Missing Girls: Ultrasound Access and Excess Female Mortality*

S Anukriti[†] Sonia Bhalotra[‡] Hiu Tam[§]

December 2015

Abstract

This paper examines the effects of access to ultrasound technology on the gender gap in child health outcomes in India. A comparison of second- and higher-parity births in firstborn-girl families with those in firstborn-boy families and with first births during 1973-2005 shows that ultrasound access nearly eliminated the gender gaps in post-neonatal child mortality and postnatal health investments, such as breastfeeding and vaccination. Excess female neonatal mortality also decreased. These impacts are driven by (i) a complete closing of the gender gap in sibling size caused by abortion of unwanted daughters and (ii) substitution of postnatal discrimination with sex-selective abortions. However, the mortality decline for girls is of a much smaller magnitude than the increase in the male-female sex ratio at birth due to access to sex-selection technology—for every girl that survived from age one to age five, 5.7 girls were selectively aborted.

Keywords: India, Gender Discrimination, Sex-selection, Child Mortality, Health Investments

*We thank Mahesh Karra, Adriana Kugler, Rachel Heath, Melanie Khamis, Annemie Maertens, Laura Schechter, and Shing-Yi Wang, and conference and seminar participants at ISI Delhi, NEUDC, PAA Annual Meetings, and Université Laval for their helpful comments and suggestions.

[†]Department of Economics, Boston College. anukriti@bc.edu.

[‡]Department of Economics, University of Essex. srbhal@essex.ac.uk.

[§]Department of Economics, London School of Economics. h.f.tam@lse.ac.uk.

1 Introduction

In 2010, 126 million women were "missing" from the global population, with China and India accounting for 85 percent of this male-bias in sex ratios (Bongaarts and Guilmoto (2015)).[1] Historically, postnatal excess female mortality (EFM) has been the primary source of missing women. In the absence of technology for prenatal sex-selection, postnatal EFM can occur in two ways. First, conditional on fertility, within-family gender gaps can emerge if parents actively discriminate against girls in the intra-household allocation of resources ("discriminatory treatment channel"). Second, if parents continue childbearing until they achieve their desired number of sons, girls have more siblings than boys. In this case, even if parents do not actively discriminate against daughters, a gender gap in outcomes may emerge at the aggregate level despite no within-family gender gaps ("fertility selection channel").[2] The fertility channel is reflected in the higher likelihood of the lastborn child being a boy and higher-order children being female.

In recent decades, the availability of a reliable and low cost technology, i.e., ultrasound scans, has made fetal sex detection feasible. Ultrasound access is likely to alter the two above-mentioned channels and may thereby have a causal impact on postnatal EFM and other child health outcomes. First, the ability to detect fetal sex may lead to substitution between postnatal and prenatal discrimination. If parents substitute postnatal discrimination with sex-selective abortions,[3] within-family gender gaps may narrow with an increase in the sex ratio at birth (Goodkind (1996)). On the other hand, sex detection may not induce all son-preferring parents to opt for an induced abortion; instead, if parents substitute postnatal discrimination with selective decreases in health investments in women pregnant with girls (Bharadwaj and Lakdawala (2013)), gender gaps in spontaneous abortions, stillbirths, and neonatal mortality[4] may increase, along with potential decline in post-neonatal EFM. Second, abortion of unwanted daughters may narrow the sibling-size gap between boys and girls, causing EFM and gender gaps in health investments to decline.

In this paper, we estimate the overall effects of ultrasound access on the gender gaps in child mortality and health investments and assess the treatment and selection mechanisms

[1] Sex ratio is defined as the ratio of men to women. The phrase "missing women" refers to the fact that the sex ratio is abnormally male-biased, i.e., the difference in the numbers of men and women is much larger than what would be expected under normal conditions (Coale (1991), Sen (1990)).

[2] Among others, this point has been made by Clark (2000), Jensen (2012), and Rosenblum (2013).

[3] In fact, the global annual number of sex-selective abortions has increased from nearly zero in the late 1970s to 1.6 million per year in 2005-2010 (Bongaarts and Guilmoto (2015)).

[4] Neonatal mortality primarily reflects poor maternal health and delivery conditions (Bozzoli et al. (2009), Chay et al. (2009), Almond et al. (2008)).

in the context of India. Prior research on India has shown that ultrasound access led to a significant growth in sex-selective abortions and prenatal gender discrimination in maternal and fetal health investments. Bhalotra and Cochrane (2010) estimate that nearly 6 percent of potential female births were selectively aborted during 1995-2005 due to ultrasound access. Bharadwaj and Lakdawala (2013) show that, once ultrasound technology became available, mothers were 3 percent more likely to receive prenatal care when pregnant with a boy, and discrimination in maternal tetanus vaccination can explain 4 to 10.5 percent of neonatal EFM. These findings establish the crucial intermediate steps necessary for ultrasound access to have an impact on the gender gaps in postnatal health outcomes.

Our paper is related to a small and inconclusive literature on the relationship between prenatal sex-selection and postnatal gender gaps. Lin et al. (2014) show that abortion legalization in Taiwan decreased neonatal EFM for higher-parity births, although they do not examine the effects on health investments. In contrast, Almond et al. (2010) find that ultrasound access *increased* neonatal EFM in China and had no impact on the gender gaps in post-neonatal mortality and postnatal health investments; but they do not examine fertility. The paper most closely related to ours is Hu and Schlosser (2015), which finds that higher sex ratios at birth (reflecting sex-selective abortions) in India are associated with lower malnutrition rates for girls relative to boys but *not with* lower EFM. Shepherd (2008) also finds no significant link between prenatal sex-selection and postnatal EFM in India. Our paper is concurrent to Hu and Schlosser (2015) and Almond et al. (2010).

We estimate the causal effects of ultrasound access on postnatal health outcomes of second and higher-order births in a triple differences-in-differences framework where the three dimensions of variation are (i) child gender, (ii) sex of the oldest sibling, i.e., mother's first birth, and (iii) temporal variation in ultrasound access during the year of birth. We define 1973-1984 as the pre-ultrasound period, 1985-1994 as the early diffusion period, and 1995-2005 as the late diffusion period when ultrasound use became widespread. This empirical strategy is based on two assumptions that we defend in Section 3: (1) firstborn sex is random, i.e., there is no sex-selection for first births and (2) access to ultrasound technology did not vary by firstborn sex. Our identifying assumption is that in the absence of ultrasound availability, the counterfactual trends in gender gaps for second and higher order births across firstborn boy and firstborn girl families would have been identical. But once parents had access to ultrasound, random exposure to "firstborn girl treatment" increased their willingness to practice sex-selection for higher-parity births in order to achieve the desired number of sons. Since our dataset comprises multiple births per woman, we also estimate specifications that compare outcomes for children that are born to the *same* mother but are differentially exposed to ultrasound technology.

Like Hu and Schlosser (2015), we use data from the National Family Health Survey (NFHS) of India for our mortality analysis. Contrary to Hu and Schlosser (2015), however, we find that ultrasound access reduced postnatal EFM in India quite significantly, both within and across families. During the pre-ultrasound period, excess post-neonatal female child mortality for second and higher-parity births was 1.8 percentage points (p.p.) higher in families with a firstborn girl relative to EFM for second and higher-parity births in firstborn-boy families and relative to EFM for first births. This gender gap declined by 54 percent and 77 percent, respectively, during the early and late diffusion periods, thereby eliminating the pre-ultrasound gender gap in child mortality.[5] The effects on neonatal EFM are smaller, although, contrary to Almond et al. (2010), we find it too significantly declined by 66 percent (from a pre-ultrasound gap of 1.4 p.p.) in the late diffusion period.[6]

Consistent with the decline in EFM, we find that gender gaps in health investments also declined due to ultrasound access. Data from the NFHS is not perfectly suitable for this analysis as information on health investments was not collected for the pre-ultrasound period. In fact, this lack of pre-ultrasound data is a major drawback of the results on nutritional status and health investments in Hu and Schlosser (2015). We avoid this pitfall by using data from the 1999 round of the Rural Economic and Demographic Survey (REDS) that collected information on some health investment variables for all children who were alive in the survey year, giving us a large pre-ultrasound window. We find that ultrasound access significantly narrowed the gender gaps in child vaccination and breastfeeding; in fact, Hu and Schlosser (2015) do not examine the effect on vaccination due to the unreliable nature of NFHS data on vaccinations. Back-of-the-envelope calculations suggest that changes in vaccination and breastfeeding explain 13 to 18 percent of the post-neonatal decline in EFM.[7]

We explore three mechanisms through which EFM and the gender gap in postnatal investments declined concomitantly with increased ultrasound access: (1) substitution of postnatal

[5]This does not, however, imply that ultrasound access has eliminated all postnatal EFM in India. Our estimates only capture the decline in EFM among second and higher order births in firstborn girl families that existed over and above the EFM in our control group (i.e., second and higher order births in firstborn boy families and first births).

[6]In fact, the decline in neonatal EFM biases our estimates of the decline in post-neonatal EFM in the direction of not finding any effects. This is because in the post-ultrasound cohorts more girls survive the neonatal stage than in the pre-ultrasound cohorts, and these marginal survivors are negatively selected (i.e., in the pre-ultrasound period they would have succumbed to neonatal mortality, but now they "just survive"). This compositional effect will make the post-neonatal mortality gender gap higher. In other words, the post-ultrasound sample of neonatal-survivors entering the group at risk of post-neonatal mortality are more risky irrespective of any parental behaviors. This will slightly offset the effects of improvements in investments in girls and downward bias our estimates of the impact of ultrasound access on post-neonatal EFM.

[7]We also find some suggestive evidence of a decrease in the gender gap in health expenditure on children during illness, although the effects are insignificant.

discrimination with sex-selective abortions, (2) substitution of postnatal discrimination with discrimination in prenatal maternal health investments, and (3) the gender gap in sibling size. These channels are likely to operate more strongly among firstborn-girl families relative to firstborn-boy families. Our mother fixed effects specifications show that ultrasound access decreased EFM even within the same family, thereby supporting channel (1). In addition, we find that fertility declined respectively by 33 percent and 52 percent during the early and late diffusion periods (from a pre-ultrasound gap of 0.15 in families with a firstborn girl), thus completely closing the gender gaps in sibling size. However, we do not find any support for channel (2). Consistent with the decline in gender gaps in the health dimension, we also observe some suggestive improvements in girls' educational attainment relative to boys.

We also analyze heterogeneity in our results across various socioeconomic dimensions. Scheduled Caste (SC) families in low socioeconomic status (SES) groups[8] had no significant gender inequality along the fertility and within-family discrimination dimensions at baseline, and hence experienced no significant changes in outcomes. On the other hand, both within-family discrimination and excess fertility were significant for non-SC households prior to ultrasound availability, and they exhibit substantial declines in these channels due to ultrasound access. Interestingly, while high SES SC families did not practice within-family discrimination during the pre-ultrasound period, consistent with the phenomenon of *Sanskritization*, gender gaps in sibling size were prevalent for them. Like upper castes, ultrasound access also lowered excess fertility for high SES lower caste families.

A major advantage of the triple differences-in-differences framework is that it allows us to control non-parametrically for a large number of confounding factors. Additionally, we conduct numerous robustness checks to ensure that our results capture the causal effects of ultrasound access and are not driven by pre-existing trends in preferences for fertility and child sex ratio and changes in these preferences that might be correlated with ultrasound availability.

We believe that the difference in identification strategies can explain why we find a significant effect of sex-selection on EFM while Hu and Schlosser (2015) do not. Hu and Schlosser (2015) use state-year variation in the sex ratio at birth as a measure of sex-selection to estimate its effect on the gender gap in health outcomes. However, the sex ratio at birth is highly endogenous. Their results are likely to be confounded since their identification relies on the assumption that changes in the sex ratio at birth within a state over time are unrelated to other unobserved factors that could differentially affect male and female outcomes. For example, if states that have better access to ultrasound technology also have better medical

[8]SES refers to educational attainment, rural residence, and wealth.

infrastructure, the latter could have an independent impact on EFM. By comparing EFM by firstborn sex we can difference out any such factors. It is also noteworthy that average EFM does not adequately capture the variation in EFM by firstborn sex, e.g., in the pre-ultrasound period, excess post-neonatal child mortality was 1.5 percent in the aggregate sample, was 0.9 percent for births preceded by a firstborn boy, and was 3 percent for births preceded by a firstborn girl.

Gender equity in health and survival is a critical policy goal, especially in less developed countries. Our paper is the first to show that access to prenatal sex-detection technology leads to significant declines in *post-neonatal* excess female child mortality in any country; in fact, other papers on India find no effects on any mortality measure. Although Lin et al. (2014) show that abortion legalization decreased neonatal EFM in Taiwan, the Indian context is quite different. First, the level of EFM in Taiwan even before access to abortion was several orders of magnitude smaller than the EFM in India. For instance, before abortion legalization, the average neonatal EFM in Taiwan was 0.09 percent whereas average post-neonatal excess female child mortality in India was 1.5 percent overall and 3 percent among children preceded by a firstborn girl. Second, the bulk of the gender gap in mortality in Taiwan (and in China) occurs at the neonatal stage, which is perhaps why Lin et al. (2014) find no effect on post-neonatal EFM. In contrast, neonatal EFM has been negligible in India both before and after ultrasound access (Table B.1). More generally, India and China substantially differ in the age distribution of young missing girls.[9] While bulk of the missing girls below age five in China are missing at birth (83 percent), the numbers are more evenly spread out over early childhood in India (Table B.2).[10] EFM during the post-neonatal stage contributes 33% to the number of missing girls in India but only 3 percent in China.

Relative to the literature, our paper provides a more comprehensive analysis by examining the effects of ultrasound access on fertility, prenatal and postnatal health investments, sex-selection, and mortality outcomes within and across mothers. Closing of the gender gaps in health investments is crucial not only for child survival, but also matters for later life outcomes (Currie and Rossin-Slater (2015)). Lower fertility and parents' ability to avoid unwanted births may lead to improvements in child quality for both boys and girls as well as better social and economic outcomes during adulthood.[11] Nevertheless, our findings do not

[9] These differences may partly be due to higher fertility in India as some parents may wait for realization of a birth and revelation of its sex before discriminating; so the discrimination may be post-neonatal. For instance, once a son is born, parents can neglect an older girl by ceasing to breastfeed, by taking up employment (Rose (2000)), or by limiting immunization (Oster (2009)).

[10] This table is derived from calculations in Anderson and Ray (2010).

[11] Ananat et al. (2009), Charles and Stephens Jr. (2006), Donohue and Levitt (2001), Pop-Eleches (2006).

imply that policymakers should ignore sex-selective abortions because of these unintended benefits. On the contrary, we show that the EFM decline, although substantial, is overshadowed by the even larger increase in the sex ratio of birth caused by sex-detection technology. Our calculations suggest that about 48,264 postnatal female deaths were averted each year due to ultrasound access. However, the number of sex-selective abortions each year has been much higher (Bhalotra and Cochrane (2010)). For every girl that indirectly survived due to ultrasound access, 5.7 girls were selectively aborted. Thus, the net effect has been a worsening of the gender balance in the child population. This implies that policies that increase the cost of fetal sex-detection may successfully lower the total number of missing girls, despite increasing EFM.

2 Context

While son preference has characterized parts of Indian society for centuries, the availability of affordable prenatal sex diagnostic techniques combined with legal access to abortion is more recent. The latter was in place by 1972 but the former only really emerged after 1980, becoming evident by 1985 and widespread by 1995. Abortion was legalized in India with the passage of the Medical Termination of Pregnancy (MTP) Act in 1971, effective in most states in 1972. The Act specifies the reasons for which an abortion can be legally performed and requires that it be performed by a registered medical practitioner in certified abortion facilities.[12] Abortion is legal if the pregnancy that it terminates endangers the woman's life, causes grave injury to her physical or mental health, is a result of rape or contraceptive failure (the latter applies only to married women), or is likely to result in the birth of a child suffering from serious physical or mental abnormalities. Consent is not required from the woman's husband or from other family members; however, a guardian's consent is required if the woman seeking an abortion is either less than 18 years old or is mentally ill. The Act allows an unintended pregnancy to be terminated up to 20 weeks' gestation; however, if the pregnancy is beyond 12 weeks, approval is required from two medical practitioners (Arnold et al. (2002)). The stated purpose of the Act was to regulate and ensure access to safe abortion, although it has been argued that the political motivation was population control (Phadke (1997)).

Fetal sex determination first became possible in India with the advent of amniocentesis in the 1970s. This technology was introduced to detect genetic abnormalities but began to be used as a way of determining the sex of a fetus. As early as 1976, the government banned the use of these tests for sex determination in government facilities (Arnold et al. (2002)).

[12] More information on the certification criteria is available in Stillman et al. (2014).

The private sector remained unregulated but widespread use was limited by the high direct cost and the invasiveness of amniocentesis. In the early 1980s, ultrasound scans emerged and spread rapidly and improvements in technology over time made it easier to detect sex earlier in pregnancy. The time trends in ultrasound availability are primarily driven by the liberalization of India's import sector, that first began in 1981 and gained sharp momentum in 1991. The first ultrasound scanner was imported in 1987 (Mahal et al. (2006)). Thereafter, the quantity of imports rapidly increased (Figure 1). In addition, domestic production of ultrasound machines grew 15-times between 1988 and 2003 (Grover and Vijayvergia (2006), George (2006)). Demand proliferated as a result of the technology being non-invasive and its wide affordability at about \$10-\$20 for a scan or an abortion (Arnold et al. (2002)).[13] The trend in ultrasound use (also in Figure 1) closely tracks the supply of ultrasound machines. Clinics and portable facilities have mushroomed, advertising availability of ultrasound with slogans such as that the cost of a scan is much lower than the future costs of dowry. Additional amendments to the MTP Act in 2002 and 2003 increased public sector provision and made abortion safer (Stillman et al. (2014)). Other things equal, this could have contributed to a further increase in feticide since 2002.

