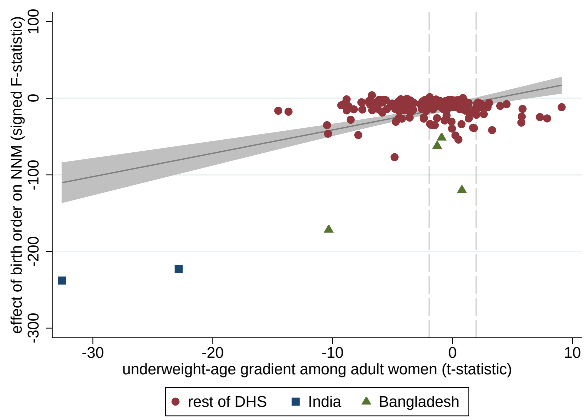
(a) linear birth order t-statistic, no controls



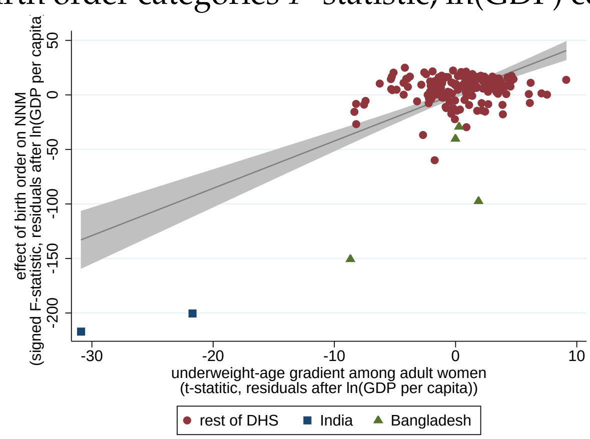
(b) linear birth order t-statistic, ln(GDP) control



(c) birth order categories F-statistic, no controls



(d) birth order categories F-statistic, ln(GDP) control



The sample is DHS survey rounds used to construct the main DHS sample of births discussed in section 3. In all panels, each point plots regression results from two separate regressions, estimated for one DHS survey round at a time. The horizontal axis in all panels plots the t-statistics from the same coefficients in the regressions of underweight on the age of adult women in figure 7. In panels (a) and (b), the vertical axis plots the t-statistics on the linear birth order coefficient from the regressions in figure 7 of NNM on birth order, entered linearly, with mother fixed effects. In panels (c) and (d), the vertical axis plots F-statistics (multiplied by the sign of the linear birth order coefficient) from a joint test of all birth order indicators in a regression of NNM on birth order indicators (instead of birth order as a linear independent variable) in regressions with mother fixed effects. The results in panels (b) and (d) additionally control (by residualizing the variables in the horizontal and vertical axes in two separate regressions) for a DHS-survey-round-level mean of GDP per capita; for more detail see section 6.5.