Since the late 1980s, sex-selection has become the dominant concern amongst women's and human rights organizations.[14] Their campaigns led to the central government passing the Prenatal Sex Diagnostic Techniques (Regulation and Prevention of Misuse) (PNDT) Act in 1994. This act became fully effective throughout India on January 1, 1996. The PNDT Act made it illegal to use prenatal sex diagnostic techniques (like ultrasound) to reveal the sex of a fetus. Following the revelation in the 2001 Census of a continuing deterioration in the sex ratio, the PNDT Act was strengthened by a 2002 Amendment (effective 2003) incorporating a ban on advertising prenatal sex determination and increased penalties for violations.[15] It is widely believed that these regulations have made little difference (Visaria (2005)), although Nandi and Deolalikar (2013) find that they did have some impact. These bans are difficult to enforce because ultrasound scans (or alternatives like amniocentesis) are also used for medical purposes and in routine prenatal care, making it easy to cover up sex determination as a motive.

In general, however, fetal environment has improved in India. The growth in income and

[13]These may be significant costs in a country where many live under the \$1.25-a-day line. The costs cumulate if repeated scans and abortions are needed before a boy is conceived and vary with distance of the household from the clinic and with the safety of the procedures.

[14]Indian feminists have been divided by the seeming contradiction of supporting a woman's right to abortion while opposing sex-selective abortion (Kumar (1983), Gangoli (1998)).

[15]More details on the PNDT Act are available in Retherford and Roy (2003) and Visaria (2005).

the decline in poverty since the early 1980s has been widely documented; fertility decline set in from 1981 (Bhalotra and van Soest (2008)); and neonatal mortality rates have been decreasing. Maternal mortality is estimated to have declined (Bhat (2002)) and maternal age at birth has risen. Our identification strategy, discussed next, flexibly controls for these secular trends in fetal conditions at the state and national level.

3 Empirical Methodology

The goal of this paper is to estimate the causal effects of sex-detection technology on post-natal health investments and mortality, and to understand the intermediate mechanisms. Like Bhalotra and Cochrane (2010), our empirical analysis is based on triple differences-in-differences estimation where the three sources of variation are: (1) child gender, (2) sex of the mother's first child, and (3) temporal variation in access to ultrasound technology.

To capture the time variation in ultrasound availability, we split our sample into three broad time-periods, defining 1973-1984 as the pre-ultrasound period, 1985-1994 as the early diffusion period, and 1995-2005 as the late diffusion period when ultrasound use became widespread. Bhalotra and Cochrane (2010) identify 1985 as a break-point in the trend of the average sex ratio at birth using nonparametric plots and flexible parametric specifications. They also identify 1995 as a second break-point based on the sharp increase in the supply of ultrasound scanners following the acceleration of trade liberalization in the early and mid-1990s; this trend-break is clearly visible in Figure 1. Our results qualitatively remain the same even when we make small adjustments to the thresholds used to define the three time periods. Moreover, the use of wide intervals for each period helps minimize any measurement errors in exposure to ultrasound technology.

Our estimates identify the causal impact of ultrasound access if (1) sex of the first child is randomly determined and (2) access or exposure to ultrasound technology did not vary by firstborn sex. Our identifying assumption is that, in the absence of ultrasound availability, the counterfactual trends in gender gaps for second and higher order births across firstborn boy and firstborn girl families would have been identical.

Our assumption that sex of the first child is randomly determined is strongly supported by data and has been widely used in prior literature on India (e.g., Bhalotra and Cochrane (2010), Das Gupta and Bhat (1997), Visaria (2005)). This assumption is consistent with recent survey data that suggests that parents do not always prefer having a son over a daughter. Jayachandran (2014) finds that although the vast majority of families want to have a son if they can only have one child, at a family size of two they prefer having one daughter and one son over having two sons. As desired and actual fertility in India is well above one (Table B.14), it is reasonable to assume that parents are not averse to having one daughter, despite a strong desire for at least one son. In fact, as the top left graph in Figure 2 shows, the sex ratio at first birth in India lies within the normal range during our sample period, and shows no tendency to increase over time.[16] Additionally, there are no significant socioeconomic differences between families with a firstborn son and a firstborn daughter (to be presented shortly in Table B.3).

It is also well-established that parents randomly exposed to a "firstborn girl treatment" are more likely to practice sex-selection at higher-parity births (e.g., Pörtner (2010) and Rosenblum (2013)) since they desire at least one son. Figure 2 clearly depicts this pattern: after ultrasound technology became available, second, third, and fourth births became increasingly more male but only for families without a son. Consequently, the interaction with first child's sex captures the differential incentives to sex-select among otherwise similar families. Note that the identification strategy in Hu and Schlosser (2015) does not utilize the variation in firstborn sex, which is clearly a significant determinant of prenatal sex-selection.

If sex of the firstborn is random, EFM among families with a firstborn girl and a firstborn boy should follow a similar trend before the availability of prenatal sex-selection technology. Our data suggests that this is true. Panel A in Figure 3 plots the 5-year moving average of EFM for firstborn-boy and firstborn-girl families for our sample period and Panel B plots the differential trend for these two groups. Although EFM is significantly higher for births preceded by a firstborn girl during the pre-ultrasound period, the gap remained constant until 1985, providing support for our identifying assumption.

3.1 Regression Specifications

For child i of birth order b born to mother j in year t and state s,[17] we estimate the following specification to measure the impact of ultrasound availability on EFM and the gender gaps in health investments:

$$\begin{aligned} Y_{ibjts} =& \alpha + \beta_1 G_j * F_i * Post_t^1 + \beta_2 G_j * F_i * Post_t^2 + \gamma G_j * F_i + \omega_t G_j + \sigma_t F_i \\ &+ X_{ijt}^{'}\tau + \delta_s F_i + \nu_s G_j + \psi_b F_i + \xi_b G_j + \rho_{bt} + \eta_{bs} + \phi_{st} + \epsilon_{ibjts} \end{aligned} \tag{1}$$

The dependent variable, Y_{ibjts}, is either a mortality indicator for child i or measures health investments, such as breastfeeding and vaccination status.[18] The indicator variable G_j equals one if the first child of mother j is a girl. The dummy variable F_i equals one if child i is female. $Post_t^1$ indicates that t belongs to the early diffusion period (1985-1994) and $Post_t^2$

[16]Figure 2 reproduces Figures 1-4 from Bhalotra and Cochrane (2010).

[17]The variable state refers to the mother's state of residence at the time of survey and may differ from the child's state of birth.

[18]More details on the variables used in the regression analysis are available in Appendix A.

indicates that t belongs to the widespread or late diffusion period (1995-2005). The vector of socioeconomic and demographic characteristics, X_{ijt}, comprise indicators for household wealth quintiles, educational attainment of child's parents, mother's birth cohort, mother's age at birth, caste, religion, and residence in a rural area. We also control for the main effects of G_j and F_i and fixed effects for state, birth year, and birth order, although these have not been explicitly mentioned above for notational ease.

The firstborn sex specific year fixed effects ($\omega_t G_j$) control for nationwide trends that can differentially affect mortality of children in firstborn girl and firstborn boy families irrespective of child sex. For instance, the "Trivers-Willards hypothesis" would imply that firstborn boy families are more likely to be of higher SES than firstborn girl families and the trends for higher SES groups may differ from other groups. The gender-specific year fixed effects ($\sigma_t F_i$) take into account any nationwide changes that may affect the gender gap in child mortality, e.g., improvements in maternal health and prenatal care which are likely to benefit male fetuses more than female fetuses due to the former's greater sensitivity to prenatal inputs, or a decline in son preference due to modernization. State-specific gender effects, $\delta_s F_i$, control for state-level time-invariant differences in factors, such as soil quality (Carranza (2015)), that may affect gender outcomes. We also include state-specific firstborn sex effects ($\nu_s G_j$), birth order specific gender effects ($\psi_b F_i$) and birth order specific firstborn sex effects ($\xi_b G_j$). Lastly, ϕ_{st}, η_{bs}, and ρ_{bt} provide full non-parametric control for, respectively, state-specific time effects (e.g., differential growth rates of state GDP or availability of abortion and other health services), state-specific birth order effects, and birth order specific time effects. This rich set of fixed effects enables us to rule out a wide range of confounding variables and trends that can interfere with a causal interpretation of our findings.

We include first births in our sample and set G_j equal to zero for them.[19] This implies that the "control" group comprises: (1) births during the pre-ultrasound period, (2) second and higher order births to mothers whose firstborn is a boy, and (3) first births. The coefficient γ measures the difference in EFM or the gender gap in health investments between the treatment and control groups during the pre-ultrasound period. The coefficients β_1 and β_2 capture how these gaps evolved over the early and late diffusion periods relative to the pre-ultrasound period. Thus, β_1 and β_2 measure the impact of ultrasound availability on EFM or the gender gap in health investments for the treatment group relative to the control group. We cluster standard errors by state.

Next we test for the mechanisms that may underlie the effects of ultrasound availability on EFM and health investments: a) substitution of within-family postnatal discrimination

[19]For higher-order births, G_j equals one if the first child of mother j is a girl and otherwise equals zero.

with prenatal discrimination and b) decline in the gender gap in sibling size.

To examine (a), we re-estimate specification (1) by including mother fixed effects and test if EFM has declined within families. A comparison of the magnitudes and the significance of the γ coefficients from specifications with and without mother fixed effects can reveal the relative importance of within- and across-family gender gaps in the pre-ultrasound period. Moreover, the β_1 and β_2 coefficients from the mother fixed-effects specification estimate the substitution of within-family postnatal discrimination with sex-selective abortions and discrimination in prenatal care of the mother or the fetus.[20]

To test for (b), we estimate the following differences-in-differences specification for woman j surveyed in state s and round r of the NFHS and whose first and last births occurred in years f and l:

$$\begin{aligned} N_{jsrfl} =& \alpha + \beta_1 G_j * Post^1_{fl} + \beta_2 G_j * Post^2_{fl} + \gamma G_j + \sigma_f + \psi_l \\ &+ X'_{jr}\tau + \delta_s + \omega_r + \phi_{sr} + \theta_{sf} + \nu_{sl} + \nu_s G_j + \epsilon_{jsrfl} \end{aligned} \tag{2}$$

The dependent variable is the number of births by the time of survey. For the fertility regressions, we restrict our sample to mothers whose fertile period falls strictly within one of our three time-periods, i.e., a mother belongs to the pre-ultrasound, early diffusion, and late diffusion periods if her first and last children are respectively born before 1985, during 1985-1995 ($Post^1_{fl}$) and after 1995 ($Post^2_{fl}$).[21] Since our objective here is to estimate the effect of ultrasound access on a woman's total fertility (albeit censored by the survey year), inclusion of women who were "treated" by ultrasound availability for only a portion of their fertility history in the sample would complicate the distinction between treated women and untreated women. Thus, for a cleaner interpretation of the β_1 and β_2 coefficients, we drop women whose fertility histories overlap more than one of our three periods.

The variable G_j is defined as in (1). The vector X_{jr} comprises indicators for household wealth quintiles, educational attainment of the woman and her husband, woman's birth cohort, woman's age at first birth, woman's age at the time of survey, caste, religion, and residence in a rural area. In addition, we include state fixed effects (δ_s), state-specific firstborn girl fixed effects ($\nu_s G_j$), fixed effects for year of first birth (σ_f), year of last birth (ψ_l), and survey year (ω_r) and allow their effects to vary by state (θ_{sf}, ν_{sl}, and ϕ_{sr}). The coefficients β_1 and β_2 then capture the impacts of ultrasound access on excess fertility due to a firstborn

[20] Although we do not observe large differences in the socioeconomic characteristics of firstborn boy and firstborn girl families (in Table B.3), the mother fixed effects specification also allows us to address any potential bias due to the higher likelihood of male births in higher socioeconomic status families ("Trivers-Willards hypothesis") even in the absence of sex-selection.

[21] This implies that the sample excludes women who have never given birth.

girl during the early and late diffusion periods relative to the pre-ultrasound period. Our dependent variable does not accurately reflect completed fertility for all women, as it is censored by the year of survey. We do, however, include fixed effects for the woman's age at the time of survey to take this into account.

The decline in the gender gap in sibling size due to ultrasound access may occur not just via sex-selective abortions but also through lower conception rates in the post-ultrasound period. The is because ultrasound access enables parents to achieve the desired sex composition of births sooner. We calculate the contributions of sex-selective abortions and reduction in conception rate to the decline in excess fertility by first calculating the number of births avoided due to ultrasound access (as implied by β_1 and β_2) and then comparing that number with the number of sex-selective abortions implied by the effects on the sex ratio at birth.

4 Data

The analysis of EFM and fertility is based on three rounds of the NFHS conducted in 1992-93, 1998-99, and 2005-06. These nationwide, repeated, cross-sectional surveys are representative at the state level and report complete birth histories for all interviewed women, including children's month, year, and order of birth, mother's age at birth, and the age at death for deceased children.[22] Our NFHS sample comprises 503,316 births for 232,259 mothers for the time-period 1973-2005. For the mortality regressions we pool the samples of births and for the fertility regressions we pool the sample of women.

Before early 1980s, the gender gaps in post-neonatal infant and child mortality were quite large in India. The time trends in EFM by sex of the first child are depicted in Figure 3 and Table 1. During 1973-1984, girls preceded by a firstborn girl were 3 percent more likely than boys to suffer post-neonatal child mortality. Thereafter, access to ultrasound technology facilitated abortion of unwanted daughters (Bhalotra and Cochrane (2010)). Concurrently, the gender gap in mortality also declined. However, this decline was concentrated among families with a firstborn girl, for whom excess female post-neonatal child mortality fell to 1.78 percent during 1985-1994 and further declined to 1.18 percent during 1995-2005. In contrast, the gender gap in post-neonatal mortality outcomes in families with a firstborn son was quite small to begin with and has remained small during the post-ultrasound period. For instance, excess female post-neonatal child mortality among firstborn-son families was 0.88 percent during 1973-1984 and 0.50 percent and 0.15 percent during the two post-ultrasound periods. We show that the decline in gender gap in EFM in firstborn-girl families can be *causally* explained by increased access to prenatal sex-diagnostic technology.

[22]Since the state of Sikkim changed its border during the period of analysis, we exclude it from our sample.

Table B.3 reports the summary statistics for the key variables from the NFHS used in our analysis for the pre-ultrasound, early diffusion, and late diffusion periods, separately by firstborn sex. Fertility is lower for mothers with a firstborn son relative to a firstborn daughter across all time periods, with a larger decline over time for the latter. The fraction of female births has also declined from 0.48 in the pre-ultrasound period to 0.47 in the late diffusion period for births preceded by a firstborn girl, but not for births preceded by a firstborn boy. Mother's age at birth has increased over time, more so for mothers with a firstborn girl; this is consistent with greater prenatal sex-selection by this group. The composition of firstborn-boy and firstborn-girl families is largely similar in terms of rural residence, religion, caste, wealth, and father's education during each period. However, over time, births preceded by a firstborn girl are increasingly born to less educated mothers relative to births preceded by a firstborn boy. To take into account these small compositional differences, we control for all these variables in our regressions. Additionally, we estimate specifications with mother fixed effects that are free from any potential bias introduced by differences in SES of firstborn boy and firstborn girl families.

The data on health investments in the NFHS is not suitable for our analysis since it does not cover the pre-ultrasound period. Instead, we utilize the 1999 round of REDS that surveyed rural women from 16 major states. Unlike NFHS, the REDS sample excludes urban women and eleven minor states. Moreover, the REDS data only reports age at death and does not report the year of birth for children who did not survive till the year of survey. Consequently, the REDS sample is restricted to children who were alive in 1999. To the extent that deceased children are likely to have received lower health investments than surviving children and (as we will show) EFM was higher in the pre-ultrasound period than the post-ultrasound period, the exclusion of deceased children from the sample is in fact likely to bias our effects in the downward direction, i.e., in the direction of not finding an effect.

Table B.4 reports the summary statistics for the key variables used in our analysis for the REDS sample. The definition of pre-ultrasound and early diffusion period is the same as in Table B.3 but the late diffusion period is shorter (1995-1999). The sample sizes are significantly smaller than the NFHS sample. Vaccination rates have increased over time for all children. In the pre-ultrasound period, children preceded by a firstborn boy were more likely to be immunized than children preceded by a firstborn girl and this gap reversed during the post-ultrasound years. Breastfeeding is nearly universal for both girls and boys in India. The mean duration of breastfeeding was about 19 months in the pre-ultrasound period and nearly 90% of boys and girls (who survived till the survey) were breastfed for at least 12 months. The gender gaps manifest in terms of breastfeeding duration, especially after age one, though they are not apparent in the sample means in Table B.4.[23]

5 Main Results

In this section we describe our findings for the effects of ultrasound access on EFM and the gender gap in child health investments in India.

5.1 Excess Female Mortality

In Table 2, we present estimates of the effects of ultrasound availability on three measures of mortality: neonatal mortality (Panel A), post-neonatal infant mortality (Panel B), and post-neonatal child mortality (Panel C). In this section we focus on columns (1)-(3). The most basic specification in column (1) controls for the main effects of *Firstborn girl* and *Female*, and their triple- and double-interactions with $Post^1$ and $Post^2$ along with fixed effects for state, birth year, and birth order. In column (2), we also control for demographic and socioeconomic characteristics of the parents. In column (3), we add the remaining fixed effects mentioned in specification (1).

For all three mortality measures, the coefficients in the first row are positive and highly significant. This implies that, during the pre-ultrasound period, girls are significantly more likely than boys to die neonatally, during infancy, and during early childhood among children preceded by a firstborn girl relative to a firstborn boy. For instance, post-neonatal child mortality for girls was 1.8 p.p. (in column (3) of Panel C) higher than for boys in firstborn-girl families relative to firstborn-boy families during the pre-ultrasound period.[24] The triple-interaction coefficients in the second and third rows are negative in all panels, indicating that EFM decreased once ultrasound technology became available. The largest and the most significant decline occurred in post-neonatal child mortality (Panel C) where ultrasound technology closed the gender gap by 1 p.p. in the early diffusion period and by 1.4 p.p. in the late diffusion period (in column (3)). These coefficients translate into, respectively, a 54 percent and a 77 percent decrease in the early and late diffusion periods, relative to the pre-ultrasound level of EFM (= 1.759). The effects on post-neonatal infant mortality (in Panel B) are insignificant in columns (1)-(3). For neonatal mortality (in Panel A), the decline in EFM is significant only during the late diffusion period, and its magnitude is smaller than the corresponding decline in post-neonatal child mortality in Panel C. The triple-interaction coefficient in column (3) of Panel A translates into a 66 percent decline in neonatal EFM

[23]The mean breastfeeding duration is mechanically lower in the 1995-1999 period because some of the children in that group were of breastfeeding age at the time of survey.

[24]The probability of post-neonatal child mortality for boys in the pre-ultrasound period was 6.2 percent in firstborn-boy families and was 5.7 percent in firstborn girl families.

during the late diffusion period.

The pattern of our results is consistent with the fact that neonatal deaths are primarily caused by poor maternal health and delivery conditions while post-neonatal mortality is caused by a poor disease environment, insufficient postnatal investments, and inadequate hospital care. If the main mechanism through which ultrasound access decreases EFM is the decline in gender gap in postnatal parental investments or intra-household resource allocation, it follows that the decline in EFM should also be largest for post-neonatal mortality. Prior literature has found similarly heterogeneous results for neonatal and post-neonatal mortality. Bozzoli et al. (2009) show that adult height increases in the United States and Europe are more strongly associated with decline in post-neonatal mortality relative to neonatal mortality. Chay et al. (2009) find that the convergence in black-white gap in average test scores in the United States is highly correlated with decline in post-neonatal mortality rates but not with neonatal mortality and Almond et al. (2008) demonstrate that the former can be explained by the decline in racial gap in hospital access. In the context of India, The Million Deaths Study (2010) shows that only 3.2 percent of neonatal deaths were caused by diarrhea in contrast to 22.2 percent of post-neonatal deaths.[25]

Altogether, the results in Table 2 show that the diffusion of ultrasound technology eliminated the gender gap in post-neonatal child mortality for second and higher order births in firstborn girl families relative to first births and relative to second and higher order births in firstborn boy families.

5.1.1 Exploiting Variation in Self-reported Ultrasound Use

To further corroborate our prior findings, we replace the temporal variation in ultrasound access (i.e., $Post^1_t$ and $Post^2_t$) in specification (1) with state-year variation in self-reported ultrasound use, $Ultra_{st}$. Specifically, $Ultra_{st}$ measures the percentage of births in a state-year for which the mother reports receiving an ultrasound test at some point during the pregnancy.[26] Although ultrasound use is generally not illegal in India, its use for fetal sex-detection is. Hence, self-reported ultrasound use may be underreported in the survey data. Moreover, the earliest year for which information on ultrasound use is available is 1996, which implies that the estimates for this specification compare mortality for children born to mothers with varying intensity of ultrasound use, *conditional on ultrasound technology being available*. Thus, we expect the estimated effects to be smaller than those reported in Table 2.

[25] Appendix Table B.5 also reports the estimated effects for infant and child mortality (in addition to neonatal and post-neonatal measures).

[26] The denominator equals the number of births with a non-missing response on the question of ultrasound use during pregnancy.

To the extent that ultrasound tests are used for reasons other than sex-detection and, *ceteris paribus*, access is more likely to translate into use for families with a stronger son preference, these estimates will be biased. Despite these caveats, like Table 2, Table B.7 shows that in the absence of ultrasound use, there is significant EFM in families with a firstborn girl and higher intensity of ultrasound use decreased this gender gap. As expected, the coefficients are less significant than those in Table 2 likely due to the larger standard errors due to the smaller sample size.

5.2 Postnatal Health Investments

Table 3 examines if ultrasound access altered the gender gaps in postnatal health investments in births preceded by a firstborn girl relative to a firstborn boy using the REDS data. In Panel A, the dependent variable in columns (1)-(3) is the number of months a child is breastfed, in columns (4)-(6) it is a dummy variable indicating that the child has received at least one vaccine, and in the last three columns it is the medical expenditure (in Rupees) on the child in the year prior to the survey. The medical expenditure (conditional upon illness) includes spending on doctor's fee, medicines, and special food eaten during the illness. In Panel B, the dependent variables are indicators for breastfeeding duration being at least 12 months, 24 months, and 36 months.[27] The specifications across columns are similar to those in Table 2.[28]

The coefficients in the first row of Panel A show that during the pre-ultrasound period in families with a firstborn girl, boys were breastfed significantly longer, were significantly more like to receive at least one vaccine, and more money was spent on their illness last year, relative to girls. The first row in Panel B shows that the gender gaps in breastfeeding duration emerge after age one and persist thereafter; this finding is consistent with the fact that most Indian children are breastfed through the first year of life. Ultrasound access nearly eliminated these gender gaps in breastfeeding and vaccination. The triple-interaction coefficients for vaccination are positive and significant for both post-ultrasound periods across all three specifications. For breastfeeding, there is an improvement in the total duration as well as breastfeeding during the second year of life, but the coefficients are significant only for the early diffusion period. The triple-interaction coefficients for breastfeeding for at least 36 months and medical expenditure are also positive for both post-periods but insignificant. We find no significant effect on the probability that a child is delivered in a hospital. The sample

[27]The sample is restricted to children who are at least 12, 24, and 36 months old, respectively.

[28]In Table 3, we exclude the urban indicator (since REDS covers only rural households), the wealth quintiles (not reported in REDS) and, to ease the computational burden on the smaller sample, we drop ρ_{bt}, $\xi_b G_j$, and $\nu_s G_j$ from the list of controls and replace ϕ_{st} with state-specific linear time trends. We continue to control for all other variables as before.

sizes in REDS are significantly smaller than those in NFHS, especially for breastfeeding and medical expenditure on sick children. Moreover, for consistency with the NFHS sample, we have restricted the pre-ultrasound period in Table 3 to 1973-1984. If we expand the number of pre-ultrasound years to increase the sample size of our REDS sample, the triple-interaction coefficients for breastfeeding and vaccination become even more significant. These results are available upon request. However, the effects on medical expenditure continue to be insignificant even with the larger sample.

Prior literature estimates that breastfeeding differences explain about 9% of the gender gap in post-neonatal child mortality (Jayachandran and Kuziemko (2011)) and sex differences in vaccinations explain between 20% - 30% of EFM (Oster (2009)) in India. Our findings in Table 3 imply that the contributions of breastfeeding and vaccination to the decline in EFM that we observe in Table 2 are, respectively, 7% - 11% and 6% - 7%. Appendix C describes how we arrive at these percentages.

Although the REDS data is superior to the NFHS data on health investments in terms of spanning pre-ultrasound years, it does not cover children who were deceased by the survey year. To ensure that our results are robust to this weakness of the REDS data, we also compare the gender gaps in health investments during the early and late diffusion periods using the NFHS data in Table B.6. In addition to immunization and breastfeeding, we examine the effects on prenatal investments (i.e., the number of antenatal checks during pregnancy) as well.[29] The findings in Table B.6 are broadly consistent with those in Table 3. The coefficients in the first row of Table B.6 estimate the gender gaps during the early diffusion period that are quite similar to the corresponding numbers (i.e., sums of the coefficients in the first two rows) in Table 3. The coefficients in the second row of Table B.6 capture the differences in the gender gaps during the two post-ultrasound periods, and are also similar to the corresponding estimates (i.e., differences of the coefficients in the second and third rows) in Table 3. For instance, column (2) of Table B.6 implies that the gender gap in the likelihood of receiving at least one vaccine was 2.5 p.p. lower in the late diffusion period relative to the early diffusion period, while the corresponding magnitude is 1.6 p.p in column (6) of Panel A in Table 3.

Although neither of our two datasets is perfect for this analysis, the consistent results we obtain from both lead us to conclude that ultrasound access significantly narrowed the gender gaps in postnatal health investments in India but not in prenatal investments that we have data on.

[29] The REDS did not collect information on prenatal health investments.

6 Mechanisms

As sex-selection technology enables parents to abort unwanted female fetuses, it allows parents to substitute postnatal discrimination with sex-selective abortions, reducing within-family gender gaps in son-preferring households. It also enables couples that follow son-biased stopping rules to achieve the desired number of sons at an earlier birth order, thereby decreasing fertility and narrowing overall gender gaps in health outcomes. The fertility decline can take place (i) through abortion of unwanted daughters and (ii) by lower conception rates as it enables parents to achieve their desired sex composition of births sooner. In this section, we directly examine these two mechanisms. Since we do not find that neonatal EFM increased due to ultrasound access, we conclude that the substitution between postnatal discrimination and prenatal discrimination in maternal health investments was not substantial.

1. Substitution of postnatal discrimination with sex-selective abortions

Since our dataset comprises multiple births per woman, in column (4) of Table 2, we re-estimate specification (1) with mother fixed effects. In all three panels, the coefficients of *Firstborn girl * Female* remain positive and highly significant, implying that the within-family discrimination channel played an important role in driving the gender gaps in the pre-ultrasound period. Moreover, the triple-interaction coefficients in column (4) of Table 2 continue to be negative and highly significant. This implies that ultrasound access decreased the gender gap in mortality across births *even within the same family* as sex-detection made abortion of unwanted daughters feasible for parents who would have otherwise discriminated against them postnatally. These estimates are also free from any compositional bias driven by differences in factors such as son preference across mothers.

2. Decline in the gender gap in sibling size

In columns (1)-(3) of Table 4 we present the regression estimates for the effects of access to ultrasound technology on a woman's number of births at the time of her survey interview to examine the effects on the gender gap in sibling size. Column (1) reports the estimates from specification (2). In column (2) we control for a woman's stated ideal number of children to capture fertility decline due to trends in women's education, for example. In column (3) we also control for a woman's ideal child sex ratio to take into account trends in subjective son preference.[30] In all three columns, the coefficient of *Firstborn Girl* is positive and significant implying that, in the pre-ultrasound period, women whose first child was a girl had more births relative to women with a firstborn son. This differential fertility by firstborn sex declined once ultrasound technology became available—the interaction coefficients in the second and third rows are negative and significant in all columns. Controlling for fertility preference and son preference does not significantly alter these effects. The coefficients -0.043 and -0.073 in column (3) respectively translate into a 48% and a 81% decrease, i.e., an elimination of the pre-ultrasound fertility gap (= 0.090) in families with a firstborn girl and a firstborn boy. Since the fertility gap between firstborn girl and firstborn boy families decreased due to abortion of unwanted girls, this also implies a decline in the sibling size gap between all boys and all girls.

To the extent that sex-selective abortions allow parents to avoid unwanted children, ultrasound access should drive actual fertility closer to desired fertility. Indeed, this is what we find. In column (4) of Table 4, the dependent variable captures excess fertility, defined as the difference between the actual number of births and the ideal number of births. The interaction coefficients in column (4) are negative, highly significant, and imply a complete elimination of excess fertility. The interaction coefficients in column (4) are also substantially larger than those in columns (1)-(3), implying that the decline in actual fertility is not driven by a decline in desired fertility.[31]

7 Robustness

Although we control for underlying trends in our outcome measures in various ways, to further confirm that our findings are not being driven by any pre-trends, in Table B.8, we restrict the sample to the pre-ultrasound period and re-estimate specification (1), albeit with a single *Post* indicator, for post-neonatal child mortality. We use six alternate "placebo" treatment years (1977 through 1982) to define the *Post* variable. If our main estimates are driven by an underlying convergence in mortality outcomes for boys and girls that is unrelated to ultrasound access, we should find a similar decline in EFM gender gap in these placebo regressions. Reassuringly, we find that the triple-difference coefficients are insignificant in all columns which suggests that our *Post* variables are indeed capturing the exogenous structural changes in ultrasound access over time.

In the previous section we showed that our fertility results hold even after we control

[30] The coefficients of ideal number of children are positive, implying that fertility is higher for women who prefer to have more children; however, the correlation between ideal sex ratio and fertility is weak.

[31] Δ Excess Fertility = Δ Actual Fertility - Δ Desired Fertility. Since $0 > \Delta$ Excess Fertility $> \Delta$ Actual Fertility $\implies \Delta$ Desired Fertility > 0.

for mother's ideal number and sex-composition of children. These two measures of ideal household structure capture the effects of a decline in desired fertility or a weakening of son preference caused by trends in women's education, for example. In columns (1) and (2) of Table B.9 we show that, like fertility, our EFM results also remain unaffected when we control for mother's fertility and son preference. In fact, we interact these preference variables with the *Female* dummy to perform an even stricter test. Then, in columns (3) and (4) of Table B.9 we control for an alternate measure of underlying son preference, the state-level gender enrollment ratio at ages 6-11 and ages 11-14 and find that our results remain the same. Note that the coefficients of *Ideal Sex Ratio * Female* and *Enrollment Gender Gap * Female* are positive, implying that EFM is higher in families with a stronger preference of sons. Moreover, the coefficients of *Ideal Fertility * Female* are negative, implying that, conditional on son preference, a declining trend in fertility leads to higher EFM.

In Table B.10, we further check for any compositional bias introduced by omitted changes in parental fertility and sex-ratio preferences that may contaminate our main findings. Specifically, we re-estimate specification (1) with mother's self-reported ideal number of sons, ideal number of daughters, and ideal proportion of sons as dependent variables to check if parental preferences are different across boys and girls born in treatment and control groups before and after ultrasound access. The triple-interaction coefficients in rows two and three show that there has been a marginally significant decrease in the ideal number of sons for mothers in the treatment group due to ultrasound access, however, the change in the ideal fraction of sons is insignificant. This implies that omitted changes in son preference are not the primary explanation for the EFM decline we find in the previous sub-section.

Lastly, we restrict the sample to women whose first child was born during the pre-ultrasound period, i.e., before 1985 and then re-estimate specification (1). While these estimates (reported in Table B.11) are free from any potential bias introduced by sex-selection at first parity due to ultrasound access, we have substantially fewer observations in the sample, especially for the late diffusion period. Nevertheless, the interaction coefficients are almost always negative and also significant for post-neonatal EFM.

8 Heterogeneous Impacts

Having established that ultrasound access caused EFM to decline via reductions in the gender gap in sibling size and via substitution of postnatal discrimination with sex-selective abortions, we now examine heterogeneity in these effects by socioeconomic characteristics of the household. The analysis of baseline heterogeneity and of the differential response of various groups to ultrasound access is non-trivial. This is because it is not obvious how the determinants of within-family discrimination and fertility vary across and over time for each SES group. The distribution of subjective preferences over fertility and sex ratio and the ability to translate them into actual fertility and sex ratio (driven by financial and informational constraints on access to contraception and ultrasound) interact with each other to jointly determine the outcomes we observe. The effects on EFM across SES groups are also likely to differ due to endogenous changes in the socioeconomic composition of births during the post-ultrasound period caused by heterogenous fertility decline. The level of baseline EFM itself determines "treatability" of a group. Households that have larger gender gaps in the pre-ultrasound period or have better access to sex-detection technology should, ceteris paribus, exhibit greater declines in EFM and fertility.

Keeping this complexity in mind, we compare the effects by household caste (SC vs non-SC),[32] rural-urban residence, wealth (bottom 40 percent vs top 20 percent), and mother's educational attainment (illiterate vs literate). Tables 5 and 6 respectively present the estimation results for the prevalence of within-family discrimination (as reflected in postneonatal child EFM) and gender gaps in sibling size during the pre-ultrasound period and the effects of ultrasound access across SES groups. In each regression, we continue to control for all other SES variables.

During the pre-ultrasound period, postneonatal EFM resulting from within-family discrimination (in Table 5) was positive and significant among all groups except for urban families and families in the top 20 percent of the wealth distribution. The magnitudes were larger for illiterate (relative to literate) and SC (relative to non-SC) mothers. Similarly, gender gaps in sibling size were present among all groups during the pre-ultrasound period (even among urban and top 20 percent families) and the magnitudes were similar across groups, except a larger gap among non-SC families relative to SC families. Thus, EFM among urban and top 20 percent families manifested via the fertility channel while the remaining groups engaged in both channels.