Table A.1: Demographic and Health Surveys in each sample

country	v000	year	main	SSA	longitudinal	long.-restricted
Albania	AL5	2008-09	✓			
Armenia	AM4	2000, 2005	✓		✓	✓
Armenia	AM7	2015-2016	✓		✓	✓
Azerbaijan	AZ5	2006	✓			
Bangladesh	BD3	1996-97, 1999-2000	✓		✓	✓
Bangladesh	BD4	2004	✓		✓	✓
Bangladesh	BD5	2007	✓		✓	✓
Bangladesh	BD6	2011, 2014	✓		✓	✓
Benin	BJ3	1996	✓		✓	✓
Benin	BJ4	2001	✓		✓	✓
Benin	BJ5	2006	✓		✓	✓
Benin	BJ6	2011-12	✓		✓	✓
Bolivia	BO3	1993-94, 1998	✓		✓	✓
Bolivia	BO4	2003-04	✓		✓	✓
Bolivia	BO5	2008	✓		✓	✓
Brazil	BR3	1996	✓			
Burkina Faso	BF2	1992-93	✓		✓	
Burkina Faso	BF3	1998-99	✓		✓	✓
Burkina Faso	BF4	2003	✓		✓	✓
Burkina Faso	BF6	2010	✓		✓	✓
Burundi	BU6	2010	✓			
Cambodia	KH4	2000	✓		✓	✓
Cambodia	KH5	2005-06, 2010-11	✓		✓	✓
Cambodia	KH6	2014	✓		✓	✓
Cameroon	CM3	1998	✓		✓	✓
Cameroon	CM4	2004	✓	✓	✓	✓
Cameroon	CM6	2011	✓		✓	✓
Central African Republic	CF3	1994-95	✓			
Chad	TD3	1996-97	✓		✓	✓
Chad	TD4	2004	✓	✓	✓	✓
Chad	TD6	2014-2015	✓		✓	✓
Colombia	CO3	1995	✓		✓	
Colombia	CO4	2000, 2004-05	✓		✓	✓
Colombia	CO5	2009-10	✓		✓	✓
Comoros	KM3	1996	✓		✓	
Comoros	KM6	2012	✓		✓	
Congo, Democratic Republic	CD5	2007	✓	✓	✓	
Congo, Democratic Republic	CD6	2013-14	✓		✓	
Cote d'Ivoire	CI3	1994, 1998-99	✓		✓	✓
Cote d'Ivoire	CI6	2011-12	✓		✓	✓
Dominican Republic	DR2	1991	✓		✓	
Dominican Republic	DR3	1996	✓		✓	✓
Dominican Republic	DR6	2013	✓		✓	✓
Egypt	EG2	1992-93	✓		✓	
Egypt	EG3	1995-96	✓		✓	
Egypt	EG4	2000, 2003, 2005	✓		✓	✓
Egypt	EG5	2008	✓		✓	✓
Egypt	EG6	2014	✓		✓	✓

Table A.1: Demographic and Health Surveys in each sample

country	v000	year	main	SSA	longitudinal	long.-restricted
Ethiopia	ET4	2000, 2005	✓	✓	✓	✓
Ethiopia	ET6	2011	✓		✓	✓
Ethiopia	ET7	2016	✓		✓	✓
Gabon	GA3	2000	✓		✓	✓
Gabon	GA6	2012	✓		✓	✓
Gambia	GM6	2013	✓			
Ghana	GH2	1993-94	✓		✓	
Ghana	GH3	1998-99	✓		✓	✓
Ghana	GH4	2003	✓		✓	✓
Ghana	GH5	2008	✓	✓	✓	✓
Ghana	GH6	2014	✓		✓	✓
Guatemala	GU3	1995, 1998-99	✓		✓	✓
Guatemala	GU6	2014-15	✓		✓	✓
Guinea	GN3	1999	✓		✓	✓
Guinea	GN4	2005	✓	✓	✓	✓
Guinea	GN6	2012	✓		✓	✓
Guyana	GY5	2009	✓			
Haiti	HT3	1994-95	✓		✓	
Haiti	HT4	2000	✓		✓	✓
Haiti	HT5	2005-06	✓		✓	✓
Haiti	HT6	2012	✓		✓	✓
Honduras	HN5	2005-06	✓		✓	
Honduras	HN6	2011-12	✓		✓	
India	IA2	1992-93	✓			
India	IA3	1998-99	✓		✓	✓
India	IA5	2005-06	✓	✓	✓	✓
Jordan	JO3	1997	✓		✓	✓
Jordan	JO4	2002	✓		✓	✓
Jordan	JO5	2007, 2009	✓		✓	
Jordan	JO6	2012	✓		✓	
Kazakhstan	KK3	1995, 1999	✓			
Kenya	KE2	1993	✓		✓	
Kenya	KE3	1998	✓		✓	✓
Kenya	KE4	2003	✓		✓	✓
Kenya	KE5	2008-09	✓	✓	✓	
Kenya	KE6	2014	✓		✓	
Kyrgyz Republic	KY3	1997	✓		✓	✓
Kyrgyz Republic	KY6	2012	✓		✓	✓
Lesotho	LS4	2004	✓	✓	✓	
Lesotho	LS5	2009	✓	✓	✓	
Lesotho	LS6	2014	✓		✓	
Liberia	LB5	2007	✓	✓	✓	
Liberia	LB6	2013	✓		✓	
Madagascar	MD3	1997	✓		✓	✓
Madagascar	MD4	2003-04	✓	✓	✓	✓
Madagascar	MD5	2008-09	✓		✓	✓
Malawi	MW2	1992	✓		✓	
Malawi	MW4	2000, 2004-05	✓	✓	✓	✓