The decline in postneonatal child EFM due to substitution of postnatal discrimination with sex-selective abortions does not exhibit substantial heterogeneity by caste and mother's education. Consistent with the lack of pre-ultrasound gaps in urban households, there is no significant effect on EFM. While there was no pre-ultrasound gap in top 20 percent wealth households as well, we find a significant decline in the early diffusion period. To understand this further, we split the top 20 percent sample by caste (in Table 7) and find that this decline was driven by non-SC top 20 percent who in fact did exhibit positive and significant

[32] We pool the general castes and OBCs because NFHS-1 does not distinguish between these two groups. Nevertheless, since OBC households are socioeconomically better-off than SC households, the two categories we use preserve the caste hierarchy present in India. We also pool STs with general castes and OBCs since treating the former as a separate group yields similar results.

EFM during the pre-ultrasound period. The effects of gender gaps in sibling size are also substantial and significant across all groups, except for SCs.

To understand the channels behind these heterogeneous effects better, we further split each subsample by caste (SC and non-SC). These results are reported in Tables 7 and 8. Caste is a unique phenomenon of Indian society. As opposed to other dimensions of SES, caste is exogenous in the sense that an individual is born into a caste and cannot choose it. The caste hierarchy is quite rigid and has been preserved by the low prevalence of inter-caste marriages despite substantial economic development.[33] In order to maintain their superior social position, upper-caste households have historically laid greater emphasis on ritual purity and adherence of religious texts, and this has often been at the expense of women's position within these households (Das Gupta et al. (2003), Das Gupta (2010)). The essential role played by a son in Hindu rituals is also considered to be an important factor underlying the strong preference for sons among upper-caste Hindus.[34] For these reasons, we expect less within-family gender discrimination and smaller gender gaps in sibling size among lower castes (i.e., SCs in our case).

Indeed, the bulk of the pre-ultrasound discrimination and excess fertility and the post-ultrasound decline was in non-SC households. Low SES (i.e., illiterate, rural, and bottom 40 percent families) SCs exhibit the most gender equal outcomes in terms of excess fertility (in Table 8). At the higher end of the SES spectrum (i.e., literate, urban, and top 20 percent families), SCs behave more like non-SCs, as reflected in the former's greater reliance on the fertility channel before ultrasound and the significant declines after ultrasound. This similarity in behavior of lower and upper castes among the relatively well-off groups is consistent with the process of *Sanskritization*, wherein lower castes emulate the rituals and practices of the upper castes seeking upward mobility within the caste heirarchy (Srinivas (1962)). As sex-selective abortions are costly (though not substantially), the high SES SCs are more financially capable of using them to express their "adopted" son preference. However, high SES SCs (like low SES SCs) still do not exhibit within-family discrimination as reflected in the insignificant coefficients in columns (1) and (3) in Table 7. For upper caste households, both within-family discrimination and excess fertility were significantly prevalent in the pre-ultrasound period and these decline significantly due to ultrasound access. These findings

[33] According to the 2005 India Human Development Survey, only 4.4 percent of women were married to a spouse from a different caste.

[34] Although caste is primarily a Hindu phenomenon, the notion of caste-based hierarchy remains well-preserved among many other religious groups in India. In the 2009 National Sample Survey, 31 percent of Sikh households identified themselves as being SC. Therefore, for the caste analysis in Tables 7 and 8 we include households of all religions and use the self-reported caste of the household for our analysis while using religion as a control variable.

are consistent with heterogeneity in the effect of ultrasound access on the sex ratio at birth (a proxy for sex-selective abortions) across caste x SES groups.[35]

9 Discussion

The stark growth in the number of sex-selective abortions since ultrasound technology became available in highly populated countries like India and China has garnered a lot of attention from academics, policymakers, and popular media. Moral arguments can be made both in favor of parents' right to choose the sex of their offspring as well as against selective abortion of girls (Kumar (1983)). Abstracting from these ethical dilemmas, there are several reasons why a significantly male-biased sex ratio at birth is undesirable. The resulting scarcity of women on the marriage market can substantially increase the number of unmarried and childless men,[36] who may face destitution in old age since children through marriage are the most important source of support for the elderly in countries like India that lack institutional social security (Das Gupta et al. (2010)). Rising sex ratios can lead to increased trafficking[37] of women, higher prevalence of sexually-transmitted diseases (Ebenstein and Sharygin (2009)), and more crime (Edlund et al. (2007), Drèze and Khera (2000)). Sex-selection may also result in girls being consistently born to lower-status parents, thereby relegating women to lower social strata (Edlund (1999)).

On the other hand, a shortage of women on the marriage market may also increase their bargaining power and welfare.[38] It has been also argued that sex-selective abortions might be preferable to infanticide or postnatal discrimination (Goodkind (1996)). Indeed, our paper shows that the increase in sex-selective abortions fueled by ultrasound access substantially decreased EFM in India. We also find that ultrasound access decreased the gender gaps in children's educational attainment (Table B.13) albeit the effects are insignificant.[39]

To explicitly measure the extent of substitution between postnatal discrimination and

[35] These results are available upon request.

[36] Bhaskar (2011) estimates that one in five boys born in recent cohorts in China will be unable to find female partners.

[37] Recent evidence shows that a shortage of women in north Indian states has led to the import of brides from other poorer states in India (Kaur (2004), Ahlawat (2009)).

[38] See Chiappori et al. (2002) and related papers for the large literature on household bargaining in developed countries. Stopnitzky (2012) shows that a relative scarcity of women in Haryana has increased their bargaining power on the marriage market and they are able to secure improved sanitation facilities at home as a result.

[39] A potential reason for insignificant effects on child education is that public school education for girls is free in India, and thus parents may not discriminate in terms of sending their children to school. It is more likely that gender discrimination manifests in the quality of schooling (private versus public schools (Azam and Kingdon (2013))) and enrollment in higher education, however, we do not have adequate data on these dimensions.

sex-selective abortions due to ultrasound access, we use our regression estimates to calculate the number of female child deaths that have been averted and compare them with the number of female fetuses that have been aborted. These calculations are presented in Table 9 and described in Appendix D. We find that for every 5.7 girls aborted, one girl survived due to access to ultrasound technology. Our estimates thus suggest that despite positive unintended consequences of sex-selection technology for the gender gap in postnatal child mortality, the improvement is of a substantially smaller scale than the increase in the gender gap in prenatal child mortality. Moreover, a large share of the sex-selective abortions in India are conducted in unsafe environments. Complications of unsafe abortion account for an estimated 9% of all maternal deaths in India (Stillman et al. (2014)).[40] Thus, on the whole, sex-selection is likely to have more costs than benefits.

We also calculate the proportion of discriminated births for which parents substituted postnatal discrimination with prenatal discrimination as the decline in the number of girls missing due to EFM (= 76,265 - 28,001 = 48,264) divided by the total number of missing girls in the pre-ultrasound period (= 163,529). This calculation implies that, for nearly 30% of the births, parents who were practicing postnatal discrimination in the pre-ultrasound period switched to prenatal discrimination after ultrasound became available. The percentage of switchers is much larger than the estimates in Lin et al. (2014) who find that 4% of parents of second-parity births and 8% of parents of third- and higher-parity births made the switch in Taiwan.

10 Conclusion

We show that access to ultrasound technology eliminated the gender gaps in child mortality and postnatal health investments for second- and higher-parity births born after a first-girl relative to a first-boy in India. These effects were driven by a complete closing of the relative sibling size gap and partial substitution of postnatal gender discrimination with sex-selective abortion of girls. The substitution towards differential prenatal investments in pregnant mothers was not significant. These effects are driven by upper caste and high SES lower caste families. While the former decreased both within-family discrimination and excess fertility, the latter primarily responded by narrowing the gender gaps in sibling size. Nevertheless, the improvements in mortality outcomes for girls cannot compensate for the much larger imbalance in the sex ratio at birth caused by the same technology. These relative magnitudes suggest that policy measures that increase the cost of sex-selective abortion may be able to decrease the total number of missing girls, even if they worsen EFM.

[40] The maternal mortality ratio in India was 178 maternal deaths per 100,000 live births in 2010-12.

References

Ahlawat, N. (2009): "Missing Brides in Rural Haryana: A Study of Adverse Sex Ratio, Poverty and Addiction," *Social Change*, 39, 46–63.

Almond, D., K. Y. Chay, and M. Greenstone (2008): "Civil Rights, the War on Poverty, and Black-White Convergence in Infant Mortality in the Rural South and Mississippi," *American Economic Review (conditionally accepted)*.

Almond, D., H. Li, and L. Meng (2010): "Son Preference and Early Childhood Investments in China," *Working Paper*.

Ananat, E. O., J. Gruber, P. B. Levine, and D. Staiger (2009): "Abortion and Selection," *Review of Economics and Statistics*, 91, 124–136.

Anderson, S. and D. Ray (2010): "Missing Women: Age and Disease," *Review of Economic Studies*, 77, 1262–1300.

Arnold, F., S. Kishor, and T. Roy (2002): "Sex-selective Abortions in India," *Population and Development Review*, 28, 759–785.

Azam, M. and G. G. Kingdon (2013): "Are girls the fairer sex in India? Revisiting intra-household allocation of education expenditure," *World Development*, 42, 143–164.

Bhalotra, S. and T. Cochrane (2010): "Where Have All the Young Girls Gone? Identification of Sex Selection in India," *IZA Discussion Paper No. 5381*.

Bhalotra, S. and A. van Soest (2008): "Birth-Spacing, Fertility and Neonatal Mortality in India: Dynamics, Frailty, and Fecundity," *Journal of Econometrics*, 143, 274–290.

Bharadwaj, P. and L. K. Lakdawala (2013): "Discrimination Begins in the Womb: Evidence of Sex-Selective Prenatal Investments," *Journal of Human Resources*, 48, 71–113.

Bhaskar, V. (2011): "Sex Selection and Gender Balance," *American Economic Journal: Microeconomics*, 3, 214–244.

Bhat, P. (2002): "Maternal Mortality in India: An Update," *Studies in Family Planning*, 33, 227–236.

Bongaarts, J. and C. Guilmoto (2015): "How Many More Missing Women? Excess Female Mortality and Prenatal Sex Selection, 1970–2050," *Population and Development Review*, 41, 241–269.

Bozzoli, C., A. Deaton, and C. Quintana-Domeque (2009): "Adult Height and Childhood Disease," *Demography*, 46, 647–669.

Carranza, E. (2015): "Soil Endowments, Female Labor Force Participation, and the Demographic Deficit of Women in India," *American Economic Journal: Applied Economics*, 6, 1997–225.

Charles, K. K. and M. Stephens Jr. (2006): "Abortion Legalization and Adolescent Substance Abuse," *Journal of Law and Economics*, 49, 481–505.

Chay, K. Y., J. Guryan, and B. Mazumder (2009): "Birth Cohort and the Black-White Achievement Gap: The Roles of Access and Health Soon After Birth," *NBER Working Paper 15078*.

Chiappori, P.-A., B. Fortin, and G. Lacroix (2002): "Household Labor Supply, Sharing Rule and the Marriage Market," *Journal of Political Economy*, 110, 37–72.

Clark, S. (2000): "Son Preference and Sex Composition of Children: Evidence from India," *Demography*, 37, 95–108.

Coale, A. J. (1991): "Excess Female Mortality and the Balance of the Sexes in the Population: An Estimate of the Number of "Missing Females"," *Population and Development Review*, 17, 517–523.

Currie, J. and M. Rossin-Slater (2015): "Early-life Origins of Lifecycle Well-being: Research and Policy Implications," *Journal of Policy Analysis and Management*, 34, 208–242.

Das Gupta, M. (2010): "Family Systems, Political Systems, and Asia's 'Missing Girls': The Construction of Son Preference and Its Unraveling," *Asian Population Studies*, 6, 123–152.

Das Gupta, M. and P. Bhat (1997): "Fertility Decline and Increased Manifestation of Sex Bias in India," *Population Studies*, 51, 307–315.

Das Gupta, M., A. Ebenstein, and E. J. Sharygin (2010): "China's Marriage Market and Upcoming Challenges for Elderly Men," *World Bank Policy Research Working Paper 5351*.

Das Gupta, M., J. Zhenghua, L. Bohua, X. Zhenming, W. Chung, and B. Hwa-Ok (2003): "Why is Son Preference So Persistent in East and South Asia? A Cross-country Study of China, India and the Republic of Korea," *Journal of Development Studies*, 40, 153–187.

Donohue, J. J. I. and S. D. Levitt (2001): "The Impact of Legalized Abortion on Crime," *Quarterly Journal of Economics*, 141, 379–420.

Drèze, J. and R. Khera (2000): "Crime, Gender, and Society in India: Insights from Homicide Data," *Population and Development Review*, 26, 335–352.

Ebenstein, A. Y. and E. J. Sharygin (2009): "The Consequences of the Missing Girls of China," *The World Bank Economic Review*, 23, 399–425.

Edlund, L. (1999): "Son Preference, Sex Ratios and Marriage Patterns," *Journal of Political Economy*, 107, 1275–1304.

Edlund, L., H. Li, J. Yi, and J. Zhang (2007): "Sex Ratios and Crime: Evidence from China's One Child Policy," *IZA Discussion Paper 3214*.

Gangoli, G. (1998): "Reproduction, Abortion and Women's Health," *Social Scientist*, 26, 83–105.

George, S. (2006): "Sex Ratio in India, Response to Jha, Prabhat, Rajesh Kumar, Neeraj Dhingra," *The Lancet*, 367, 1725.

Goodkind, D. (1996): "On Substituting Sex Preference Strategies in East Asia: Does Prenatal Sex Selection Reduce Postnatal Discrimination?" *Population and Development Review*, 22, 111–125.

Grover, A. and R. Vijayvergia (2006): "Sex Ratio in India, Response to Jha, Prabhat, Rajesh Kumar, Neeraj Dhingra," *The Lancet*, 367, 1726.

Hu, L. and A. Schlosser (2015): "Prenatal Sex Determination and Girls' Well-Being: Evidence from India," *Economic Journal*, 125, 1227–1261.

Jayachandran, S. (2014): "Fertility Decline and Missing Women," *NBER Working Paper 20272*.

Jayachandran, S. and I. Kuziemko (2011): "Why Do Mothers Breastfeed Girls Less Than Boys: Evidence and Implications for Child Health in India," *Quarterly Journal of Economics*, 126, 1485–1538.

Jensen, R. (2012): "Another Mouth to Feed? The Effects of Fertility on Girls' Malnutrition," *CESifo Economic Studies*, 58, 322–47.

Kaur, R. (2004): "Across-Region Marriages: Poverty, Female Migration and the Sex Ratio," *Economic and Political Weekly*, 39, 2595–2603.

Kumar, D. (1983): "Male Utopias or Nightmares?" *Economic and Political Weekly*, 18, 61–64.

Lin, M.-J., J.-T. Liu, and N. Qian (2014): "More Missing Women, Fewer Dying Girls: The Impact of Abortion on Sex Ratios at Birth and Excess Female Mortality in Taiwan," *Journal of European Economic Association*, 12.

Mahal, A., A. Varshney, and S. Taman (2006): "Diffusion of Diagnostic Medical Devices and Policy Implications for India," *International Journal of Technology Assessment in Health Care*, 22, 184–190.

Nandi, A. and A. B. Deolalikar (2013): "Does a legal ban on sex-selective abortions improve child sex ratios? Evidence from a policy change in India," *Journal of Development Economics*, 103, 216–228.

Oster, E. (2009): "Proximate Sources of Population Sex Imbalances in India," *Demography*, 46.

Phadke, S. (1997): "Pro Choice or Population Control: A Study of the Medical Termination of Pregnancy Act, Government of India 1971," *Re/Productions*.

Pop-Eleches, C. (2006): "The Impact of a Change in Abortion Regime on Socio-Economic Outcomes of Children: Evidence from Romania," *Journal of Political Economy*, 114, 744–773.

Pörtner, C. C. (2010): "Sex Selective Abortions, Fertility and Birth Spacing," *University of Washington, Department of Economics, Working Paper UWEC-2010-4-R.*

Retherford, R. D. and T. Roy (2003): "Factors Affecting Sex-Selective Abortion In India," *National Family Heath Survey Bulletin*, 17.

Rose, E. (2000): "Gender Bias, Credit Constraints and Time Allocation in Rural India," *Economic Journal*, 110, 738–758.

Rosenblum, D. (2013): "The effect of fertility decisions on excess female mortality in India," *Journal of Population Economics*, 26, 147–180.

Sen, A. (1990): "More Than 100 Million Women Are Missing," *New York Review of Books*, 61–66.

Shepherd, M. (2008): *The Selective Abortion in India: The Impact on Child Mortality*, Cambria Press.

Srinivas, M. (1962): *Caste in Modern India: And Other Essays*, Asia Publishing House, Bombay.

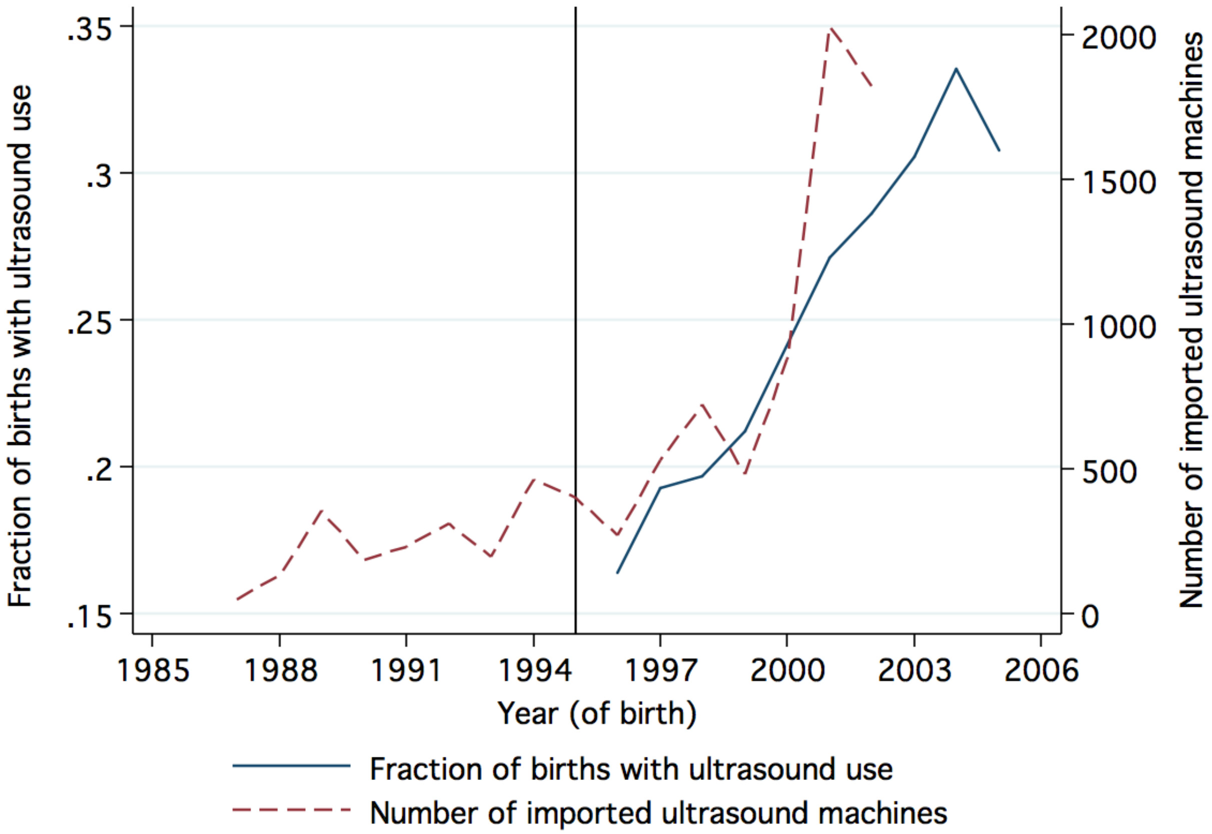
Stillman, M., J. J. Frost, S. Singh, A. M. Moore, and S. Kalyanwala (2014): "Abortion in India: A Literature Review," New York: Guttmacher Institute.

Stopnitzky, Y. (2012): "The Bargaining Power of Missing Women: Evidence from a Sanitation Campaign in India," Unpublished manuscript, University of San Francisco.

Visaria, L. (2005): "Female Deficit in India: Role of Prevention of Sex Selective Abortion Act," *mimeo.*

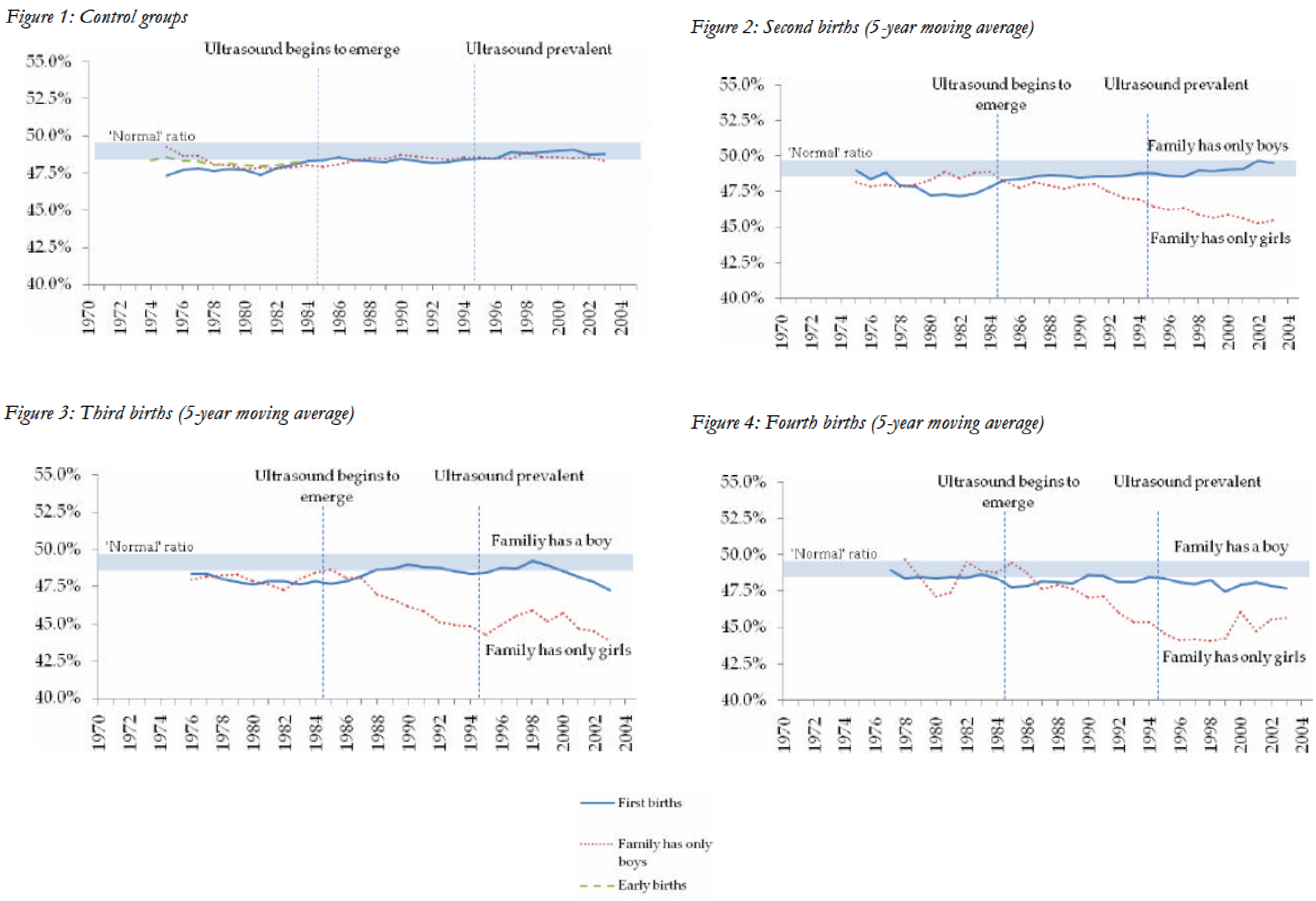
11 Figures

Figure 1: Ultrasound use by mothers and number of ultrasound scanners imported in India



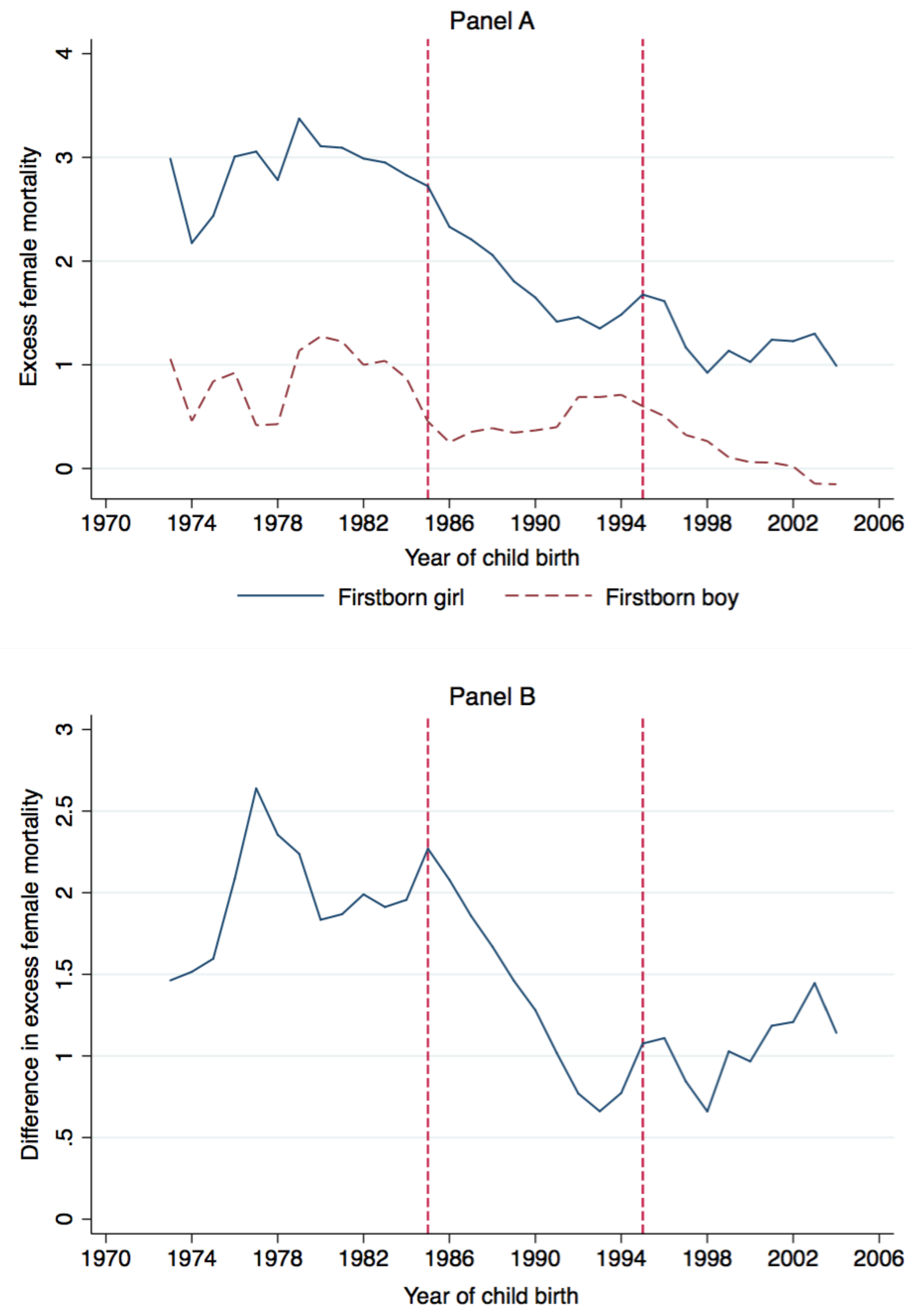
NOTES: (1) The solid line plots the fraction of births in a year for which the mother reports getting an ultrasound test at some point during the pregnancy (the denominator equals the number of births with a non-missing response on ultrasound use). The relevant question was not asked in NFHS-1; in NFHS-2 and NFHS-3, data on ultrasound use was collected for births since January 1995 and January 2001, respectively. The years 1995 and 2000 have been dropped due to extremely small sample sizes. (2) The dashed line plots the number of ultrasound scanners imported at the national level (Source: Mahal et al. (2006)). No import data is available for years before 1987.

Figure 2: Trends in proportion of females at birth by birth order and sex composition of older siblings



NOTES: This figure reproduces Figures 1-4 from Bhalotra and Cochrane (2010). Figure 1 shows the evolution of fraction of female births over time for first births and families that have only boys. In figures 2, 3, and 4 the trend in fraction of female births is plotted respectively for second, third, and fourth births separately for families that have one boy and families with no boys. In all cases, the y-axis shows the 5-year moving average of the fraction of female births.

Figure 3: Post-neonatal excess female child mortality, by firstborn's sex



NOTES: Post-neonatal excess female child mortality equals the percentage of female births that die minus the percentage of male births that die after the first month of birth but before age five. The graph in Panel A plots the 5-year moving average of EFM among families with a firstborn girl and families with a firstborn boy; Panel B plots the EFM for births in firstborn girl families minus the EFM for births in firstborn boy families. The vertical lines denote the pre-ultrasound period (1973-1985), the early diffusion period (1985-1994), and the late diffusion period (1995-2005).

12 Tables

Table 1: Mortality for treatment and control groups (%), NFHS

	Firstborn boy			Firsborn girl		
	(1)	(2)	(3)	(4)	(5)	(6)
	Male	Female	EFM	Male	Female	EFM
			(2)-(1)			(5)-(4)
1. Pre-ultrasound: 1973-1984						
Neonatal	7.326	5.536	-1.79	5.060	5.035	-0.025
Post-neonatal Infant	3.629	3.944	0.315	3.260	4.593	1.333
Post-neonatal Child	6.169	7.052	0.883	5.721	8.771	3.050
N	43,833	40,425		17,252	15,908	
2. Early diffusion period: 1985-1994						
Neonatal	5.692	4.528	-1.164	4.439	4.352	-0.087
Post-neonatal Infant	2.563	2.759	0.196	2.429	3.320	0.891
Post-neonatal Child	4.380	4.880	0.500	4.246	6.021	1.775
N	82,579	77,699		43,547	39,519	
3. Late diffusion period: 1995-2005						
Neonatal	4.434	3.627	-0.807	3.450	3.554	0.104
Post-neonatal Infant	1.755	1.636	-0.119	1.558	2.225	0.667
Post-neonatal Child	2.507	2.658	0.151	2.523	3.702	1.179
N	46,504	44,196		27,713	24,141	

NOTES: This table reports the percentage of second- and higher-order children, by firstborn sex and child's gender, who suffered from neonatal, post-neonatal infant, or post-neonatal child mortality over the three time-periods in our sample. Columns (3) and (4) report the differences between the mortality numbers in columns (1) - (2) and (4) - (5), respectively.

Table 2: Excess Female Mortality, NFHS

A. Neonatal Mortality	(1)	(2)	(3)	(4)
*Firstborn girl * Female*	1.754***	1.705***	1.352***	1.529***
	(0.379)	(0.373)	(0.383)	(0.446)
*Firstborn girl * Female * Post1*	-0.698	-0.665	-0.682	-0.963*
	(0.426)	(0.422)	(0.423)	(0.488)
*Firstborn girl * Female * Post2*	-0.872**	-0.875**	-0.891**	-1.353***
	(0.353)	(0.348)	(0.359)	(0.463)
N		503,316		
B. Post-Neonatal Infant Mortality	(1)	(2)	(3)	(4)
*Firstborn girl * Female*	1.026***	1.002***	0.838***	0.964***
	(0.282)	(0.283)	(0.272)	(0.281)
*Firstborn girl * Female * Post1*	-0.342	-0.320	-0.380	-0.603*
	(0.301)	(0.302)	(0.299)	(0.297)
*Firstborn girl * Female * Post2*	-0.264	-0.283	-0.372	-0.932***
	(0.243)	(0.238)	(0.240)	(0.309)
N		478,843		
C. Post-Neonatal Child Mortality	(1)	(2)	(3)	(4)
*Firstborn girl * Female*	2.171***	2.123***	1.759***	1.952***
	(0.333)	(0.332)	(0.312)	(0.365)
*Firstborn girl * Female * Post1*	-0.919**	-0.872**	-0.955**	-1.312**
	(0.402)	(0.401)	(0.403)	(0.475)
*Firstborn girl * Female * Post2*	-1.191***	-1.229***	-1.354***	-2.215***
	(0.397)	(0.380)	(0.361)	(0.581)
N		478,843		
*Female * Post1* and *Female * Post2*	x	x		
*Firstborn Girl * Post1* and *Firstborn Girl * Post2*	x	x		
X_{ijt}		x	x	x
Firstborn Girl x Birth year FE			x	x
Female x Birth year FE			x	x
Female x State FE			x	x
Female x Birth order FE			x	x
Birth order x Birth year FE			x	x
Birth order x State FE			x	x
State x Birth year FE			x	x
Mother FE				x

NOTES: This table reports the coefficients from specification (1). Each column within a panel is from a separate regression. The dependent variables measure mortality as percentage of births that do not survive. We control for *Female* and fixed effects for birth year and birth order in all columns and for *Firstborn girl* and state fixed effects in columns (1)-(3). The vector X_{ijt} comprises mother's age at birth and, except in column (4), household wealth quintiles, caste, religion, residence in a rural area, educational attainment of child's parents, and mother's birth cohort. Standard errors in parentheses are clustered by state. *** 1%, ** 5%, * 10%.