Table A.1: Demographic and Health Surveys in each sample

country	v000	year	main	SSA	longitudinal	long.-restricted
Malawi	MW5	2010	✓		✓	✓
Malawi	MW7	2015-16	✓		✓	✓
Maldives	MV5	2009	✓			
Mali	ML3	1995-96	✓		✓	
Mali	ML4	2001	✓		✓	✓
Mali	ML5	2006	✓	✓	✓	✓
Mali	ML6	2012-13	✓		✓	✓
Moldova	MB4	2005	✓			
Morocco	MA2	1992	✓		✓	
Morocco	MA4	2003-04	✓		✓	
Mozambique	MZ3	1997	✓		✓	✓
Mozambique	MZ4	2003-04	✓		✓	✓
Mozambique	MZ6	2011	✓		✓	✓
Namibia	NM2	1992	✓		✓	
Namibia	NM5	2006-07	✓	✓	✓	
Namibia	NM6	2013	✓		✓	
Nepal	NP3	1996	✓		✓	
Nepal	NP4	2001	✓		✓	
Nepal	NP5	2006	✓		✓	
Nepal	NP6	2011	✓		✓	
Nicaragua	NC3	1998	✓		✓	✓
Nicaragua	NC4	2001	✓		✓	✓
Niger	NI2	1992	✓		✓	
Niger	NI3	1998	✓		✓	✓
Niger	NI5	2006-07	✓	✓	✓	✓
Niger	NI6	2012	✓		✓	✓
Nigeria	NG4	2003	✓		✓	
Nigeria	NG5	2008	✓	✓	✓	
Nigeria	NG6	2013	✓		✓	
Pakistan	PK6	2012-13	✓			
Peru	PE2	1991-92	✓		✓	
Peru	PE3	1996	✓		✓	✓
Peru	PE4	2000	✓		✓	✓
Peru	PE5	2004-08	✓		✓	✓
Peru	PE6	2009, 2010, 2011	✓		✓	✓
Republic of Congo	CG5	2005	✓	✓	✓	
Republic of Congo	CG6	2011-2012	✓		✓	
Rwanda	RW4	2000, 2005	✓	✓	✓	✓
Rwanda	RW6	2010-11, 2014-15	✓		✓	✓
Sao Tome and Principe	ST5	2008-09	✓	✓		
Senegal	SN2	1992-93	✓		✓	
Senegal	SN4	2005	✓	✓	✓	
Senegal	SN6	2010-11	✓		✓	
Sierra Leone	SL5	2008	✓	✓	✓	
Sierra Leone	SL6	2013	✓		✓	
Swaziland	SZ5	2006-07	✓	✓		
Tajikistan	TJ6	2012	✓			
Tanzania	TZ2	1991-92	✓		✓	