Table 3: Postnatal Health Investments, 1999 REDS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A:	Months breastfed			Received $\geq$ one vaccine			Rupees spent on illness last year		
*First girl*Female*	-5.124**	-4.451**	-3.820**	-0.130**	-0.091**	-0.068	-27.150	-15.583	-74.084
	(1.879)	(1.846)	(1.724)	(0.051)	(0.038)	(0.046)	(50.961)	(50.910)	(56.223)
*First girl*Female*Post1*	4.739**	4.040*	2.409	0.112**	0.096*	0.079*	17.108	6.186	64.624
	(2.012)	(2.042)	(2.035)	(0.049)	(0.048)	(0.042)	(68.645)	(65.100)	(81.158)
*First girl*Female*Post2*	4.162	3.735	1.464	0.094*	0.068*	0.095**	44.955	31.177	97.876
	(3.140)	(2.594)	(2.450)	(0.051)	(0.033)	(0.039)	(50.283)	(51.044)	(62.189)
N		13,084			20,561			15,156	
Panel B:	Breastfed $\geq$ 12 months			Breastfed $\geq$ 24 months			Breastfed $\geq$ 36 months		
*First girl*Female*	-0.096	-0.083	-0.035	-0.269***	-0.269***	-0.212**	-0.103**	-0.083**	-0.068
	(0.071)	(0.090)	(0.081)	(0.090)	(0.079)	(0.084)	(0.044)	(0.038)	(0.043)
*First girl*Female*Post1*	0.085	0.092	-0.007	0.321***	0.275**	0.178	0.087	0.071	0.032
	(0.110)	(0.087)	(0.080)	(0.104)	(0.114)	(0.124)	(0.069)	(0.065)	(0.073)
*First girl*Female*Post2*	0.096	0.047	-0.026	0.178	0.222	0.119	0.053	0.033	0.020
	(0.101)	(0.094)	(0.093)	(0.190)	(0.161)	(0.148)	(0.082)	(0.073)	(0.064)
N		12,447			11,760			10,942	
*Female*Post1* & *Female*Post2*	x	x		x	x		x	x	
*1st Girl*Post1* & *1st Girl*Post2*	x	x		x	x		x	x	
X_{ijt}		x	x		x	x		x	x
1st Girl x Birth year FE			x			x			x
Female x Birth year FE			x			x			x
Female x State FE			x			x			x
Female x Birth order FE			x			x			x
Birth order x State FE			x			x			x
State-specific time trends			x			x			x

NOTES: This table reports the coefficients from specification (1) estimated on the 1999 REDS sample. Each column within a panel is from a separate regression. We control for *Female*, *Firstborn girl*, and fixed effects for birth year, birth order, and state in all columns. The vector X_{ijt} comprises mother's age at birth, caste, religion, educational attainment of child's parents, and mother's birth cohort. Breastfeeding results are based on the last two surviving births of a mother. Vaccination and health expenditure results are based on all surviving children of a mother. Standard errors in parentheses are clustered by state. *** 1%, ** 5%, * 10%.

Table 4: Fertility

	Number of births			Excess Fertility
	(1)	(2)	(3)	(4)
Firstborn girl	0.101***	0.105***	0.090***	0.116***
	(0.011)	(0.011)	(0.012)	(0.015)
*Firstborn girl * Post1*	-0.051***	-0.057***	-0.043***	-0.128***
	(0.010)	(0.010)	(0.013)	(0.016)
*Firstborn girl * Post2*	-0.079***	-0.087***	-0.073***	-0.185***
	(0.012)	(0.011)	(0.013)	(0.017)
Ideal no. of children		0.057***	0.106***	
		(0.003)	(0.006)	
Ideal sex ratio			-0.002	
			(0.006)	
N	118,663	110,242	85,208	110,242

NOTES: This table presents estimates from specification (2). The dependent variable in columns (1)-(3) is the number of births at the time of interview and in column (4) is excess fertility which equals number of births minus ideal number of children. A mother belongs to the pre-ultrasound, early diffusion, and late diffusion periods if her first and last children are respectively born before 1985, during 1985-1995 ($Post1$) and after 1995 ($Post2$). Standard errors in parentheses are clustered by state. *** 1%, ** 5%, * 10%.

Table 5: Heterogeneity in Effects on Postneonatal Child EFM, with mother FE

	Mother's Education		**Wealth**	
	Illiterate	Literate	Bottom 40%	Top 20%
	(1)	(2)	(3)	(4)
*Firstborn girl * Female*	2.421***	1.318**	2.407***	1.004
	(0.599)	(0.545)	(0.789)	(0.625)
*Firstborn girl * Female * Post1*	-1.390*	-1.520**	-0.770	-1.590**
	(0.677)	(0.639)	(1.028)	(0.628)
*Firstborn girl * Female * Post2*	-2.401***	-1.928***	-2.738***	-1.016
	(0.852)	(0.642)	(0.911)	(0.621)
N	262,539	216,304	194,658	96,819
Baseline mean	8.94	3.44	9.93	2.86
	SC	**General/OBC/ST**	**Rural**	**Urban**
*Firstborn girl * Female*	2.824**	1.808***	2.619***	0.380
	(1.292)	(0.399)	(0.445)	(0.503)
*Firstborn girl * Female * Post1*	-1.562	-1.384**	-1.646**	-0.729
	(1.337)	(0.516)	(0.615)	(0.682)
*Firstborn girl * Female * Post2*	-3.054*	-2.196***	-3.159***	-0.240
	(1.618)	(0.700)	(0.635)	(0.651)
N	77,471	401,372	322,945	155,898
Baseline mean	9.32	6.36	7.92	4.19

NOTES: This table presents estimates from specification (1) with mother FE for various sub-samples. Each column within a panel is from a separate regression. SC, ST, OBC, and General respectively denote scheduled castes, scheduled tribes, other backward classes, and upper castes. The wealth categories in Panel D are based on the national household wealth distribution. Standard errors in parentheses are clustered by state. *** 1%, ** 5%, * 10%.

Table 6: Heterogeneity in Effects on Fertility

	Mother's Education		**Wealth**	
	Illiterate	Literate	Bottom 40%	Top 20%
	(1)	(2)	(3)	(4)
Firstborn girl	0.101***	0.112***	0.097***	0.107***
	(0.019)	(0.015)	(0.023)	(0.017)
*Firstborn girl * Post1*	-0.043**	-0.064***	-0.054**	-0.045***
	(0.028)	(0.011)	(0.026)	(0.015)
*Firstborn girl * Post2*	-0.072***	-0.088***	-0.068**	-0.071***
	(0.017)	(0.015)	(0.025)	(0.020)
N	46,597	72,066	36,831	36,352
Baseline mean	3.23	2.81	3.10	2.77
	SC	General/OBC/ST	Rural	Urban
	(5)	(6)	(7)	(8)
Firstborn girl	0.086**	0.103***	0.099***	0.105***
	(0.031)	(0.012)	(0.019)	(0.009)
*Firstborn girl * Post1*	-0.021	-0.054***	-0.054***	-0.047***
	(0.035)	(0.010)	(0.018)	(0.013)
*Firstborn girl * Post2*	-0.045	-0.084***	-0.073***	-0.088***
	(0.034)	(0.013)	(0.019)	(0.010)
N	17,043	101,620	71,155	47,508
Baseline mean	3.24	2.97	3.11	2.85

NOTES: This table presents estimates from specification (2). The dependent variable is the number of births at the time of interview. A mother belongs to the pre-ultrasound, early diffusion, and late diffusion periods if her first and last children are respectively born before 1985, during 1985-1995 ($Post1$) and after 1995 ($Post2$). Standard errors in parentheses are clustered by state. *** 1%, ** 5%, * 10%.

Table 7: Heterogeneity in Effects on Post-neonatal Child EFM, by caste (with mother fixed effects)

	Mother Illiterate		Mother Literate	
	SC	General/OBC/ST	SC	General/OBC/ST
	(1)	(2)	(3)	(4)
*Firstborn girl * Female*	3.729**	2.120***	-0.322	1.429***
	(1.608)	(0.598)	(3.047)	(0.505)
*Firstborn girl * Female * Post1*	-1.695	-1.371*	-0.839	-1.551**
	(1.651)	(0.740)	(2.752)	(0.598)
*Firstborn girl * Female * Post2*	-2.756	-2.457**	-1.962	-1.754**
	(2.149)	(0.932)	(2.885)	(0.668)
N	53,369	209,170	24,102	192,202
Baseline mean	10.42	8.63	5.31	3.28
	Rural		Urban	
	SC	General/OBC/ST	SC	General/OBC/ST
	(1)	(2)	(3)	(4)
*Firstborn girl * Female*	3.783*	2.403***	-1.098	0.512
	(2.056)	(0.458)	(1.823)	(0.506)
*Firstborn girl * Female * Post1*	-2.094	-1.628**	0.973	-0.851
	(2.073)	(0.621)	(1.966)	(0.711)
*Firstborn girl * Female * Post2*	-3.766*	-3.164***	0.264	-0.177
	(2.183)	(0.801)	(1.368)	(0.722)
N	54,909	268,036	22,562	133,336
Baseline mean	10.40	7.49	6.19	3.93
	Bottom 40 %		Top 20 %	
	SC	General/OBC/ST	SC	General/OBC/ST
	(1)	(2)	(3)	(4)
*Firstborn girl * Female*	2.429	2.407***	2.722	1.145*
	(2.308)	(0.713)	(2.693)	(0.612)
*Firstborn girl * Female * Post1*	-0.430	-0.892	-2.358	-1.822***
	(2.516)	(1.005)	(3.253)	(0.591)
*Firstborn girl * Female * Post2*	-3.230	-2.794**	-4.012	-0.938
	(2.555)	(1.018)	(3.077)	(0.616)
N	37,362	157,296	8,782	88,037
Baseline mean	12.25	9.47	4.70	2.70

Table 8: Heterogeneity in Effects on Fertility, by caste

	Mother Illiterate		Mother Literate	
	SC	General/OBC/ST	SC	General/OBC/ST
	(1)	(2)	(3)	(4)
*Firstborn girl * Female*	0.042	0.108***	0.208***	0.106***
	(0.047)	(0.021)	(0.058)	(0.016)
*Firstborn girl * Female * Post1*	0.035	-0.056***	-0.162**	-0.057***
	(0.050)	(0.018)	(0.071)	(0.012)
*Firstborn girl * Female * Post2*	-0.004	-0.084***	-0.168**	-0.086***
	(0.053)	(0.020)	(0.062)	(0.017)
N	9,191	37,406	7,852	64,214
Baseline mean	4.23	4.11	3.44	3.23
	Rural		Urban	
	SC	General/OBC/ST	SC	General/OBC/ST
	(1)	(2)	(3)	(4)
*Firstborn girl * Female*	0.058	0.107***	0.160**	0.010***
	(0.057)	(0.017)	(0.067)	(0.010)
*Firstborn girl * Female * Post1*	-0.002	-0.063***	-0.094	-0.043***
	(0.056)	(0.015)	(0.078)	(0.011)
*Firstborn girl * Female * Post2*	-0.014	-0.083***	-0.112	-0.086***
	(0.055)	(0.019)	(0.070)	(0.011)
N	11,132	60,023	5,911	41,597
Baseline mean	4.16	3.88	3.76	3.35
	Bottom 40 %		Top 20 %	
	SC	General/OBC/ST	SC	General/OBC/ST
	(1)	(2)	(3)	(4)
*Firstborn girl * Female*	0.049	0.115***	0.262***	0.103***
	(0.083)	(0.025)	(0.066)	(0.017)
*Firstborn girl * Female * Post1*	0.003	-0.072**	-0.149*	-0.043***
	(0.069)	(0.027)	(0.085)	(0.015)
*Firstborn girl * Female * Post2*	-0.002	-0.088***	-0.215***	-0.069***
	(0.082)	(0.029)	(0.062)	(0.021)
N	6,759	30,072	3,117	33,235
Baseline mean	4.17	4.01	3.58	3.16

Table 9: Substitution between Sex-Selective Abortions and Postnatal Discrimination

	A. Regression Estimates	
X	Pre-ultrasound fraction of females in births preceded by a firstborn girl	0.479
Y	Δ(Fraction of females in births preceded by a firstborn girl)	
	(coefficient of *Firstborn girl**Post2* in the SRB regression)	-0.019
X + Y	Post-ultrasound fraction of females in births preceded by a firstborn girl	0.461
W	Pre-ultrasound EFM due to son preference	
	(coefficient of *Firstborn girl* * *Female*)	0.021
Z	Decline in EFM due to ultrasound access	
	(coefficient of *Firstborn girl* * *Female* * *Post1*)	-0.013
W + Z	Post-ultrasound EFM	0.008

	B. Estimate of Substitution	Pre-ultrasound (1)	Post-ultrasound (2)
A	Number of births in India (UN Statistics Division, 1997)	27,300,000	
B	Fraction of births preceded by a firstborn girl	0.334	
C	Number of births preceded by a firstborn girl (= A * B)	9,118,200	
D	Fraction of females in births preceded by a firstborn girl	0.479	0.461
E	Fraction of males in births preceded by a firstborn girl (= 1 - D)	0.521	0.540
F	Number of male births preceded by a firstborn girl (= E * C)	≈ 4,750,582	≈ 4,919,268
G	Hypothetical number of female births given the observed		
	number of male births preceded by a firstborn girl (= (0.49/0.51) * F)	≈ 4,564,284	≈ 4,726,356
H	Actual number of female births preceded by a firstborn girl (= C * D)	≈ 4,367,617	≈ 4,198,931
I	Number of "missing" girls (G - H)	≈ 196,667	≈ 527,425
J	EFM (post-neonatal child)	0.021	0.008
K	Number of postnatal female deaths (= H * J)	≈ 91,719	≈ 33,675
L	Increase in sex-selective abortions / Decrease in EFM (= Δ I / Δ K)	5.70	

NOTES: Unless otherwise stated, all statistics are calculated from the sample of 503,316 births used in the mortality regressions. The coefficient Y is obtained from the following specification that estimates the impact of ultrasound access on the sex ratio at birth (results in Appendix Table B.12): $G_{ibjt} = \alpha + \beta_1 F_i + \beta_2 F_i * Post_t^1 + \beta_3 F_i * Post_t^2 + X_{ijt}^{'}\tau + \Pi'\gamma + \epsilon_{ibjt}$, where G_{ibjt} indicates that child i of birth order b born to mother j in year t is female; F_i indicates that the firstborn is a girl; $X_i'\tau$ is a vector of household characteristics and $\Pi'\gamma$ is a vector of fixed effects that are analogous to equation (1), except that all interactions with F_i are omitted. Post-ultrasound refers to the late diffusion period (1995-2005).

A Data Appendix

- Excess Female Mortality: Female mortality - Male mortality
- Neonatal mortality: Death within one month of birth
- Post-neonatal infant mortality: Death during 2-12 months of birth
- Post-neonatal child mortality: Death after the first month of birth but before age five
- $Post_t^1$: indicator variable for $t \in 1985 - 1994$
- $Post_t^2$: indicator variable for $t \in 1995 - 2005$
- F_i: child i is female
- G_j: first child of mother j is female
- $Ultra_{st}$: percentage of births in state s and year t for which the mother reports getting an ultrasound test at some point during the pregnancy
- Education categories: no education, incomplete secondary education, and secondary or higher education
- Categories for mother's birth cohort: 1942-1960, 1961-1970, and 1971-1987
- Categories for Mother's age at birth: 12-15 years, 16-18 years, 19-24 years, 25-30 years, and 31-49 years
- Caste categories: Scheduled Castes (SC), Scheduled Tribes (ST), and Others
- Religion categories: Hindus, Muslims, and Others

B Additional Figures and Tables

Table B.1: Sample means: Mortality by period

	(1) Male	(2) Female	(3) EFM
1. Pre-ultrasound: 1973-1984			
Neonatal	6.686	5.395	-1.291
Post-neonatal Infant	3.523	4.128	0.605
Post-neonatal Child	6.040	7.539	1.499
N	61,085	56,333	
2. Post-ultrasound: 1985-1994			
Neonatal	5.259	4.469	-0.790
Post-neonatal Infant	2.516	2.949	0.433
Post-neonatal Child	4.333	5.265	0.932
N	126,126	117,218	
3. Post-ultrasound: 1995-2005			
Neonatal	4.066	3.601	-0.465
Post-neonatal Infant	1.681	1.844	0.163
Post-neonatal Child	2.513	3.027	0.514
N	74,217	68,337	

NOTES: This table reports the percentage of second- and higher-order children, by child's gender, who suffered from neonatal, post-neonatal infant, or post-neonatal child mortality over the three time-periods in our sample. Column (3) reports the difference between the mortality numbers in columns (1) and (2).

Table B.2: Age Distribution of Missing Girls in 2000

Age group	No. missing (in 000s)			% of all missing women			% of under-5 missing girls	
	India	China		India	China		India	China
	(1)	(2)	(3)	(4)	(5)	(6)		
At birth	184	644		11%	37%		37%	83%
0-1	146	109		9%	6%		30%	14%
1-4	164	23		10%	1%		33%	3%
< 5	494	776		29%	45%			
5-14	93	2		5%	0%			
≥ 15	1125	947		66%	55%			
Total	1712	1727						

NOTES: This table is based on Anderson and Ray (2010) and reports the number of missing girls for various age groups (columns (1) and (2), missing girls as a percentage of all missing women (columns (3) and (4)), and missing girls across age groups as a percentage of all under-5 missing girls (columns (5) and (6)), separately for India and China.

Table B.3: Sample means, NFHS

	1973-1984		1985-1994		1995-2005	
	First boy	First girl	First boy	First girl	First boy	First girl
	(1)	(2)	(3)	(4)	(5)	(6)
Number of children	2.91	3.12	2.13	2.22	1.85	1.96
N (Mothers)	14,095	10,690	25,857	22,169	23,480	22,372
N (Births)	84,258	33,160	160,278	83,066	90,700	51,854
Female	0.48	0.48	0.48	0.48	0.49	0.47
Rural	0.69	0.70	0.68	0.71	0.63	0.67
Hindu	0.77	0.77	0.75	0.75	0.71	0.71
Muslim	0.11	0.12	0.13	0.14	0.15	0.16
SC	0.14	0.14	0.16	0.17	0.18	0.19
ST	0.12	0.13	0.14	0.14	0.16	0.16
Mother birth cohort:						
1942-1960	0.60	0.73	0.11	0.19	0.01	0.01
1961-1970	0.40	0.27	0.62	0.67	0.17	0.28
1971-1987	0.00	0.00	0.28	0.14	0.82	0.71
Mother's age at birth:						
12-15	0.09	0.01	0.06	0.01	0.03	0.00
16-18	0.26	0.12	0.20	0.08	0.15	0.06
19-24	0.49	0.56	0.49	0.49	0.49	0.44
25-30	0.15	0.27	0.20	0.33	0.25	0.37
31-49	0.02	0.04	0.05	0.09	0.08	0.13
Mother's education:						
No education	0.61	0.63	0.56	0.62	0.43	0.53
Incomplete secondary	0.34	0.34	0.36	0.33	0.43	0.38
Secondary or higher	0.05	0.03	0.08	0.06	0.14	0.08
Father's education:						
No education	0.33	0.34	0.31	0.33	0.25	0.30
Incomplete secondary	0.51	0.52	0.51	0.50	0.56	0.55
Secondary or higher	0.17	0.14	0.19	0.16	0.19	0.15
Household wealth:						
2nd quintile	0.15	0.14	0.17	0.17	0.18	0.21
3rd quintile	0.18	0.19	0.17	0.18	0.18	0.19
4th quintile	0.21	0.22	0.21	0.21	0.21	0.20
Richest quintile	0.22	0.21	0.20	0.17	0.21	0.16
Child can read and write	0.80	0.79	0.81	0.79	0.73	0.71
Child still in school	0.52	0.62	0.77	0.79	0.70	0.69
N	51,484	20,531	67,794	32,749	26,379	14,475
Full immunization			0.39	0.35	0.51	0.45
N			19,154	11,398	31,127	18,130
Number of months breastfed			13.04	13.34	13.64	14.10
N			19,871	12,057	32,324	19,228
Number of antenatal checks			2.62	2.11	3.75	3.07
N			23,571	13,865	34,197	20,892

NOTES: SC and ST denote Scheduled Castes and Scheduled Tribes. Number of children refers to fertility at the time of survey.

Table B.4: Sample means, 1999 REDS

Variable	1973-1984 First boy	1973-1984 First girl	1985-1994 First boy	1985-1994 First girl	1995-1999 First boy	1995-1999 First girl
Female	0.44	0.47	0.46	0.47	0.47	0.45
SC	0.13	0.14	0.14	0.16	0.15	0.16
ST	0.07	0.06	0.08	0.07	0.09	0.08
OBC	0.35	0.39	0.35	0.34	0.35	0.34
Hindu	0.88	0.90	0.87	0.91	0.89	0.90
Muslim	0.08	0.06	0.09	0.06	0.07	0.07
Sikh	0.03	0.03	0.03	0.02	0.03	0.02
Christian	0.01	0.00	0.01	0.00	0.01	0.01
Mother's age at birth	24.12	26.31	23.62	26.03	23.72	26.21
Mother is literate	1.52	1.49	1.47	1.47	1.36	1.43
Father's years of education	5.23	5.54	5.83	5.71	6.93	6.15
At least one vaccine	0.73	0.70	0.88	0.89	0.93	0.94
N (Births)	5,788	1,962	6,440	2,744	2,960	1,268
Breastfed	0.99	0.99	0.99	0.99	0.77	0.79
No. of months breastfed	18.88	19.07	18.34	18.32	12.66	13.39
N (Births)	2,674	1,021	3,969	1,846	2,765	1,209
Breastfed at least 12 months	0.90	0.90	0.88	0.89	0.71	0.75
N (Births)	2,674	1,021	3,969	1,846	2,332	976
Breastfed at least 24 months	0.40	0.40	0.36	0.35	0.26	0.29
N (Births)	2,674	1,021	3,969	1,846	1,820	780
Breastfed at least 36 months	0.07	0.08	0.07	0.05	0.03	0.05
N (Births)	2,674	1,021	3,969	1,846	1,217	527
Expense on illness (last year)	160.78	227.01	168.16	152.01	216.64	184.66
N (Births)	192	643	6,253	2,665	2,877	1,240

NOTES: SC, ST, and OBC denote Scheduled Castes, Scheduled Tribes, and Other Backward Classes. The sample is restricted to children who were alive at the time of survey. Breastfeeding information is available only for a woman's last two children who were alive at the time of survey. Sample is restricted to children at least 12, 24, and 36 months old while calculating the proportion of children who were breastfed for 12, 24, and 36 months, respctively. Expenditure on illness is in Rupees.

Table B.5: Effects on Excess Female Mortality

	Neonatal (1)	Post-neo Infant (2)	Infant (3)	Post-neo Child (4)	Child (5)
*Firstborn girl * Female*	1.352***	0.838***	2.071***	1.759***	2.897***
	(0.383)	(0.272)	(0.479)	(0.312)	(0.481)
*Firstborn girl * Female * Post1*	-0.682	-0.380	-0.984*	-0.955**	-1.491**
	(0.423)	(0.299)	(0.537)	(0.403)	(0.550)
*Firstborn girl * Female * Post2*	-0.891**	-0.372	-1.168***	-1.354***	-2.055***
	(0.359)	(0.240)	(0.409)	(0.361)	(0.467)
N	503,316	478,843	503,316	478,843	503,316

NOTES: This table reports the coefficients from specification (1). The explanatory variables are the same as those in Column (3) of Table 2. Standard errors in parentheses are clustered by state. *** 1%, ** 5%, * 10%.

Table B.6: Prenatal and Postnatal Health Investments, NFHS

	# Antenatal Checks	At least 1 vaccination	Full immunization	# Months breastfed
	(1)	(2)	(3)	(4)
*Firstborn girl * Female*	-0.040	-0.029**	-0.033***	-0.420**
	(0.059)	(0.012)	(0.011)	(0.155)
*Firstborn girl * Female * Post2*	0.001	0.025**	0.017	0.137
	(0.060)	(0.012)	(0.017)	(0.258)
N	92,525	79,809	79,809	83,480

NOTES: Due to data limitations, the sample used in this table does not cover the pre-ultrasound period, restricting us to a comparison of outcomes across the two post-ultrasound periods. The estimates are from the following specification for child i of birth order b born to mother j in year t: $I_{ibjt} = \alpha + \beta G_j * F_i * Post^2_t + \gamma G_j * F_i + \omega_t G_j + \sigma_t F_i + \psi_b F_i + X^{'}_{ijt}\tau + \delta_s F_i + \rho_{bt} + \eta_{bs} + \phi_{st} + \epsilon_{ibjt}$. Among children who were at least 12 months old at the time of survey, we define a child to be fully immunized if he or she had received the eight most common vaccines by that time. Standard errors in parentheses are clustered by state. *** 1%, ** 5%, * 10%.

Table B.7: Self-reported Ultrasound Use

	Neonatal (1)	Post-neonatal Infant (2)	Post-neonatal Child (3)
*Firstborn girl * Female*	0.933**	0.736**	0.767*
	(0.336)	(0.284)	(0.376)
*Firstborn girl * Female * $Ultra_{st}$*	-1.238	-1.219	-1.022
	(0.875)	(0.862)	(1.038)
N	113,170	108,837	108,837

NOTES: This table reports the coefficients from a specification similar to (1) except that $Post_t^1$ and $Post_t^2$ have been replaced with $Ultra_{st}$. Each column is from a separate regression. The sample is restricted to years after 1995. *** 1%, ** 5%, * 10%.

Table B.8: Placebo test: Alternate Treatment Years

Dependent variable: Post-neonatal Child Mortality						
Treatment Year →	1977 (1)	1978 (2)	1979 (3)	1980 (4)	1981 (5)	1982 (6)
*Firstborn girl * Female*	2.046**	1.916**	1.981***	2.176***	2.288***	1.860***
	(0.879)	(0.791)	(0.659)	(0.609)	(0.600)	(0.424)
*Firstborn girl * Female *Post*	-0.272	-0.136	-0.228	-0.522	-0.802	-0.120
	(0.991)	(0.875)	(0.712)	(0.589)	(0.668)	(0.431)
N	110,295					

NOTES: This table presents coefficients from a specification similar to (1), except that a single *Post* indicator is used. The treatment year used to define *Post* varies across columns. Each column represents a different regression. The sample is restricted to the 1973-1984 period (i.e., pre-Ultrasound period). Standard errors in parentheses are clustered by state. *** 1%, ** 5%, * 10%.

Table B.9: Placebo test: Ideal Household Structure and Gender Gap in School Enrollment

	Neonatal (1)	Post-neo Child (2)	Neonatal (3)	Post-neo Child (4)
*Firstborn girl * Female*	1.354***	1.875***	1.262**	1.929***
	(0.378)	(0.387)	(0.456)	(0.365)
*Firstborn girl * Female * Post1*	-0.208	-0.764	-0.514	-0.948*
	(0.398)	(0.498)	(0.522)	(0.493)
*Firstborn girl * Female * Post2*	-0.508	-1.362***	-0.647	-1.643***
	(0.344)	(0.380)	(0.395)	(0.543)
*Ideal Fertility * Female*	-0.430***	-0.368***		
	(0.075)	(0.093)		
*Ideal Sex Ratio * Female*	1.226***	1.355***		
	(0.082)	(0.231)		
*6-11 Enrollment Gender Gap * Female*			0.167***	0.458***
			(0.052)	(0.074)
*11-14 Enrollment Gender Gap * Female*			3.274***	0.202
			(0.908)	(0.707)
N	400,035	380,605	364,989	345,078

NOTES: This table presents estimates from specification (1) with additional controls. Standard errors in parentheses are clustered by state. *** 1%, ** 5%, * 10%.

Table B.10: Mother's Fertility Preference and Son Preference

	Ideal No. of Boys (1)	Ideal No. of Girls (2)	Ideal Fraction of Sons (3)
*Firstborn girl * Female*	0.025	-0.046***	0.011***
	(0.016)	(0.013)	(0.003)
*Firstborn girl * Female * Post1*	-0.025*	0.004	-0.002
	(0.013)	(0.011)	(0.002)
*Firstborn girl * Female * Post2*	-0.024	0.005	0.001
	(0.017)	(0.013)	(0.003)
N	473,218	473,211	471,559

NOTES: This table presents estimates from specification (1) for three different dependent variables. Ideal fraction of sons = $\frac{ideal_{boys}+(0.5*ideal_{either})}{ideal_{kids}}$ if $ideal_{kids} > 0$, where $ideal_{boys}$ is the ideal number of boys, $ideal_{either}$ is the ideal number of children of either sex, and $ideal_{kids}$ is the ideal number of total children, as reported by a woman. Standard errors in parentheses are clustered by state. *** 1%, ** 5%, * 10%.

Table B.11: Effects on Excess Female Mortality: First birth before Ultrasound Access (1985)

	Neonatal (1)	Post-neo Infant (2)	Post-neo Child (3)
*Firstborn girl * Female*	1.184***	0.733**	1.791***
	(0.381)	(0.301)	(0.397)
*Firstborn girl * Female * Post1*	-0.969*	0.019	-0.492
	(0.553)	(0.357)	(0.516)
*Firstborn girl * Female * Post2*	-1.241	-1.285	-2.111*
	(1.524)	(0.934)	(1.091)
N	196,374	185,894	185,894

NOTES: This table reports the coefficients from specification (1) for the sample of women whose first child was born before 1985. The explanatory variables are the same as those in Column (3) of Table 2. Standard errors in parentheses are clustered by state. *** 1%, ** 5%, * 10%.

Table B.12: Effect on the Sex Ratio at Birth

Dependent Variable: Child is Female	
Firstborn girl	-0.002
	(0.004)
*Firstborn girl * Post1*	-0.008*
	(0.005)
*Firstborn girl * Post2*	-0.018***
	(0.006)
N	503,316

NOTES: This table reports the coefficients from the following specification: $G_{ibjt} = \alpha + \beta_1 F_i + \beta_2 F_i * Post^1_t + \beta_3 F_i * Post^2_t + X^{'}_{ijt}\tau + \Pi'\gamma + \epsilon_{ibjt}$, where G_{ibjt} indicates that child i of birth order b born to mother j in year t is female; F_i indicates that the firstborn is a girl; $X'_i\tau$ is a vector of household characteristics and $\Pi'\gamma$ is a vector of fixed effects that are analogous to equation (1), except that all interactions with F_i are omitted. Standard errors in parentheses are clustered by state. *** 1%, ** 5%, * 10%.

Table B.13: Effects on Children's Educational Attainment

	Can read & write	Attending school
*Firstborn girl * Female*	-0.013	-0.013
	(0.008)	(0.008)
*Firstborn girl * Female * Post1*	0.003	0.004
	(0.008)	(0.009)
*Firstborn girl * Female * Post2*	0.002	0.010
	(0.013)	(0.011)
N	213,412	229,330

NOTES: In addition to the controls in specification (1), the regressions in this table also include fixed effects for child's age in the survey year. The sample is restricted to children at least age 5. Standard errors in parentheses are clustered by state. *** 1%, ** 5%, * 10%.

Table B.14: Sample means: Gaps between Actual and Ideal Fertility and Fraction of Sons

	(1) Actual	(2) Ideal	(3) Actual - Ideal
1. Pre-ultrasound: 1973-1984			
Fertility	2.96	2.21	0.75
Fraction of Sons	0.58	0.57	0.01
N			
2. Post-ultrasound: 1985-1994			
Fertility	2.16	2.17	-0.01
Fraction of Sons	0.55	0.56	-0.01
N			
3. Post-ultrasound: 1995-2005			
Fertility	1.91	1.93	-0.03
Fraction of Sons	0.53	0.55	-0.02
N			

NOTES: This table reports the percentage of second- and higher-order children, by child's gender, who suffered from neonatal, post-neonatal infant, or post-neonatal child mortality over the three time-periods in our sample. Column (3) reports the difference between the mortality numbers in columns (1) and (2).

C Contributions of Breastfeeding and Vaccination

Our estimates suggest that ultrasound access reduced post-neonatal child mortality by 2.215 p.p. (column (4) of Table 2) and increased the likelihood of being breastfed for at least 24 months by 11.9 p.p. to 17.8 p.p. (triple-interaction coefficients in column (6) of Panel B in Table 3). Since there was no significant effect on breastfeeding during the first year of birth, we assume that the 11.9 p.p. to 17.8 p.p. increase took place between 12 and 24 months from birth. According to the World Health Organization (2000), breastfeeding between the ages one and two decreases mortality by 50% relative to no breastfeeding. Applying this factor to the share of children who are being breastfed and the mortality rate during 12-24 months,[41] the implied mortality rate for breastfed children is 1.35%[42] and is 2.7% (1.35 * 2 = 2.7) for non-breastfed children in the 12-24 months range. This implies that not being breastfed during the 12-24 months age range increases the risk of mortality by 1.35 p.p. (2.7 - 1.35 = 1.35). If breastfeeding disparities (during 12-24 months) were the only cause of post-neonatal child mortality differences by gender, the EFM decline due to improvements in the breastfeeding gender gap would be 0.16 p.p. (0.119 * 1.35 = 0.161) to 0.24 p.p. (0.178 * 1.35 = 0.240). Thus breastfeeding explains about 7% (0.16/2.215 = 0.072) to 11% (0.24/2.215 = 0.108) of the estimated EFM decline.

Moreover, we find that ultrasound availability increased the probability of a child receiving at least one vaccination by 0.079 to 0.095 (triple-interaction coefficient in column (6) of Panel A in Table 3). The average number of vaccinations (conditional on receiving at least one vaccination) for girls preceded by a firstborn girl during the early diffusion period is 6.64 in NFHS data. Thus the estimated effects for at least one vaccination translate into an average increase in the number of vaccinations of 0.525 (6.64 * 0.079 = 0.525) to 0.631 (6.64 * 0.095 = 0.631). Oster (2009) suggests that each vaccination reduces mortality during ages 1 to 4 by 0.26 p.p.. Thus the implied effect on EFM through vaccination is 0.137 p.p. (0.26 * 0.525 = 0.137) to 0.164 p.p. (0.26 * 0.631 = 0.164), which translates into 6.2% (0.137/2.215 = 0.062) to 7.4% (0.164/2.215 = 0.074) of the decline in EFM.

Note that the mortality measure is 12-36 months in Jayachandran and Kuziemko (2011) and is 1-4 years in Oster (2009). However, any exogenous change in these mortality measures would generate an almost one-to-one change in the mortality measure we use, i.e., death during 1 month to 5 years of birth.

[41] We assume that the share of children who are being breastfed and the mortality rate during 12-24 months are the same as those for 12-36 months used in Jayachandran and Kuziemko (2011).

[42] Solving $0.481x + 2(1 - 0.481)x = 2.05$ yields $x = 1.35$.