Table A.1: Demographic and Health Surveys in each sample

country	v000	year	main	SSA	longitudinal	long.-restricted
Tanzania	TZ3	1996	✓		✓	✓
Tanzania	TZ4	2004-05	✓	✓	✓	✓
Tanzania	TZ5	2009-10	✓	✓	✓	✓
Tanzania	TZ7	2015-16	✓		✓	✓
Timor-Leste	TL5	2009-10	✓			
Togo	TG3	1998	✓		✓	✓
Togo	TG6	2013-14	✓		✓	✓
Turkey	TR2	1993	✓		✓	
Turkey	TR3	1998	✓		✓	✓
Turkey	TR4	2003-04	✓		✓	✓
Uganda	UG3	1995	✓		✓	
Uganda	UG4	2000-01	✓		✓	✓
Uganda	UG5	2006	✓	✓	✓	✓
Uganda	UG6	2011	✓		✓	✓
Uzbekistan	UZ3	1996	✓			
Yemen	YE6	2013	✓			
Zambia	ZM2	1992	✓		✓	
Zambia	ZM3	1996-97	✓		✓	✓
Zambia	ZM4	2001-02	✓		✓	✓
Zambia	ZM5	2007	✓	✓	✓	✓
Zambia	ZM6	2013-14	✓		✓	✓
Zimbabwe	ZW3	1994	✓		✓	
Zimbabwe	ZW4	1999	✓		✓	✓
Zimbabwe	ZW5	2005-06	✓	✓	✓	✓
Zimbabwe	ZW6	2010-11	✓		✓	✓

Each row is one of 169 survey rounds of the Demographic and Health Surveys. We include in our main DHS sample of births (marked "main") all DHS rounds that measured maternal anthropometry plus the three Indian DHS. "SSA" indicates the replication sample that compares India with sub-Saharan Africa (such as in figure A.2; this set of DHS rounds matches that used to study height by Jayachandran and Pande, 2017 and Spears, 2017). The longitudinal and longitudinal-restricted samples are used in panels (a) and (b), respectively, of figures 6 and A.8; surveys are excluded if there is only one round per country with adult women's anthropometry. For the reader's convenience, we include v000, which is the code for a DHS survey round provided with the data. All data are publicly available free of charge at measuredhs.com.

Table A.2: Effects of birth order on NNM, India vs. rest of DHS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
dependent variable:	NNM	NNM	NNM	NNM	NNM	NNM	NNM	NNM	NNM
birth order 2 × India	-4.363***	-3.787***	0.364	-5.591***	-3.477***	-6.528***	-3.478***	-5.570***	-6.065***
	(0.654)	(0.654)	(0.678)	(0.706)	(0.749)	(0.725)	(0.749)	(0.707)	(0.937)
birth order 3 × India	-4.075***	-3.533***	3.952***	-13.07***	-9.138***	-14.88***	-9.118***	-13.03***	-14.05***
	(0.750)	(0.754)	(0.834)	(0.865)	(1.006)	(0.925)	(1.006)	(0.866)	(1.488)
birth order 4 × India	-1.907*	-1.271	9.805***	-21.48***	-15.86***	-24.12***	-15.82***	-21.39***	-23.03***
	(0.898)	(0.904)	(1.047)	(1.068)	(1.298)	(1.166)	(1.300)	(1.068)	(2.055)
birth order 5 × India	0.385	1.269	15.98***	-29.57***	-22.33***	-33.03***	-22.28***	-29.38***	-31.69***
	(1.126)	(1.131)	(1.332)	(1.349)	(1.645)	(1.474)	(1.646)	(1.349)	(2.662)
birth order 6+ × India	2.886*	4.128**	24.73***	-39.31***	-29.73***	-43.97***	-29.70***	-39.17***	-41.77***
	(1.281)	(1.301)	(1.627)	(1.599)	(2.000)	(1.784)	(2.000)	(1.600)	(3.450)
birth order 2	-10.02***	-9.167***	-5.891***	-14.68***	-13.04***	-15.87***	-13.03***	-14.67***	-18.80***
	(0.211)	(0.211)	(0.221)	(0.230)	(0.246)	(0.238)	(0.246)	(0.230)	(0.278)
birth order 3	-11.91***	-10.39***	-4.129***	-21.92***	-18.68***	-24.26***	-18.67***	-21.91***	-30.03***
	(0.239)	(0.239)	(0.268)	(0.272)	(0.320)	(0.297)	(0.320)	(0.272)	(0.411)
birth order 4	-10.47***	-8.316***	0.629+	-24.96***	-20.22***	-28.35***	-20.21***	-24.94***	-36.75***
	(0.271)	(0.273)	(0.324)	(0.315)	(0.399)	(0.359)	(0.399)	(0.315)	(0.547)
birth order 5	-8.711***	-5.867***	5.635***	-27.08***	-20.91***	-31.46***	-20.89***	-27.07***	-42.38***
	(0.315)	(0.318)	(0.390)	(0.366)	(0.484)	(0.427)	(0.484)	(0.366)	(0.688)
birth order 6+	-0.636*	3.766***	20.42***	-29.15***	-20.17***	-35.46***	-20.14***	-29.13***	-51.18***
	(0.316)	(0.324)	(0.452)	(0.388)	(0.574)	(0.490)	(0.574)	(0.388)	(0.881)
survey round fixed effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
child sex and birth cohort		✓	✓	✓	✓	✓	✓	✓	✓
mother birth cohort			✓		✓		✓		✓
sibsize				✓	✓				
sibling sex combinations						✓	✓		
mother fixed effects								✓	✓
n (live births)	6,695,004	6,695,004	6,695,004	6,695,004	6,695,004	6,695,004	6,695,004	6,339,396	6,339,396

Main DHS sample of births, described in section 3. The results in column 9 of this table are plotted in panel (b) of figure 2. NNM = neonatal mortality. Observations are live births that occurred at least 1 month before the interview date. Mother and child cohorts are cubic polynomials of CMC code of month of birth. All controls are fully interacted with an India indicator. Standard errors clustered by DHS PSU.

Table A.3: Effects of birth order on IMR, India vs. rest of DHS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
dependent variable:	IMR	IMR	IMR	IMR	IMR	IMR	IMR	IMR	IMR
birth order 2 × India	-4.402***	-3.659***	0.427	-4.996***	-2.947**	-5.385***	-2.939**	-4.378***	-2.661*
	(0.825)	(0.828)	(0.864)	(0.877)	(0.936)	(0.898)	(0.936)	(0.887)	(1.184)
birth order 3 × India	-3.768***	-3.260***	3.871***	-13.93***	-10.24***	-14.72***	-10.22***	-12.85***	-9.436***
	(0.975)	(0.980)	(1.082)	(1.100)	(1.273)	(1.165)	(1.275)	(1.110)	(1.909)
birth order 4 × India	1.575	1.979+	12.75***	-23.07***	-17.80***	-24.31***	-17.82***	-21.71***	-16.74***
	(1.184)	(1.194)	(1.372)	(1.370)	(1.658)	(1.481)	(1.660)	(1.379)	(2.632)
birth order 5 × India	5.153***	5.676***	20.24***	-33.04***	-26.20***	-34.71***	-26.25***	-31.47***	-25.02***
	(1.462)	(1.474)	(1.727)	(1.699)	(2.070)	(1.836)	(2.072)	(1.707)	(3.357)
birth order 6+ × India	12.06***	12.36***	32.32***	-41.79***	-33.53***	-44.00***	-33.65***	-40.68***	-31.16***
	(1.717)	(1.745)	(2.153)	(2.061)	(2.572)	(2.258)	(2.573)	(2.070)	(4.372)
birth order 2	-10.82***	-8.870***	-0.949**	-20.04***	-14.22***	-21.48***	-14.21***	-19.38***	-22.39***
	(0.299)	(0.300)	(0.315)	(0.320)	(0.341)	(0.329)	(0.341)	(0.324)	(0.392)
birth order 3	-12.47***	-8.948***	6.216***	-32.48***	-21.26***	-35.38***	-21.24***	-31.68***	-37.68***
	(0.341)	(0.343)	(0.385)	(0.380)	(0.446)	(0.410)	(0.446)	(0.384)	(0.579)
birth order 4	-10.10***	-5.088***	16.63***	-40.23***	-24.06***	-44.49***	-24.04***	-39.43***	-48.20***
	(0.392)	(0.396)	(0.468)	(0.445)	(0.560)	(0.499)	(0.560)	(0.449)	(0.774)
birth order 5	-7.150***	-0.539	27.42***	-46.49***	-25.64***	-52.05***	-25.61***	-45.80***	-57.23***
	(0.456)	(0.460)	(0.561)	(0.520)	(0.680)	(0.596)	(0.680)	(0.524)	(0.973)
birth order 6+	4.736***	14.93***	55.37***	-56.55***	-26.65***	-64.61***	-26.61***	-55.93***	-72.43***
	(0.452)	(0.461)	(0.641)	(0.558)	(0.806)	(0.681)	(0.806)	(0.562)	(1.239)
survey round fixed effects	✓	✓	✓	✓	✓	✓	✓	✓	✓
child sex and birth cohort		✓	✓	✓	✓	✓	✓	✓	✓
mother birth cohort			✓		✓		✓		✓
sibsize indicators				✓	✓				
sibling sex combinations						✓	✓		
mother fixed effects								✓	✓
n (live births)	6,373,337	6,373,337	6,373,337	6,373,337	6,373,337	6,373,337	6,373,337	6,030,617	6,030,617

Main DHS sample of births, described in section 3. Regressions and sample correspond with figure 2, where panel (a) plots column 9. IMR = neonatal mortality. Observations are live births in the DHS birth history at least 1 year before the interview date. Mother and child cohorts are cubic polynomials of CMC code of month of birth. All controls are fully interacted with an India indicator. Standard errors clustered by DHS PSU.

Table A.4: The effect of birth order on NNM is robust to controlling for sibsize × India × own sex indicators

	(1)	(2)
dependent variable:	NNM	NNM
birth order 2 × India	-6.07***	-6.05***
	(0.94)	(0.94)
birth order 3 × India	-14.05***	-13.90***
	(1.49)	(1.49)
birth order 4 × India	-23.03***	-22.94***
	(2.06)	(2.05)
birth order 5 × India	-31.69***	-31.76***
	(2.66)	(2.66)
birth order 6+ × India	-41.77***	-42.12***
	(3.45)	(3.45)
non-interacted birth order indicators	✓	✓
survey round fixed effects	✓	✓
child sex and birth cohort (cubic) × India	✓	✓
mother birth cohort (cubic) × India	✓	✓
mother fixed effects	✓	✓
sibsize × India × child own sex		✓
n (live births)	6,339,396	6,339,396

Main DHS sample of births, described in section 3. NNM = neonatal mortality. Observations are live births that occurred at least 1 month before the interview date. Mother and child cohorts are cubic polynomials of CMC code of month of birth. All controls are fully interacted with an India indicator. Standard errors clustered by DHS PSU. The sample in this table is smaller than the sample in table A.2, which presents similar results, because the fixed effects are finer and observations are omitted in fixed effect categories with no within variation.

Table A.5: Institutional delivery: Regression results for children under 5

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
sample:	full	columns 2-7 include only children under 5 with recorded delivery place					
dependent variable:	NNM	NNM	NNM	NNM	NNM	institutional	institutional
2nd born	-18.87***	-42.60***	-42.62***	-47.17***	-46.77***	-0.0130*	-0.0970***
	(1.105)	(3.368)	(3.368)	(3.571)	(3.566)	(0.00611)	(0.00672)
3rd born	-35.92***	-87.99***	-87.97***	-97.73***	-97.15***	0.0134	-0.143***
	(1.437)	(5.524)	(5.526)	(6.053)	(6.033)	(0.00981)	(0.0115)
4th born	-48.86***	-125.0***	-124.9***	-140.3***	-139.7***	0.0561***	-0.159***
	(1.856)	(8.537)	(8.552)	(9.355)	(9.311)	(0.0135)	(0.0164)
5th born	-63.26***	-168.2***	-168.1***	-190.5***	-189.8***	0.0938***	-0.175***
	(2.625)	(11.72)	(11.75)	(12.80)	(12.72)	(0.0174)	(0.0214)
6th born	-73.91***	-186.3***	-186.2***	-217.2***	-216.4***	0.134***	-0.185***
	(3.828)	(14.56)	(14.59)	(15.80)	(15.74)	(0.0220)	(0.0270)
institutional			-1.158		4.064†		
			(1.887)		(2.081)		
sibsize indicators	✓	✓	✓	✓	✓	✓	✓
further controls				✓	✓		✓
n	221,743	48,156	48,156	48,156	48,156	48,156	48,156

Data are India's 2005-6 DHS, corresponding with figure 3. Standard errors clustered by survey PSU. "Institutional" is an indicator for institutional delivery, rather than delivery at a home. "Further controls" are the century-month code of the birth cohort of the child and the mother (both entered as quadratic polynomials), the sex of the child, and whether the child lives in an urban or rural place.

Note on sample restriction: The results in column 1 use a sample that includes all available births from the 2005-6 Indian DHS. These results are included for comparison because the results in columns 2-7 necessarily use a restricted sample of children under 5 years old because these are the children for whom place of birth was recorded. This sample restriction complicates the identification of birth order effects, even if sibsize is controlled for. This is because birth order, sibsize, and birth spacing jointly predict selection into the sample (Spears et al., 2019). Consider, for example, a child of birth order 1 in a sibsize of 3: such a child will only be under 5 at the time of the survey if his or her mother has had three children in less than five years, and therefore if he or she comes from a household with low birth spacing. In contrast, a child of birth order 2 in a sibsize of 3 would be expected to have longer birth spacing than the first child, and a child of birth order 3 could have been born at any point in the five year period with any birth spacing. So, part of what appears to be a birth order effect in this sample is, in fact, a household composition effect of selection into the sample. This is why the birth order gradient is steeper here (and in columns 2-5) than in the main result (or, comparably, in column 1). Our point in including this analysis is merely to verify that *institutional delivery* is not an omitted variable in our results: it is not predicted by birth order, and controlling for it does not change the coefficient on birth order predicting NNM.

Table A.6: Following Lundberg and Svaleryd (2017), we find that excluding possible-replacement last births (after prior sibling NNM) preserves the pattern

	(1)	(2)
dependent variable:	NNM	NNM
excluded:	last-borns w/prior sibling death	last-borns w/prior sibling NNM
birth order 2 × India	-4.028***	-4.078***
	(0.679)	(0.676)
birth order 3 × India	-6.860***	-6.841***
	(0.834)	(0.821)
birth order 4 × India	-10.08***	-9.460***
	(1.067)	(1.026)
birth order 5 × India	-12.66***	-10.92***
	(1.400)	(1.311)
birth order 6 × India	-26.19***	-23.22***
	(1.711)	(1.606)
mother FEs & controls	✓	✓
n	6,066,288	6,227,729
NNM among included	38.54	38.07
NNM among excluded	69.52	140.7

The sample starts from the main "India vs. rest of DHS" sample in Table A.2, but excludes last-born children (where "last-born" is at the time of the survey, within a sibship) whose prior sibling has died (either at a neonatal age or at any age, according to the column header). This robustness check is intended to rule out the biasing threat of endogenous fertility, where mothers would be more likely to have a "replacement" birth after the death of a prior child. Note that because this analysis uses mother fixed effects, we do not use an explicit sibsize variable, so this last-born exclusion does not require a counterfactual sibsize (recall also that controlling for sibship size and sex structure rather than mother fixed effects did not change our main result). This analysis follows that of Lundberg and Svaleryd (2017), who use it to investigate the possible threat of endogenous fertility in a study of birth order in Swedish data.

Note that, although our effect remains visible with these births (and deaths) excluded from the sample — suggesting that endogenous fertility does not drive our result in this way — this is not the type of robustness check where we would expect the coefficient estimates to be quantitatively unchanged. That is because there is unobserved heterogeneity in the "frailty" of children, for reasons that would be correlated within sibships but orthogonal to birth order within a sibship (such as the sanitation and disease environment of a village). By excluding children whose sibling has died, we are reducing the average frailty of our sample. Thus, in the last row of the table, NNM is higher among excluded births than among included births.

Lundberg and Svaleryd report results excluding *all* children who are last-born to their mothers. Although not reported in this table (but available in the replication files), our results are robust to using this sample (with about 4.7 million observations): the coefficients on birth order × India are numerically similar to our main results: -8 for second-born, -15 for third-born, -22 for fouth-born, etc. Such a robustness check, unlike those reported in this table, does not selectively exclude children of high-frailty sibships.

Table A.7: India's later-born NNM advantage is seen for sibships with first-born boys and first-born girls, but is stronger in sibships of first-born boys

	(1)	(2)	(3)	(4)	(5)	(6)
sex of first-born to mother:	boy	girl	boy	girl	boy	girl
birth order 2 × India	-7.802***	-1.189	-10.70***	0.458	-7.807***	-1.144
	(1.148)	(1.069)	(1.478)	(1.353)	(1.148)	(1.070)
birth order 3 × India	-18.31***	-5.655***	-24.02***	-2.508	-18.28***	-5.614***
	(1.388)	(1.232)	(2.297)	(2.017)	(1.388)	(1.231)
birth order 4 × India	-31.67***	-9.509***	-40.20***	-5.072+	-31.69***	-9.452***
	(1.643)	(1.489)	(3.101)	(2.785)	(1.644)	(1.488)
birth order 5 × India	-39.55***	-17.64***	-50.89***	-12.03***	-39.68***	-17.62***
	(2.050)	(1.834)	(3.999)	(3.605)	(2.052)	(1.834)
birth order 6 × India	-49.60***	-26.96***	-64.64***	-18.65***	-49.71***	-26.85***
	(2.432)	(2.101)	(5.188)	(4.577)	(2.431)	(2.100)
birth order 2	-16.76***	-11.72***	-21.64***	-15.07***	-16.72***	-11.78***
	(0.363)	(0.340)	(0.428)	(0.402)	(0.364)	(0.340)
birth order 3	-25.23***	-17.67***	-34.83***	-24.27***	-25.19***	-17.73***
	(0.420)	(0.390)	(0.611)	(0.576)	(0.420)	(0.391)
birth order 4	-28.94***	-20.00***	-42.88***	-29.59***	-28.90***	-20.08***
	(0.478)	(0.446)	(0.799)	(0.762)	(0.478)	(0.447)
birth order 5	-31.85***	-21.30***	-49.92***	-33.75***	-31.82***	-21.35***
	(0.544)	(0.517)	(0.995)	(0.958)	(0.544)	(0.517)
birth order 6	-33.87***	-23.40***	-59.88***	-41.34***	-33.84***	-23.46***
	(0.577)	(0.541)	(1.262)	(1.222)	(0.577)	(0.541)
n (live births)	3,238,725	3,100,671	3,238,725	3,100,671	3,422,689	3,272,315
child sex	✓	✓	✓	✓	✓	✓
mother fixed effects	✓	✓	✓	✓		
child birth cohort			✓	✓		
sibling sex combinations					✓	✓

The data are the main "India vs. rest of DHS" sample in Table A.2. Note that the sum of the sample sizes in columns 1 and 2 or 3 and 4 of this table match the sample size in columns 8 and 9 (which have mother fixed effects) of Table A.2 ($3,238,725 + 3,100,671 = 6,339,396$). Child cohort is a cubic polynomial of CMC code of month of birth. All controls are fully interacted with an India indicator. Standard errors clustered by DHS PSU.

Note that sex-selective abortion is uncommon for first-born children: even in India, where son preference shapes fertility stopping behavior, the sex of the first born is generally taken to be random (Clark, 2000). So, the sex of the first-born child is not a choice variable. However, subsequent choices, such as the decision to have an additional child, may be correlated with the sex of the first child, so that, for example, Indian mothers who have 3 children rather than 2 are poorer, on average, if they had a first boy than if they had a first girl; this example of heterogeneity, however, would be absorbed by mother fixed effects.