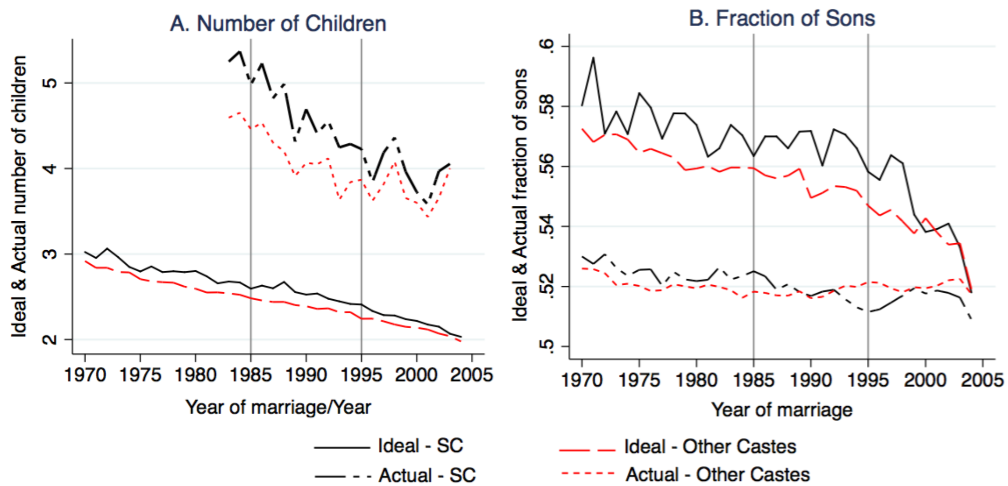
D Magnitude of Substitution

During the pre-ultrasound period, the fraction of females in births preceded by a firstborn girl was 47.9%. Ultrasound access decreased this fraction by 1.9 p.p..[43] The increase in the sex ratio at birth is accompanied by a decrease in post-neonatal excess female child mortality from a pre-ultrasound level of 2.1% to 0.8%. Approximately, 22,700,000 children were born in India during 1997; assuming the same number of annual births in the pre-ultrasound period and using the fraction of births preceded by a firstborn girl in our pre-ultrasound sample implies that 7,581,800 births should be preceded by a firstborn girl each year in the absence of sex-selection technology. Multiplying this number with the fraction of females among births preceded by a firstborn girl before and after ultrasound access shows that the number of female births preceded by a firstborn girl decreased approximately from 3,631,682 to 3,491,419 due to ultrasound access. Had there been no sex-selection, the hypothetical number female births preceded by a firstborn girl given the observed number of male births preceded by a firstborn girl should have been 3,795,211 and 3,929,974 in the two periods. Thus, the number of "missing girls" increased from 163,529 to 438,555 per year due to ultrasound access. The estimated decline in EFM, on the other hand, implies that the annual number of postnatal female deaths by age 5 fell from 76,265 to 28,001. The ratio of increase in sex-selective abortions and the decrease in EFM is 5.7, i.e., for every 5.7 girls aborted, one girl survived due to access to ultrasound technology.

[43] This number is derived from a regression specification similar to the one estimated by Bhalotra and Cochrane (2010). These results are reported in Table B.12.

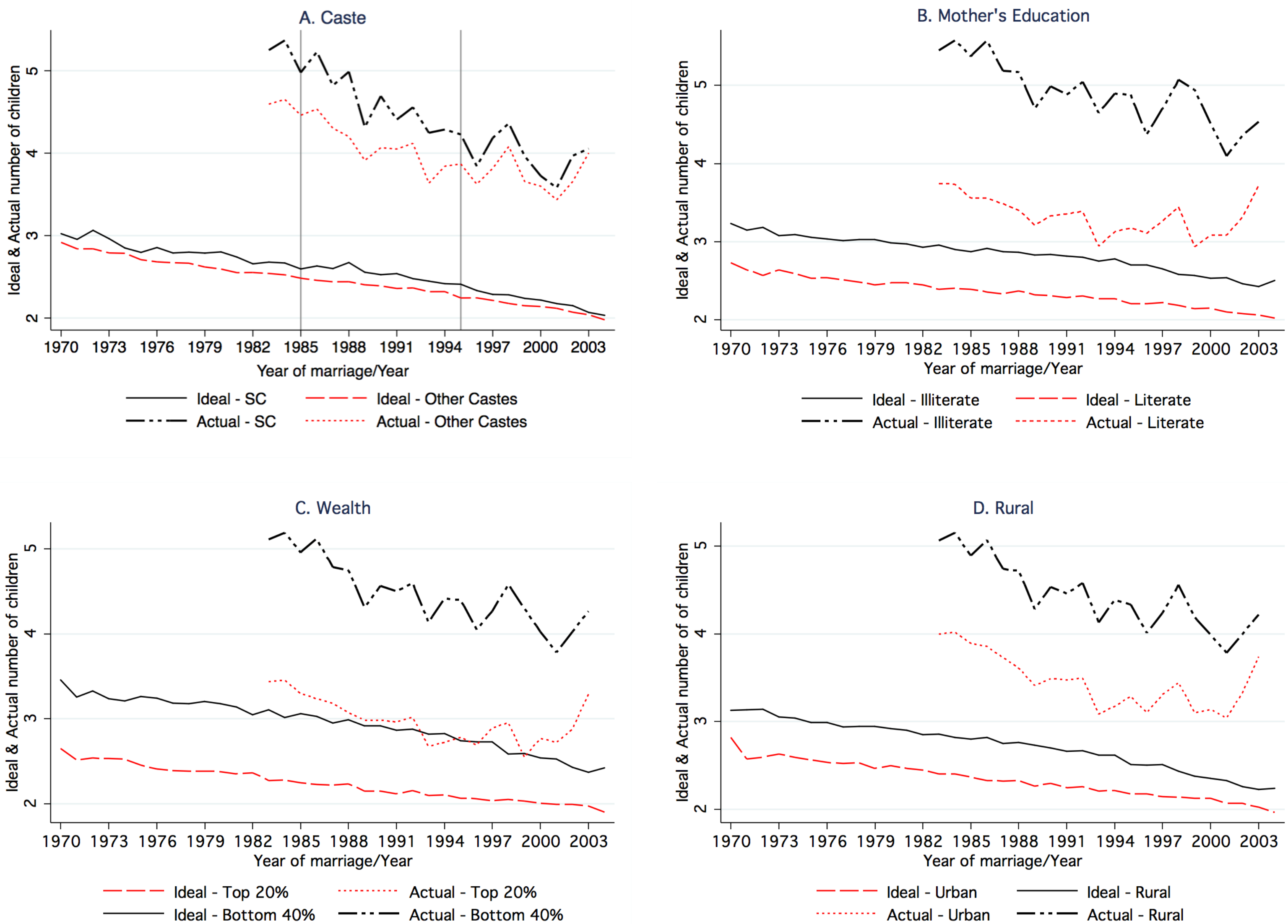
E ONLINE APPENDIX

Figure E.1: Trends in Ideal and Actual Number of Children and Fraction of Sons, by Caste



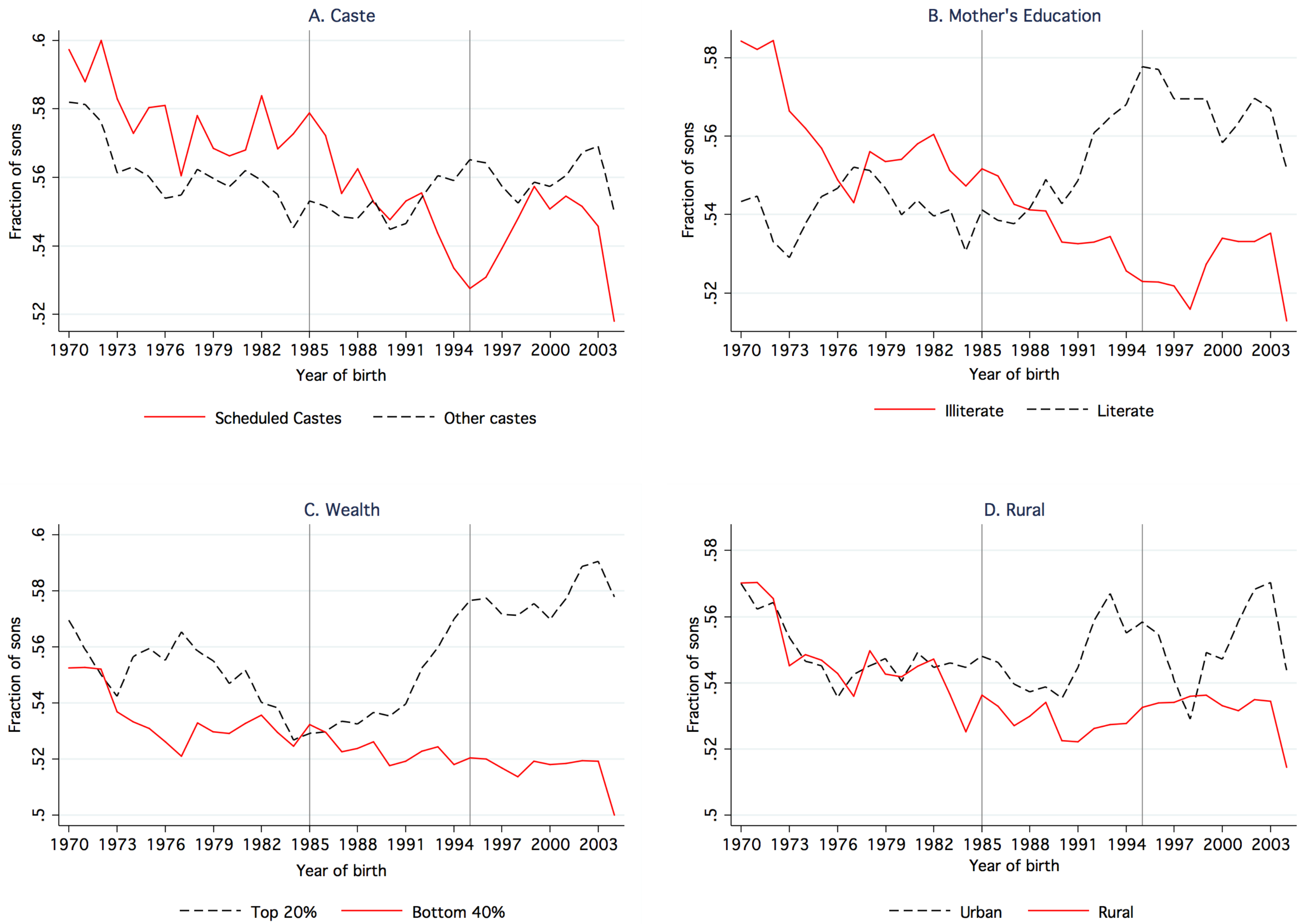
NOTES: Ideal number of children refers to the mother's desired number of children over her lifetime.

Figure E.2: Trends in Ideal & Actual Number of Children



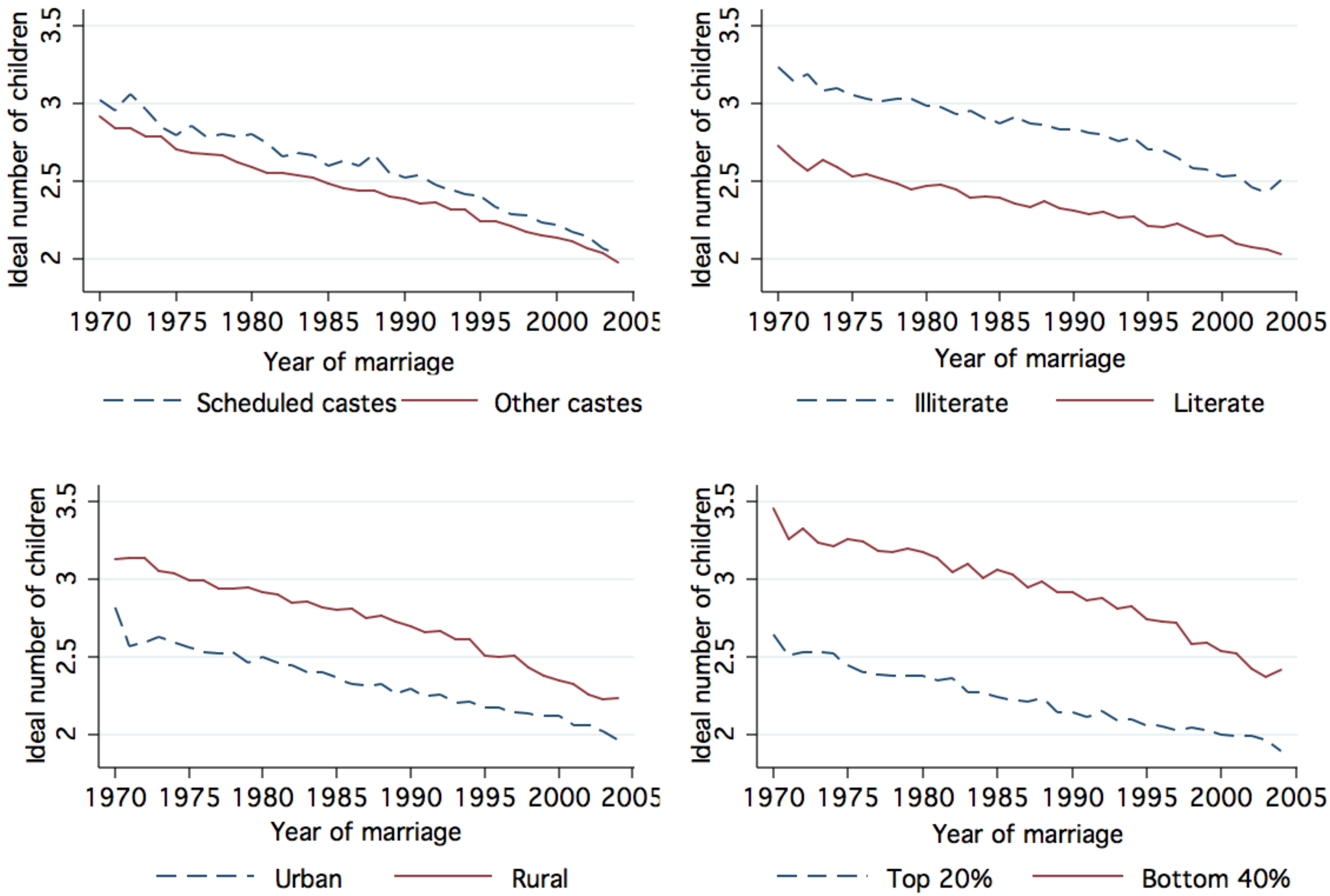
NOTES: Ideal number of children refers to the mother's desired number of children over her lifetime.

Figure E.3: Trends in Fraction of Sons



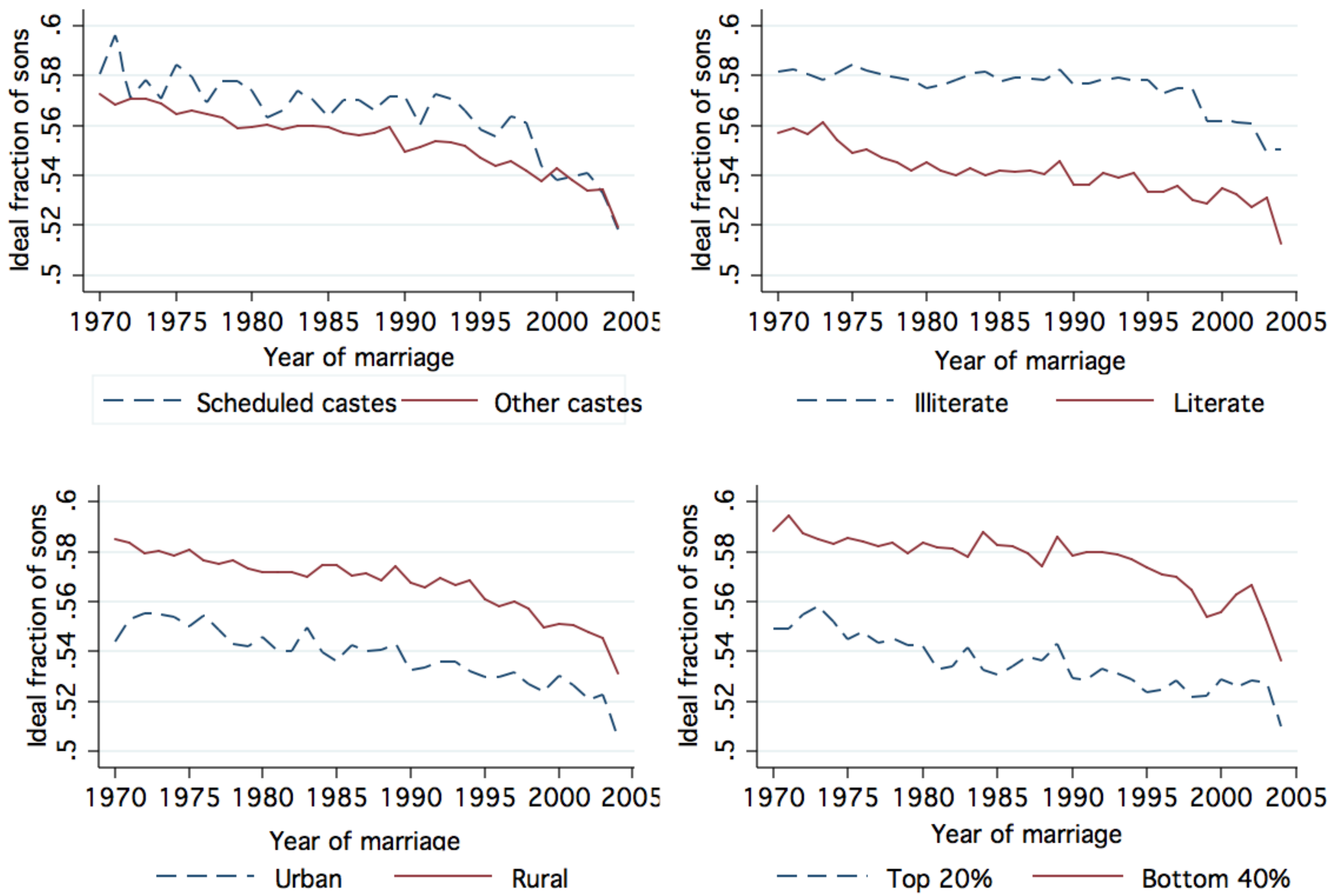
NOTES:

Figure E.4: Trends in Ideal Number of Children



NOTES:

Figure E.5: Trends in Ideal Fraction of Sons



NOTES: