Birth Spacing and Fertility in the Presence of Son Preference and Sex-Selective Abortions: India's Experience Over Four Decades*

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Abstract

Following the arrival of prenatal sex-determination technologies in the mid-1980s, India has experienced an increasingly male-biased sex ratio at birth, presumably from sex-selective abortions. Abortions lengthen birth intervals, but we know little about how birth spacing has changed or the effects of these changes. This paper shows that, although the length of birth intervals increased overall, well-educated women with no sons had the most substantial lengthening—and the most male-biased sex ratios. Furthermore, most of these changes took place immediately after the introduction of prenatal sex-determination technologies. Consequently, some women without sons now have longer birth intervals than those with sons, reversing India's traditional spacing pattern. Less-educated women continue short birth spacing when they have no sons, with only limited evidence of male-biased sex ratios. Because of the rapid lengthening of birth intervals, period fertility rates substantially overestimated how fast cohort fertility fell. Moreover, predicted cohort fertility is still 10%–20% above the period fertility rate. If lengthening of birth intervals arise from repeated abortions, the associated short pregnancy spacing may counteract any positive effects of longer birth spacing. There is, however, no evidence of this effect on infant mortality. Finally, judging from sex ratios, sex-selective abortion use is not declining.

JEL: J1, O12, I1

Keywords: India, prenatal sex determination, censoring, competing risk, nonproportional hazard

1 Introduction

India has experienced many positive changes over the past four decades: The economy has grown substantially, real wages have more than doubled, educational attainment has increased for males and females, and the total fertility rate has fallen to 2.2 children (Bosworth and Collins, 2008; Dharmalingam, Rajan and Morgan, 2014; Klasen and Pieters, 2015; International Institute for Population Sciences (IIPS) and ICF, 2017).

However, India also witnessed the advent of sex selection—the selective abortion of female fetuses based on prenatal sex determination—with the introduction of ultrasound in the mid-1980s. Combined with a strong, continued preference for sons, the result was a dramatic increase in the male–female ratio at birth (Das Gupta and Bhat, 1997; Arnold, Kishor and Roy, 2002; Retherford and Roy, 2003; Guilmoto, 2012; Pörtner, 2015; Jayachandran, 2017).

The main question I address here is how birth spacing responded to these changes, especially the spread of sex selection. The motivation is twofold. First, past research has failed to appreciate that the use of sex-selective abortions could substantially increase birth spacing. As detailed below, after an abortion it takes 6 months or more to reach the same point in the next pregnancy. Second, other major societal changes, such as women's greater educational attainment, higher household income, and a low and declining female labor force participation, all likely influence birth spacing. The combination of the apparent increasing use of sex selection and societal changes can significantly impact birth spacing, but we know little about how much.

Studying birth spacing contributes to our understanding of fertility decisions, but, equally important, birth spacing also affects the reliability of our fertility measures and may affect mortality. Therefore, I address two additional questions.

First, did changes in birth spacing lead us to overestimate the decline in cohort fertility? With longer spacing, mothers will be older at each parity, and this tempo effect makes period fertility measures, such as the total fertility rate, downward-biased estimates of cohort fertility (Hotz, Klerman and Willis, 1997; Bongaarts, 1999; Ní Bhrolcháin, 2011). Hence, a rapidly expanding use of sex selection could make the total fertility rate—our most used fertility measure—fall substantially faster than cohort fertility. In this case, households' fertility may be higher than generally accepted.

Second, what is the relationship between infant mortality and the changes in birth spacing and sex selection? In India, birth intervals have traditionally been shorter with fewer sons, contributing to girls' higher mortality risk (Whitworth and Stephenson, 2002; Bhalotra and van Soest, 2008; Maitra and Pal, 2008; Jayachandran and Kuziemko, 2011; Jayachandran and Pande, 2017). Therefore, longer birth spacing may reduce mortality through, for example, diminished sibling competition (Conde-Agudelo, Rosas-Bermudez, Castaño and Norton, 2012; Molitoris, Barclay and Kolk, 2019). However, if the spacing between births lengthens because of sex-selective abortions, the spacing between pregnancies may still be very short. Short pregnancy spacing may lead to worse child outcomes because of maternal nutritional depletion and insufficient time to recover from the previous pregnancy. Hence, children born after long birth intervals where multiple abortions have punctuated those intervals may not see the same benefits as children born after a long interval that is not punctuated by abortions.

To investigate how birth spacing has changed, I use a competing risk hazard model with two exit states: The birth of a girl or the birth of a boy. I apply the model to Hindu women's birth histories covering 1972–2016 using data from the four National Family and Health Surveys (NFHS).

The primary outcomes I examine are the 25th, 50th, and 75th percentile birth intervals durations; the sex ratio at birth; and the likelihood of giving birth. I estimate the model across four periods to capture the changing access and legality of sex selection. The key explanatory variables are maternal education, the sex of previous children, and the area of residence.

The empirical model allows me to predict cohort fertility. To examine whether tempo effects bias our standard fertility measures, I compare the predicted cohort fertility with fertility calculated from age-specific fertility rates.

I use the same data to study how infant mortality changed with birth spacing and the increasing use of sex selection. The key explanatory variables remain the same, except for the addition of birth spacing and the sex of the index child.

There are three main results.

First, birth intervals lengthened over the four decades, with the lengthening longer, the higher the parity, the more educated the woman, and the higher the percentile of the birth interval duration. Well-educated women with no sons had the most substantial lengthening of birth intervals and the most male-biased sex ratios, both likely arising from sex-selective abortions. Consequently, some women with no sons now have *longer* birth intervals than those with sons, reversing India's traditional spacing pattern. Less-educated women continued to have short spacing when they have girls, with only limited evidence of male-biased sex ratios. The likelihood of a very short birth interval changed little across most groups.

Second, the period fertility rate substantially overestimated how fast cohort fertility fell in the 1990s and early 2000s as spacing initially increased. Although the two have lately been converging, the predicted cohort fertility is still 10%–20% higher than the period fertility rate. Furthermore, predicted cohort fertility is still at or above replacement level for all but the best-educated urban women.

Finally, infant mortality has declined substantially over time for all groups, but fastest for the less educated, who are now close to the level of the best-educated women. However, mortality is still inversely related to education level, especially for very short birth intervals. There is no evidence that repeated sex-selective abortions are associated with higher mortality for the child eventually born.

2 Conceptual Framework

This section provides a conceptual framework for understanding changes in birth spacing. I first introduce three potential explanations that link fertility and birth spacing decisions: economic conditions, investment in children, and son preference (Casterline and Odden, 2016; Pörtner, 2018). Next, I discuss why female education, area of residence, and sex composition are the principal factors in the empirical analyses and tie them to the three explanations.

The improvements in economic condition, especially the doubling of real wages, are likely to affect fertility, although the direction is ambiguous; empirically, higher female wages reduce fertility, whereas higher male wages increase fertility (Hotz et al., 1997; Schultz, 1997). According to economic theory, the substitution and income effects' relative strengths determine the effect of higher wages on fertility. The substitute effect captures that when wages increase, time becomes more expensive, and people, therefore, work more and spend less time on non-wage earning activities, such as children or leisure. The income effect captures that higher wages increase the available income, which leads people to spend more time on time-intensive activities and less time working. Because women spend substantially more time on childrearing than men, the substitution effect dominates for women while the income effect dominates for men.

Higher female wages may also shorten birth spacing if having children requires mothers to curtail their economic activities. Shortening birth spacing allows parents to take advantage of economies of scale in childrearing—for example, looking after two children requires less than double the time needed for one child (Vijverberg, 1982; Hotz et al., 1997).

With increasing returns to education and lower offspring mortality, parents are likely to reduce fertility and invest more in each child (Rosenzweig and Schultz, 1982; Wolpin, 1997). The higher return to education means a stronger incentive to invest in their children's education, thereby increasing the cost of having children and lowering fertility. With lower expected mortality, parents need fewer births to reach the desired number of surviving children, which, in turn, allows parents to invest more in each child.

An increased desire to invest in children may also lengthen birth spacing. The clearest example of a positive effect of longer spacing is for health, as very short spacing—approximately 24 months or less—leads to worse child health and mortality outcomes (Whitworth and Stephenson, 2002; Conde-Agudelo et al., 2012). Whether longer spacing also improves human capital outcomes is more speculative with mixed evidence for developed countries and no evidence for developing countries (Zajonc, 1976; Powell and Steelman, 1993; Pettersson-Lidbom and Thoursie, 2009; Buckles and Munnich, 2012; Barclay and Kolk, 2017).

Stronger son preference has traditionally been associated with shorter spacing and worse health outcomes for daughters when there no sons in the household (Whitworth and Stephenson, 2002; Jayachandran and Kuziemko, 2011). Although son preference increases average fertility only marginally, differential stopping behavior means that girls tend to end up in larger families, resulting in fewer resources per child (Repetto, 1972; Clark, 2000; Basu and De Jong, 2010; Barcellos, Carvalho and Lleras-Muney, 2014).

However, with the advent of sex selection, stronger son preference may lead to longer spacing because each sex-selective abortion adds 6–12 months to the length of the birth interval. After an abortion, the uterus needs at least two menstrual cycles—approximately two months—to recover, or the subsequent risk of spontaneous abortion increases substantially (Zhou, Olsen, Nielsen and Sabroe, 2000). Once conception can be attempted, the waiting time to conception is likely between one and six months. Finally, sex-determination tests are reliable only from three months of gestation. Hence, it takes at least six months before the couple is at the same point in the next pregnancy as they were in the prior pregnancy when they decided to abort.

The closest available proxies in the data for capturing the explanations linking fertility and birth spacing are the sex composition of previous children, mothers' education, and area of residence. The remainder of the section discusses how the three variables fit into the explanations and the predicted effects.

Sex composition proxies for son preference and the use of sex selection, both unobserved.[1] In the absence of sons, sex selection appears to increase with lower desired fertility and higher parity (Pörtner, 2015; Jayachandran, 2017). Thus, for a given parity, birth intervals should lengthen substantially over time for women with no sons, lower desired fertility, and better access to sex selection.

Both higher female education and urbanization are associated with lower fertility and increased sex selection use, and, therefore, likely also changes in birth spacing (Das Gupta and Bhat, 1997; Retherford and Roy, 2003; Pörtner, 2015). Furthermore, both variables are representative of the tremendous changes in India. Figure 1 shows the substantial increase in female education, and the urban proportion of the population almost doubled from 18% in 1960 to 35% in 2019 (United Nations, 2019).

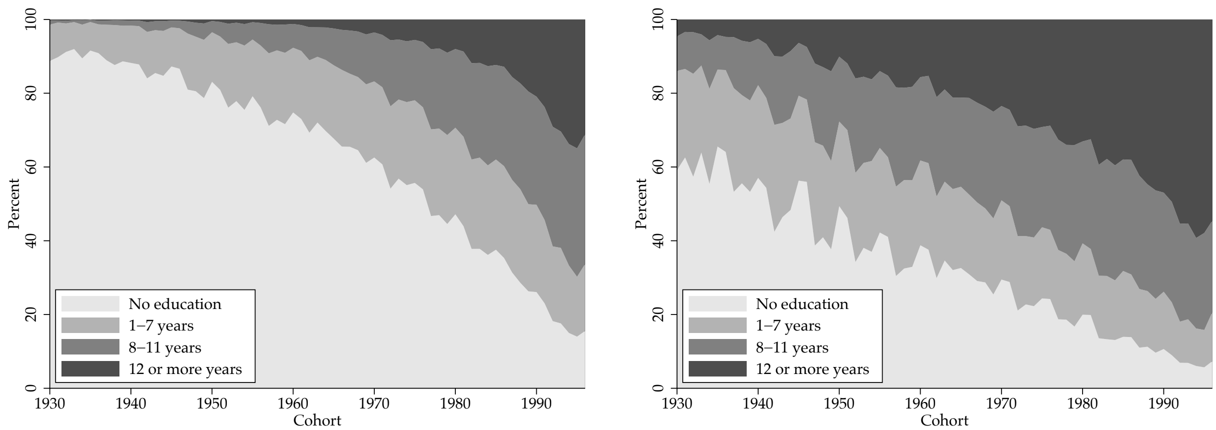
Urban women are likely to have lower fertility and higher use of sex selection than women in rural areas. The lower fertility results from the higher cost of children and lower child mortality risk in urban compared to rural areas.[2] The higher use of sex selection comes partly from the lower fertility and partly from higher income and better access to health care facilities in urban areas.

Even though higher potential wages from more education should shorten birth spacing and lower fertility, the low and declining female labor force participation suggests little economic incentive to space children closer together. Even as women's education increased, their labor force participation stagnated or decreased and is now one of the lowest outside the Middle East (Klasen and Pieters, 2015; Fletcher, Pande and Moore, 2017; Afridi, Dinkelman and Mahajan, 2018; Bhargava, 2018; Chatterjee, Desai and Vanneman, 2018).

The decline in female labor force participation appears to be driven by a combina-

[1]The surveys ask about the ideal number of sons and daughters, but these appear to be unreliable son preference indicators; better-educated women simultaneously show declining son preference and increasing sex selection (Bhat and Zavier, 2003; Pande and Astone, 2007).

[2]However, holding parental education constant, children in Indian slums have worse health outcomes than children in rural areas (Pörtner and Su, 2018).



(a) Rural

(b) Urban

Figure 1: Distribution of education by cohort for women 20 years or older using the four rounds of the NFHS

tion of a relatively small expansion in the sectors where women work and the income effect from rapidly increasing male wages and education dominating the substitution effect from higher female wages (Klasen and Pieters, 2015; Bhargava, 2018). The income effect can dominate because not only do men have a higher average level of education than women, men are also paid more than women for a given level of education, and the returns to education increases with education in India (Agrawal, 2011). Hence, increasing male education will result in a larger increase in income than a similar increase in female education.

However, higher female education might still be associated with lower fertility and more sex selection, provided better-educated women are better at producing child human capital, as suggested by Behrman, Foster, Rosenzweig and Vashishtha (1999). In a situation with increasing returns to male education, households may desire better-educated women because of their ability to produce better-educated sons, rather than because of their higher potential income. The higher return to male education provides an additional incentive to invest in sons' education—with a better-educated mother one such investment—and leads to lower desired fertility, makes sex selection more likely, and possibly increases birth spacing. The implication is that the usual policy recommendation of increased female education may not change sex selection unless there is a concurrent increase in the relative return to female education in the labor market.

Finally, the process of "Sanskritization" implies that as lower-caste females gain access to education, they adopt higher-caste norms such as stronger son preference and a retraction from the formal labor market (Srinivas, 1956). The declining female labor force participation suggests that this process still operates (Abraham, 2013; Chatterjee et al., 2018). Thus, although the expansion in female education will likely bring in groups who initially have different norms, we are unlikely to see substantial changes in how women with a given education level behave.

In summary, with substantial increases in husbands' income and a declining female labor force participation, I expect longer birth spacing over time, independent of education levels. Furthermore, birth spacing likely increases the most among the better educated as their household income increase the most, and because of their presumptive use of sex selection. Finally, "Sanskritization" implies that the changing composition of better-educated women will not substantially change the use of sex selection.

3 Estimation Strategy

The empirical analysis has three parts. First, I document the changes in birth spacing over time and how the introduction of sex selection influenced birth spacing. Second, I compare period fertility estimates with predicted cohort fertility based on the model of birth spacing. Finally, I examine how birth intervals affect infant mortality and whether the apparent increase in sex selection influenced mortality. This section presents the empirical model for my analysis of birth spacing.

The standard approach in the birth spacing literature is to use proportional hazard models with a single exit—the birth of a child—but there are two problems with the standard approach in this setting.[3]

First and foremost, the use of sex selection means that the sex of the next child is no longer random and that the spacing to the birth of a boy will differ from the spacing to a girl. Therefore, I use a competing risk setup that captures both the non-randomness of the birth outcome and the differential spacing.[4]

Second, even without sex selection, it is unlikely that characteristics, such as previous births' sex composition, have the same effects throughout the entire birth interval. The proportional hazard model requires that an individual's hazard is a fixed proportion of the hazard for any other individual. Nonconstant effects violate that assumption, and the results from a proportional hazard model would, therefore, be biased. The proportionality assumption is especially problematic for higher-order birth intervals because there are substantial differences across groups in the likelihood of progressing to the next birth and how soon couples want their next child if they are going to have one (Whitworth and Stephenson, 2002; Bhalotra and van Soest, 2008).

The introduction of prenatal sex determination exacerbates any bias from the proportionality assumption for two reasons. First, different groups have different levels of sex-selective abortion use and, thereby, birth spacing. Second, within a birth interval, a household's use of sex selection may vary, and that means that the effects of covariates vary as well.

Therefore, I use a nonproportional hazard specification that allows the shape of the hazard functions to vary across groups. Furthermore, the combination of a nonpropor-

[3]See Sheps, Menken, Ridley and Lingner (1970) and Newman and McCulloch (1984) for early discussions of why hazard models are the preferred way to deal with the censoring of birth intervals.

[4]Merli and Raftery (2000) used a discrete hazard model to examine whether there was underreporting of births in rural China, although they estimated separate waiting time regressions for boys and girls.

tional specification and a flexible baseline hazard mitigates the potential effects of unobserved heterogeneity (Dolton and von der Klaauw, 1995).

The model is a discrete-time, nonproportional, competing risk hazard model with two exit states: Either a boy or a girl is born. The unit of analysis is a spell—the period from one parity birth to the following birth or censoring. For estimation purposes, the spells begin nine months after the previous birth because this is the earliest we should expect to observe a new birth. Censoring can happen for three reasons: The survey takes place, sterilization of the woman or her husband, or imposed because of too few births for the method to work.

For each woman, $i = 1, \ldots, n$, the starting point for a spell is time $t = 1$, and the spell continues until time t_i, when either birth or censoring of the spell occurs. The time of censoring is assumed to be independent of the hazard rate, as is standard in the literature. The two exit states are the birth of a boy, $j = 1$, or a girl, $j = 2$.

The discrete-time hazard rate h_{ijt} is

$$h_{ijt} = \frac{\exp(D_j(t) + \alpha'_{jt}\mathbf{Z}_{it} + \beta'_j\mathbf{X}_i)}{1 + \sum_{l=1}^{2} \exp(D_j(t) + \alpha'_{lt}\mathbf{Z}_{it} + \beta'_l\mathbf{X}_i)} \quad j = 1, 2. \tag{1}$$

$D_j(t)$ is the piece-wise constant baseline hazard for outcome j, captured by dummies and the associated coefficients,

$$D_j(t) = \gamma_{j1}D_1 + \gamma_{j2}D_2 + \ldots + \gamma_{jT}D_T, \tag{2}$$

with $D_m = 1$ if $t = m$ and zero otherwise. This approach to modeling the baseline hazard is flexible and does not restrict the baseline hazard unnecessarily. $\mathbf{Z}$ is the nonproportional part, which includes the interactions between $D_j(t)$ and a set of explanatory variables and the interactions of those. The remaining explanatory variables, $\mathbf{X}$, enter proportionally.

Equation 1 is equivalent to the logistic hazard model and has the same likelihood function as the multinomial logit model (Allison, 1982; Jenkins, 1995). Hence, splitting spells into smaller intervals—here equal to three months—and treating them as observations, I can estimate the model using a standard multinomial logit model.

I use the model to predict birth interval lengths, parity progression probabilities, and the sex ratio rather than present coefficients because the interpretation of competing risk model coefficients is challenging (Thomas, 1996). The predicted parity progression probability is the likelihood of giving birth by the imposed censoring based on standard survival curve calculations averaged across all women in a given sample.

For birth interval lengths, I estimate a set of percentile durations. I first calculate for each woman when there is a given percentage chance that she will have given birth, conditional on the probability of giving birth in the spell. For example, with an 80% parity progression probability, the median birth interval is the predicted number of months before a woman passes the 60% $\left(100 - \frac{80}{2}\right)$ mark on her survival curve. I then add nine months to account for the start of the spell. The reported statistic is the average of a given percentile interval across all women in a given sample using the individual progression probabilities as weights.

The predicted sex ratio is the weighted average of individual predicted sex ratios, using parity progression probabilities as weights. To find the individual sex ratio, I estimate the percentage of births that are boys at t, conditional on not having had a child before t. Weighting the percent boys with the likelihood of exiting the spell with a birth across all t gives the predicted percentage of boys over the entire spell for an individual.[5]

4 Data

The data come from the four rounds of the NFHS collected in 1992–1993, 1998–1999, 2005–2006, and 2015–2016. The surveys are large: 89,777, 90,303, 124,385, and 699,686 women, respectively. NFHS-1 and NFHS-2 surveyed only ever-married women, while the two later

[5] Imagine $T = 2$. If 54% and 66% of births are boys and the likelihood of giving birth 20% and 40%, then the predicted sex ratio is $\frac{54*0.2+66*0.4}{0.2+0.4} = 62\%$ boys.

surveys included never-married.

I first discuss sample restrictions and their motivations, then introduce the potential issue of underreporting of female births and the imposed censoring of birth intervals. Next, I discuss how the analyses are split by periods to capture the introduction and changing legality in prenatal sex determination. Finally, I introduce the explanatory variables, split by whether they enter as proportional or nonproportional variables.

I focus on the three spells starting from the first birth and ending with the fourth birth. I exclude the interval from marriage to the first birth because many are imputed and the higher-order intervals because few women had five or more births, especially among the better-educated.

I restrict the sample to Hindus for two reasons. First, Hindus are the majority population group, about 80% of India's population. Second, the prior literature shows that son preference and sex selection vary substantially between Hindus and the second largest group, Muslims. Combining them and assuming that the baseline hazard is the same would lead to biased results. Because of space constraints and the relatively small number of observations once split by education and periods, I do not provide separate results for Muslims or any remaining groups, such as Sikhs, Jains, and Christians.

Finally, I exclude visitors and women in any of the following categories: Never married; no gauna yet; married more than once; divorced; not living with husband; inconsistent age at marriage; or education information missing. The same goes for women who had at least one multiple births, reported giving birth before age 12, had a birth before marriage, or had an interval between births of less than nine months.

In addition to the large number of women surveyed and the long period covered, a significant benefit of the NFHS over other surveys is that enumerators pay careful attention to the spacing between births and probe for "missed" births. For India, the main concern is the underreporting of deceased children, especially a systematic recall error where respondents' likelihood of reporting the birth of a deceased child depends on the sex of that child. Unreported deceased children inflate the length of birth intervals and, with declining mortality, make changes over time appear too small. In the online appendix, I provide a detailed analysis of systematic recall error, which shows that recall error depends heavily on how long ago a woman was married. I, consequently, drop women married 22 years or more.[6]

To ensure that there are enough births for the method to work, I censor spells at 96 months (eight years) after a woman can first give birth, equivalent to 105 months after the birth of the prior child. Less than 1% of observed births occur after the cutoff. The final sample consists of 395,695 women, with 815,360 parity one through four births.

Direct information on sex selection is not available, so I compare periods based on the changes in access and legality of prenatal sex determination in India. Abortion has been legal in India since 1971. Reports of sex determination appeared around 1982–1983, and the number of clinics quickly increased (Sudha and Rajan, 1999; Bhat, 2006; Grover and Vijayvergiya, 2006). In 1994, the Prenatal Diagnostic Techniques Act made determining and communicating the sex of a fetus illegal.[7] Finally, although sex selection increased even after 1994, we may have passed a turning point in its use in the mid-2000s (Das Gupta, Chung and Shuzhuo, 2009; Kumar and Sathyanarayana, 2012; Bongaarts, 2013; Diamond-Smith and Bishai, 2015).

I use four periods: 1972–1984, 1985–1994, 1995–2004, and 2005–2016. The first covers the period before sex selection became available and the second from when sex selection became available until the Prenatal Diagnostic Techniques Act. I have split the period from 1995 until 2016 into two to examine if there was support for the prior literature's hypothesized reversal in child sex ratios and son preference in India.

The allocation of spells into periods is determined by when conception, and, therefore, decisions on sex selection can begin. Hence, some spells cover two periods, which may

[6]Recall error is likely behind the designation of the first two rounds of NFHS as "moderate quality" in an analysis of the quality of birth histories in DHS surveys and its impact on fertility estimates (Schoumaker, 2014).

[7]There is little evidence that the ban significantly affected sex ratios (Das Gupta, 2019).

bias downward the differences between the periods. Most sterilizations take place soon after giving birth. These spells, therefore, do not show up in the samples used. Furthermore, sterilization depends strongly on prior children's sex composition; the fewer boys, the lower the probability of sterilization. The effect is to bias downward the differences in parity progression probabilities.

I divide the explanatory variables into two groups, nonproportional and proportional. The first group consists of characteristics shown in the prior literature to affect the spacing choice and the use of sex selection: Mother's education, sex composition of previous children, and area of residence. To minimize any potential bias from including proportional variables, I estimate separate models for each birth interval, education group, and period combination, rather than including education as a variable.

I divide education levels into four groups: No education, 1–7 years, 8–11 years, and 12 and more years. The latter two correspond to having completed primary and secondary school, respectively.[8] To ensure that the results are comparable with the prior literature on fertility and mortality in India, I follow the NFHS reports, except that I combine the less than five years and 5–7 years of schooling completed and the 8–9 and 10–11 years of schooling completed to ensure sufficient cell sizes.

I capture sex composition with dummy variables for the possible combinations, ignoring the ordering of births.[9] Area of residence is a dummy variable for living in an urban area.

The second group of variables consists of those expected to have an approximately proportional effect on the hazard. These include the mother's age when the spell begins, the household's land ownership, and whether it belongs to a scheduled tribe or caste. The online appendix present the descriptive statistics.

[8]Although there are variations by state, elementary education in India consists of a primary school covering grades one through five and an upper primary—or middle school—covering grades six through eight. Similarly, secondary education covers grades nine and tenth for "secondary education" and 11 and 12 for "upper secondary."

[9]With sex selection, the composition of prior children is, in principle, endogenous. It is beyond the scope of this paper to develop a method for dealing with this issue.

5 How Birth Spacing Changed

The first question I address is how birth spacing responded to the significant changes in India. I begin with a broad outline of how parity progression probabilities and sex ratios have changed over time and by groups. I then use these results to separately discuss the changes in birth spacing for women who do not appear to use sex selection and for those who do.

Figures 2 through 7 show the 25th, 50th, and 75th percentile birth interval durations in months, the sex ratio, and the probability of having a birth for each spell by education levels and area of residence.[10] The sex ratio graphs also show the natural sex ratio, approximately 51.2% boys (Jacobsen, Moller and Mouritsen, 1999; Pörtner, 2015). The underlying values with bootstrapped standard errors and tests for statistically significant differences across sex compositions are available in the online appendix.

The parity progression and the sex ratio show two broad trends. First, in line with the falling total fertility rate, the likelihood of a next birth has decreased over time. The likelihood of a next birth fell more rapidly, the higher the education and the higher the parity. Within a given spell and period, parity progressions are lower in urban than rural areas, if at least one son is present, and the more educated the mother.

Second, sex ratios have become more male-dominated for women with no sons, indicating the spread of sex selection. The percentage of boys increased more quickly, the higher the education and the higher the parity. There are no clear trends for the other sex compositions. Within a given spell and period combination and in the absence of a son, sex ratios are higher, the more educated the mother, and the higher the parity. Sex ratios are also higher in urban than in rural areas. Some women with one son also show an unnaturally high percentage of boys, although the failing fertility makes these estimates noisy.

[10]Results for urban women without education, rural women with 12 or more years of education, and the fourth spell for women with 12 or more years of education are in the online appendix because of relatively small samples.

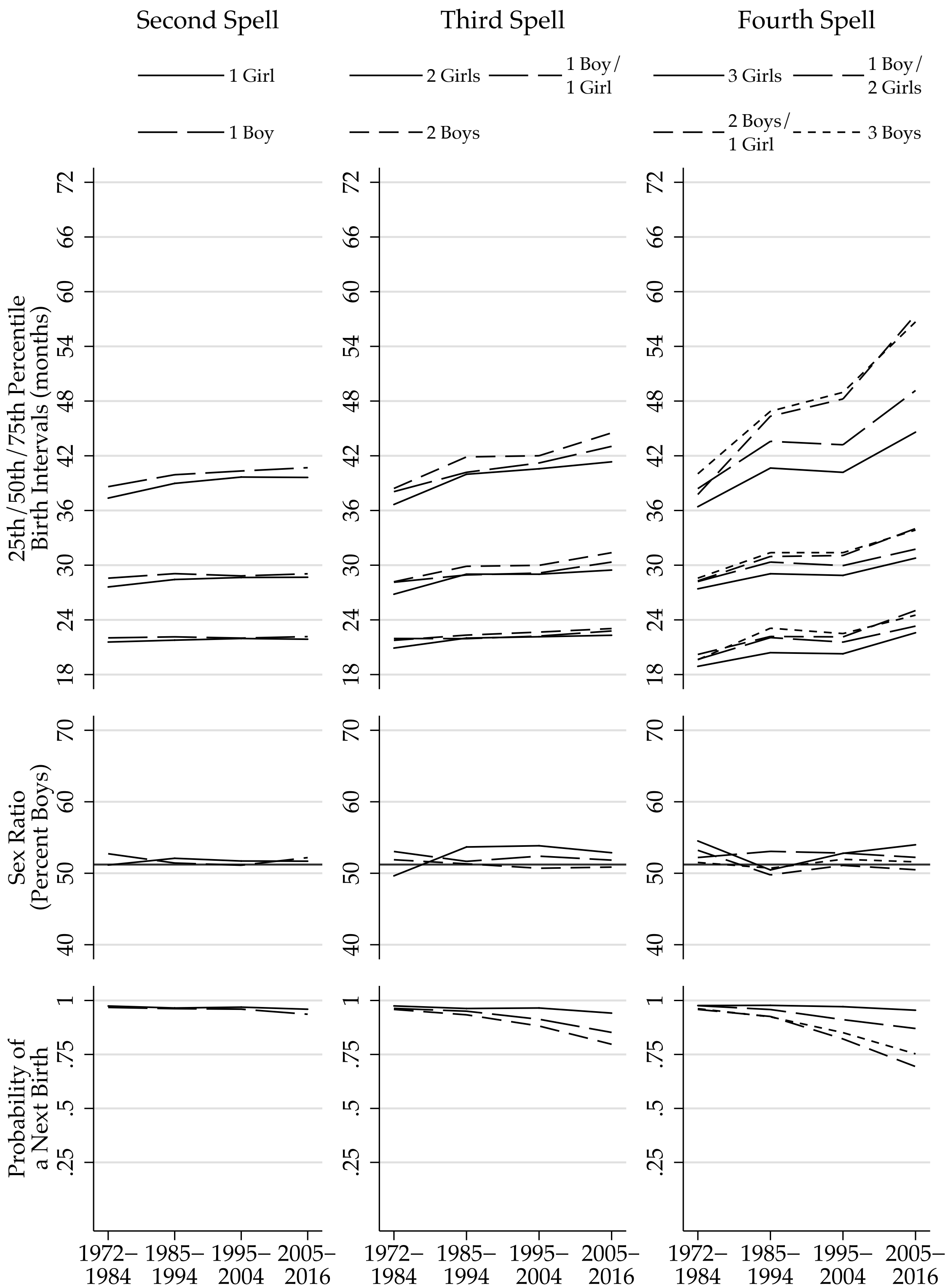


Figure 2: Percentile birth interval durations, sex ratios, and parity progression for rural women with no education by spell, sex composition, and period

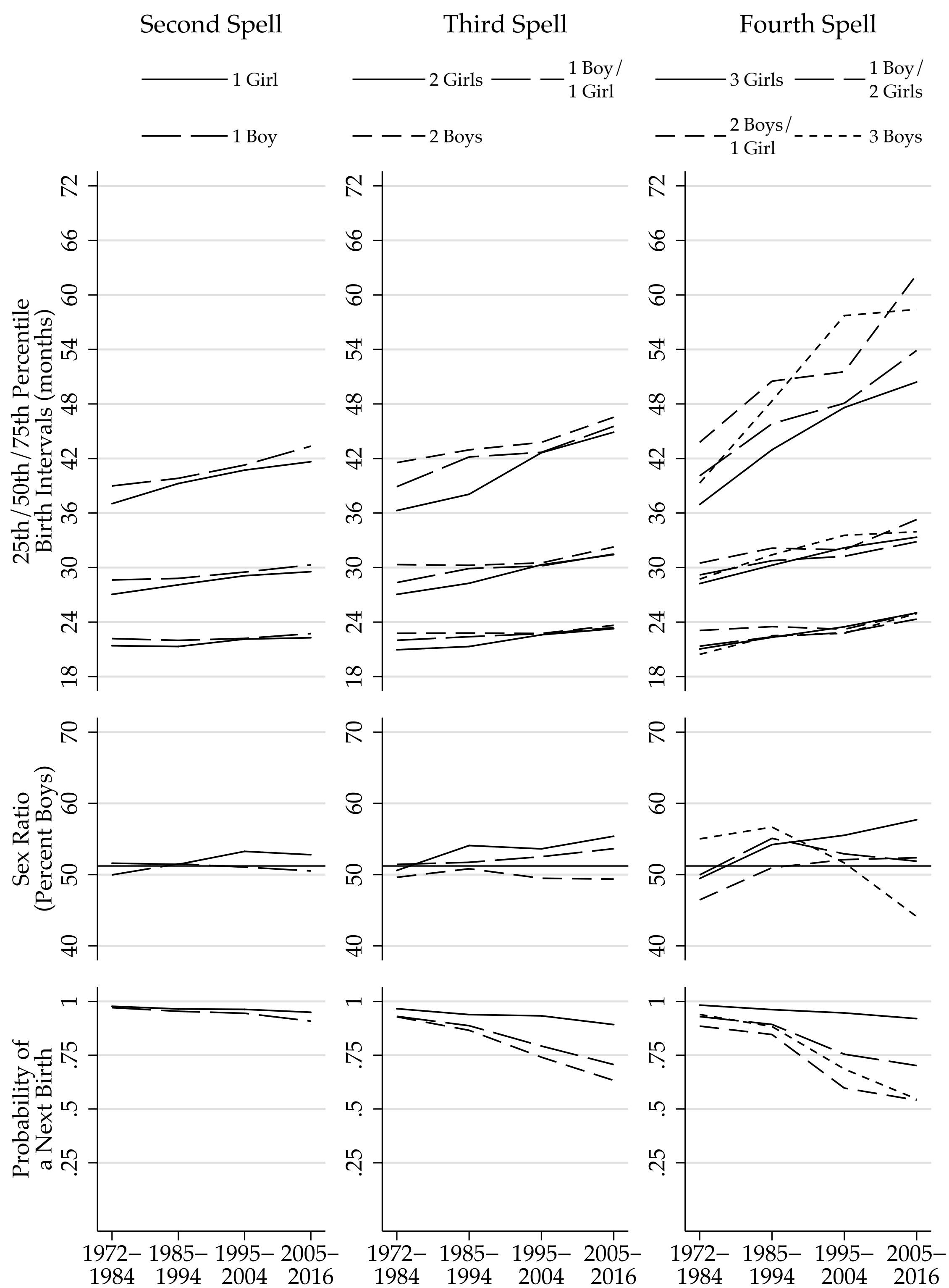


Figure 3: Percentile birth interval durations, sex ratios, and parity progression for rural women with 1–7 years of education by spell, sex composition, and period

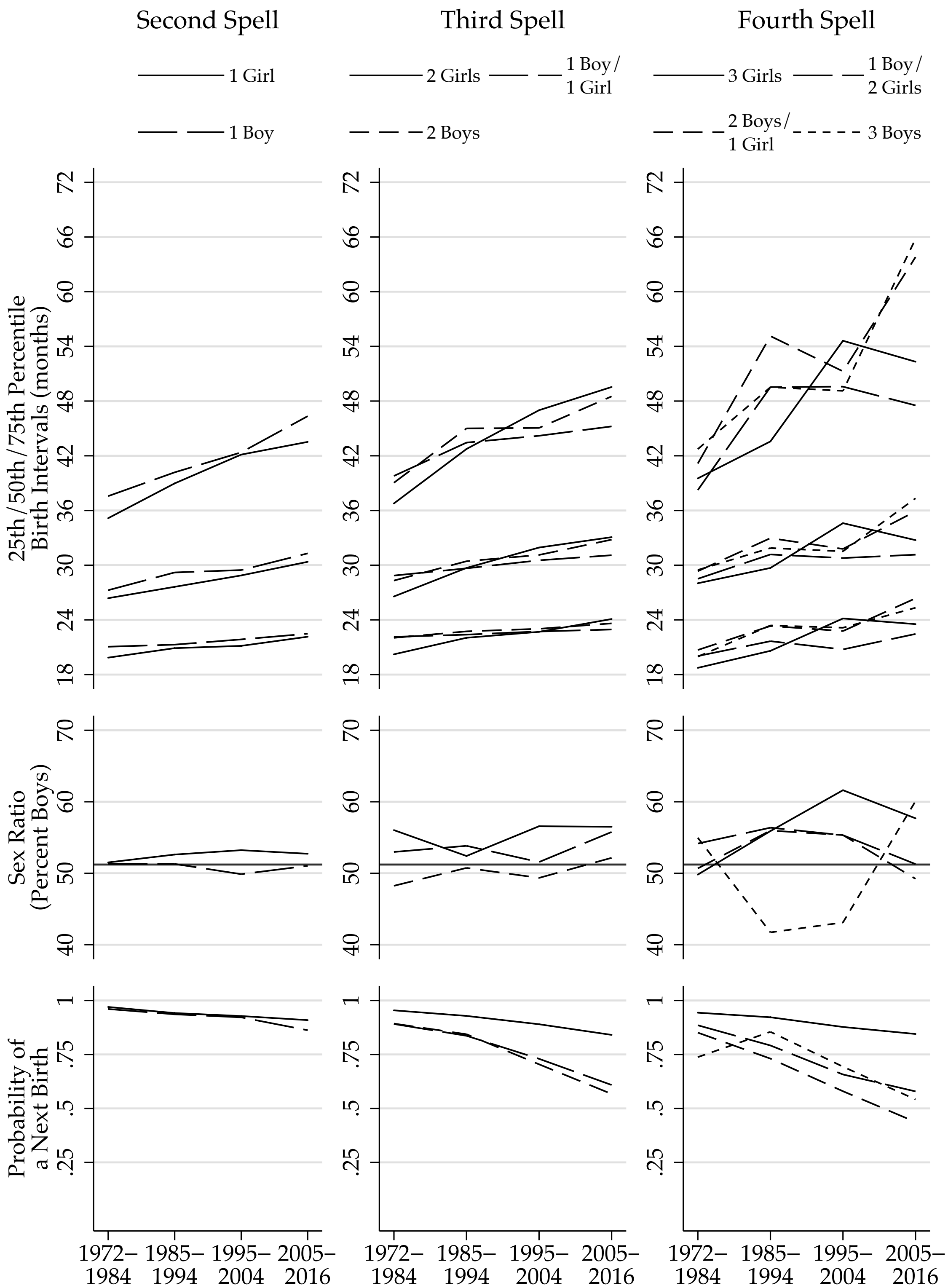


Figure 4: Percentile birth interval durations, sex ratios, and parity progression for urban women with 1–7 years of education by spell, sex composition, and period

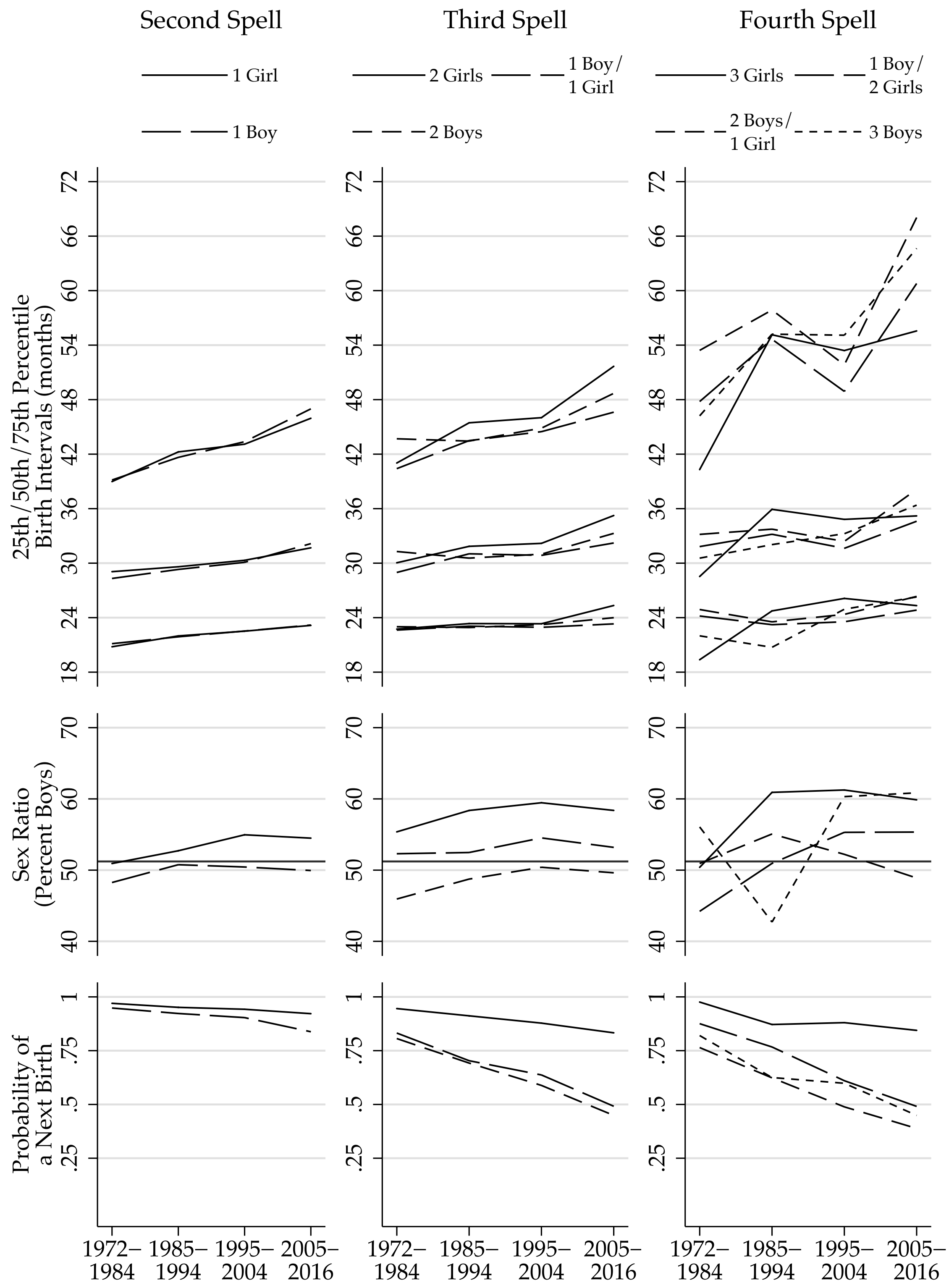


Figure 5: Percentile birth interval durations, sex ratios, and parity progression for rural women with 8–11 years of education by spell, sex composition, and period

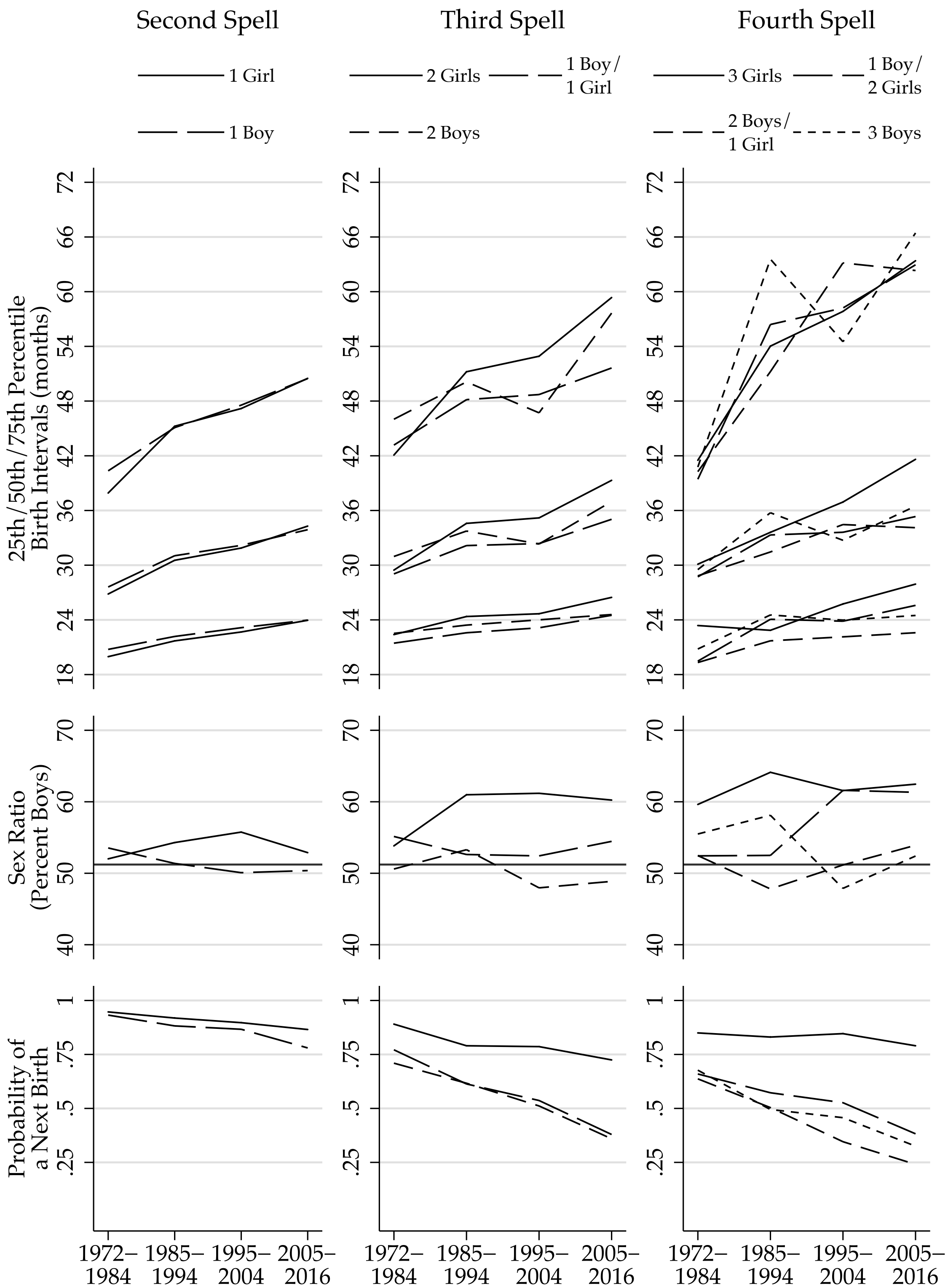


Figure 6: Percentile birth interval durations, sex ratios, and parity progression for urban women with 8–11 years of education by spell, sex composition, and period

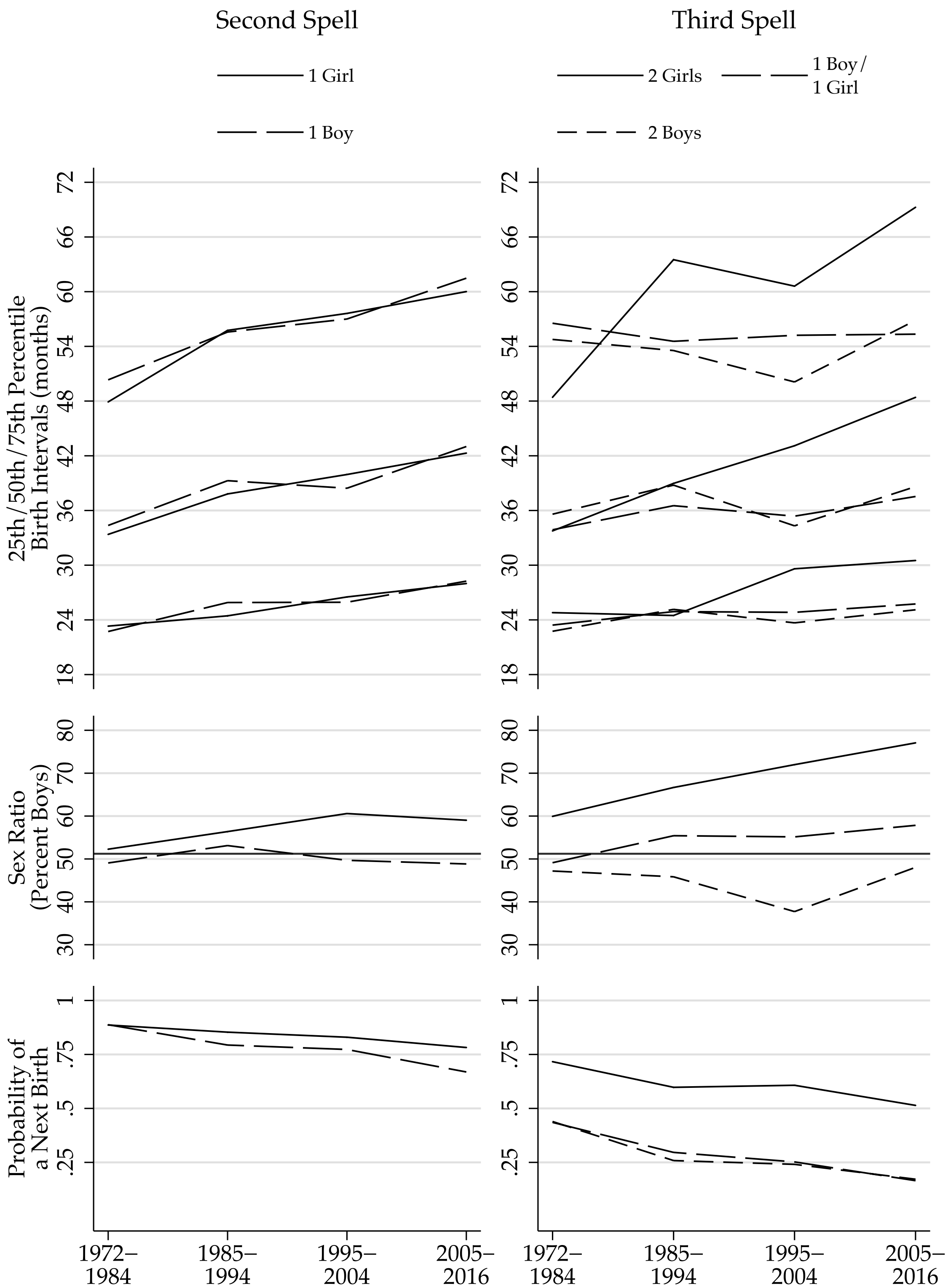


Figure 7: Percentile birth interval durations, sex ratios, and parity progression for urban women with 12 or more years of education by spell, sex composition, and period

5.1 When Sex Selection Is Less Used

To separate the effects of the introduction of sex selection and the other changes in India, I first discuss how the lengths of birth intervals have changed in situations where, based on sex ratios, there appears to be less sex selection. The group broadly covers women with no education, regardless of their children's sex composition, and women with any education who have one or two sons already.

Despite the apparent lower level of sex selection, son preference is still evident with the shortest spacing when they have only girls. Notably, for those who appear the least likely to use sex selection—rural women with no education—birth spacing is almost uniformly statistically significantly longer when at least one son is present than if no son is present. Furthermore, the difference in birth interval length across sex compositions has grown over time as spacing when sons are present has become longer.

A remarkably high proportion of birth intervals are still very short. For all but the most educated, 25% or more have their second and third child within 24 months of the previous birth. These intervals are substantially below the 24 months between *pregnancies* the WHO recommends. Even with the more substantial lengthening of birth intervals for higher parities, the 25th percentile duration is still around 24 months for the fourth spell for women with less than eight years of education.

Median birth interval lengths have also increased relatively little—only three to six months over the four decades—compared to around 3.5 months *per decade* in other countries with declining fertility (Rutstein, 2011; Casterline and Odden, 2016).[11] The result is that most of the median birth interval durations are still at 36 months or below, with the shortest only 29 months.

Birth intervals appeared to lengthen the most for women who are the least likely to work. For example, from lowest to highest education, the average duration of third-spell

[11]The NFHS reports show median durations of closed birth intervals of approximately 31 months, which have barely moved over time, underscoring the importance of accounting for censoring when examining birth spacing.

birth intervals for urban women with one boy and one girl increased by 2.7, 3.4, 5.8, and 1.8 months over the four decades.[12] Hence, women with the lowest labor force participation—those with 8–11 years of education—also saw the largest increases in average spacing, possibly driven by the substantial improvement in household income for this group from economic growth.

The most substantial changes occurred in the 75th percentile birth interval durations, where the more the parity progression probabilities declined, the more the birth interval lengthened. For example, the probability of a fourth birth for urban women with 8–11 years of education and two sons and one girl has declined by almost 40 percentage points as the 75th percentile birth interval length increased by 22 months. Compare this with rural women of no education with a boy as their first child, for whom the probability of a third birth declined by fewer than six percentage points while the birth interval increased by only slightly more than two months.

These results are in line with prior research showing that falling fertility is associated with a lengthening of particularly the longer birth intervals, although why is still an unresolved question (Casterline and Odden, 2016). The most educated women who already have a son is an exception to this trend; the probability of a third birth declined rapidly, but the birth interval lengths changed little. These women both have better access to modern contraceptives and are better at using traditional contraceptive methods (Rosenzweig and Schultz, 1989). Hence, it is possible that the lengthening of birth intervals with falling fertility in the prior research arises because unintended births become a relatively larger proportion of the total number of births for a given parity and those can occur at any time.

[12] For women with two sons, the numbers were 4.3, 6.3, 7.0, and 3.0. See the online appendix tables for the average birth interval durations.

5.2 Sex Selection and Birth Spacing

A clear illustration of how the combination of son preference and the introduction of sex selection affected birth spacing comes from the third spell of the best-educated urban women. With two girls, almost 80% of the third births are boys, and the 75th percentile birth interval length is close to 70 months, an increase of almost 21 months over the four decades. This interval has gone from being statistically significantly shorter than the intervals with at least one son to now being a statistically significant 13 months longer.

Even more striking, most of the change took place right at the introduction of sex selection. The 75th percentile birth interval with two girls increased from 48 months to 64 months in a decade, while the other sex compositions showed a slight decrease from around 55 months to 54 months. These birth spacing changes may even understate the impact because this particular group appears to have had access to sex selection even before it became widespread, as shown by the unequal sex ratio for the 1972–1984 period for women with two girls.

The 75th percentile changes are the most dramatic, but the apparent use of sex selection also affects the 25th and median birth interval lengths. For the best-educated urban women with two girls, the 25th percentile birth interval length increased by six months, or 23%, while the median percentile birth interval length increased by 15 months (43%).

Not surprisingly, given these changes, the third spell for the best-educated women shows the clearest reversal in the spacing pattern; the birth intervals with two girls are consistently statistically significantly longer than the intervals with one or two boys, no matter the percentile used. A similar reversal, although more muted, occurred for the third spell for urban women with 1–7 years of education and both urban and rural women with 8–11 years of education.

Did the predictions of declining use of sex selection come true? There is no clear evidence for or against a reversal in the use of sex selection, with some cases showing increases in sex ratios between the last two periods, others little change, and some a decline.

The best-educated women are again a good illustration. The sex ratio for women with two girls continued to increase over the last two periods, but the likelihood of a third birth declined. Furthermore, if the first child was a girl, the sex ratio for the second birth dropped slightly, as did the probability of having a second birth. However, there are also cases where there is no abatement in the increasing use of sex selection. For example, for rural women with 1–7 years of education, the sex ratios in the absence of daughters continued to increase while the likelihood of an additional birth remained high.

In summary, over the four decades, birth intervals lengthened with improving economic conditions and falling fertility. These increases are larger with higher parity and higher percentile measure. Furthermore, when there is little evidence of sex selection use, it appears that the women least likely to work are also those with the most substantial increases in birth interval lengths.

However, sex selection appears to be behind the most substantial increases in birth spacing. The best-educated women with two girls had the most biased sex ratio and the most significant increase in birth interval lengths. Over the four decades, the median birth interval length for this group increased by almost 15 months. Even more striking, the 75th percentile birth interval length increased by a staggering 21 months, most of that within a decade of the introduction of sex selection.

6 What Happened to Fertility?

The tempo effect from longer birth intervals means that the total fertility rate may underestimate cohort fertility. The next question I address is, therefore, to what extent did the changes bias the fertility estimates for India? To this end, I compare fertility based on a variation of the total fertility rate with predicted cohort fertility from the hazard model. Table 1 shows the two fertility measures by area of residence and education.

The fertility rate follows the same procedure as in the Demographic and Health Survey

Table 1: Four-parity fertility rate versus predicted cohort fertility based on hazard model

	NFHS–1		NFHS–2	NFHS–3	NFHS–4
Fertility Rate Period	1987–1988	1992–1993	1998–1999	2005–2006	2015–2016
Hazard Model Period	1972–1984		1985–1994	1995–2004	2004–2016
			Urban		
			No Education		
Fertility Rate[a]	3.55	3.06	2.80	2.54	2.45
Hazard Model[b]	3.44		3.29	3.06	2.79
			1–7 Years of Education		
Fertility Rate[a]	2.85	2.29	2.09	1.99	2.04
Hazard Model[b]	3.18		2.88	2.62	2.42
			8–11 Years of Education		
Fertility Rate[a]	2.43	2.04	1.84	1.81	1.87
Hazard Model[b]	2.72		2.41	2.28	2.07
			12 or More Years of Education		
Fertility Rate[a]	2.05	1.68	1.57	1.55	1.51
Hazard Model[b]	2.29		2.06	1.94	1.80
			Rural		
			No Education		
Fertility Rate[a]	3.57	2.93	2.63	2.74	2.81
Hazard Model[b]	3.55		3.38	3.26	3.09
			1–7 Years of Education		
Fertility Rate[a]	3.01	2.52	2.39	2.25	2.37
Hazard Model[b]	3.29		3.08	2.83	2.70
			8–11 Years of Education		
Fertility Rate[a]	2.56	2.21	2.22	2.16	2.19
Hazard Model[b]	2.93		2.68	2.49	2.31
			12 or More Years of Education		
Fertility Rate[a]	1.95	1.68	2.13	2.08	1.96
Hazard Model[b]	2.64		2.39	2.25	2.11

Note. All predictions based on births up to and including parity four births for both fertility rate and model predictions. NFHS-1 was collected in 1992–1993, and model results for 1972–1984 were applied for the predictions. NFHS-2 was collected in 1998–1999, and model results for 1985–1994 were applied for the predictions. NFHS-3 was collected in 2005–2006, and model results for 1995–2004 were applied for the predictions. NFHS-4 was collected in 2015–2016, and model results for 2005–2016 were applied for the predictions.

[a] The fertility rate is based on five-year age groups, counting births that occurred 1–36 months before the survey months. For NFHS-1 and NFHS-2, the total number of women in the five-year age groups is based on the household roster because only ever-married women are in the individual recode sample. For NFHS-3 and NFHS-4, the total number of women is based on the individual recode sample because all women were interviewed.

[b] The model predictions for fertility are the average predicted fertility across all women in a given sample, using their age of marriage as the starting point and adding three years for each spell. Observed births are not taken into account for the predictions. For each spell, the predicted probability is the likelihood of having a next birth given sex composition multiplied with the probability of that sex composition and the likelihood of getting to the spell, corrected for the probability of sterilization.

reports: I use the births from 36 to 1 month before the survey month to calculate age-specific fertility rates for five-year age groups and then sum the age-specific fertility rates multiplied by five (Croft, Marshall and Allen, 2018). However, because the hazard model predictions only use births up to parity four, I use the same set of births for the fertility rate and label it the "four-parity" fertility rate. Hence, the presented fertility rates are not directly comparable to those in the NFHS reports.

Because NFHS-1 was after the introduction of sex selection, I cannot calculate a fertility rate in precisely the same manner for a period before sex selection was widely available. Instead, I calculate the fertility rates for women between 15 and 39 years of age five years before the survey month, again using the number of births three years before. This rate is shown as "1987–1988" in the table. Given the relatively low number of births to women 40–45 years of age, this approach provides the best estimate of the fertility rate when sex selection still was not widespread.

To predict cohort fertility based on the hazard models, I estimate the parity progression probability for each spell. Because parity progression depends on the sex composition of prior children, I estimate the probability for each sex composition and weigh the probabilities with the likelihood of the sex compositions. The survey rounds do not coincide directly with the periods used for the hazard model. Therefore, I compare the model results for 1972–1984, 1985–1994, 1995–2004, and 2005–2016 with rounds 1 through 4 of the NFHS, respectively.

I include the spell from marriage to first birth, despite the problems capturing the exact timing of marriages because the estimated progression probabilities should not be affected by this problem. I begin with the age of marriage for each woman and predict the likelihood of progressing to each parity, assuming three-years increases in age between births. Shorter assumed increases in age lead to slightly higher predicted fertility.

Sterilizations are not incorporated into the hazard model because most occur immediately after giving birth. To compensate, I estimate the probability of sterilization using a

Logit model and use that to scale down the parity progression probability when predicting cohort fertility.

The predicted cohort fertility based on the hazard model is higher than the four-parity fertility rate in almost all cases. Only women with no education in the first period show little difference between the two fertility measures, a situation where fertility is high, spacing very short, and likely unchanged for an extended period.

Consistent with a more substantial bias in the period fertility rate when the age of marriage and the length of birth intervals increase, the absolute bias is least in the first and the last period and highest in the middle two periods. Hence, the fertility rate declined too fast from the mid-1980s to the century's end. Only recently, as the rate of increase for the birth interval lengths has slowed, have the two fertility measures begun to converge again. Even with the convergence, the predicted 2005–2016 cohort fertility is still above the 1992–1993 fertility rate for every group, except urban women with no education. Furthermore, for the last period, the predicted cohort fertility remains at least 10%–20% higher than the fertility rate.

Another indication of how tempo effects bias the fertility rate bias is that the fertility rate *increases* for some groups. For example, for urban women with 8–11 years of education, the fertility rates were 1.84, 1.81, and 1.87 over the last three surveys. This pattern likely arises from the stabilization of the age of first birth and the spacing between births.

Finally, even with the declines in the predicted cohort fertility, it is still mostly above replacement. Only for urban women with 12 or more years of education is the predicted cohort fertility clearly below 2.1 children. Even then, cohort fertility is still more than 0.3 children higher than the fertility rate estimate of 1.5. Furthermore, the predicted cohort fertility numbers are likely too low because I use only the first four births and births before the imposed 105-month censoring of birth interval durations.

7 Mortality and the Changing Birth Spacing

The final question I address is whether there is an association between infant mortality and increases in birth spacing associated with the introduction of sex selection. Starting with the sample used for estimating birth spacing, I select children born more than 12 months before the survey month. I restrict the analyses to parities two and three because of the small number of births and deaths at parity four. Furthermore, I do not show the results for women with 12 or more years of education for the 1972–1984 period because of the small number of women.

The dependent variable is whether the child died within the first 12 months of life. The main set of explanatory variables consists of dummies for the spacing from the prior birth. The birth interval duration dummies cover 12-month periods, starting nine months after the prior birth, until the 57-month dummy, which covers until 105 months after the prior birth. I use dummies for the sex of the index child and the sex composition of the prior children. The birth spacing dummies, the sex of the index child, and the sex composition dummies are all interacted. Because the actual number of abortions is unobserved, the interactions between the sex composition of prior children and the sex of the index child serve as proxies for the use of sex selection. The other explanatory variables are the same as above, and estimations are done separately by education level and parity.

I estimate the probability of infant mortality using a Logit model. Figures 8 and 9 show the predicted probability of the second child dying within the first year at the possible combinations of index child sex, sex composition of prior children, and birth spacing, with all other variables at their average values.[13] The graphs do not show confidence intervals to improve legibility.

An important caveat is that the estimations do not address potential selection problems. For example, suppose women who have difficulties conceiving or carrying a pregnancy to term also have a higher mortality risk for their offspring. In that case, a spurious

[13]The online appendix shows the corresponding graphs for the third child.

correlation between long birth spacing and mortality may arise (Kozuki and Walker, 2013). Unfortunately, methods to address selection, such as family fixed effects, do not work well when the number of births is as low as it is here for better-educated women (Kozuki and Walker, 2013; Molitoris et al., 2019). However, the fixed effects and linear probability results did not deviate substantially in prior research.

There has been substantial convergence in mortality risk across groups over time. For intervals 21 months or longer, there is now little difference across the education groups, with even the no-education group showing an infant mortality risk below 5%.

Very short birth intervals still exhibit a higher mortality risk, although the effect declines with education level. The mortality risk is 3%–4% for the best-educated women, whereas women with no education still show a risk that is close to 10%.

Despite the prior findings of differential mortality by sex, there is little evidence that girls have substantially higher mortality risk. There is some weak evidence that a boy born after a girl has a lower mortality risk in the earliest periods. However, this difference disappears with the general decline in mortality risk.

Despite the concern that multiple abortions might increase mortality risk by shortening the interval between pregnancies, there is no evidence for this effect. Suppose repeated sex-selective abortions lead to a higher mortality risk for the child eventually born. In that case, boys born after a girl—the solid lines—should have an increased risk with longer spacing for the two highest education groups in the last two periods. However, there are no apparent consistent differences between these groups and the other potential combinations. The same holds for the third spell.

The raw numbers for women with the most uneven sex ratio also suggest that even with a very high apparent use of sex selection, there is no impact on mortality. A total of 1,004 women with 12 or more years of education and no boys at the start of the third spell in the last period had a third child, of which 685 were boys. Of these 685 boys, only six died within the first year of life. Half of those who died were born in the 9–32-month

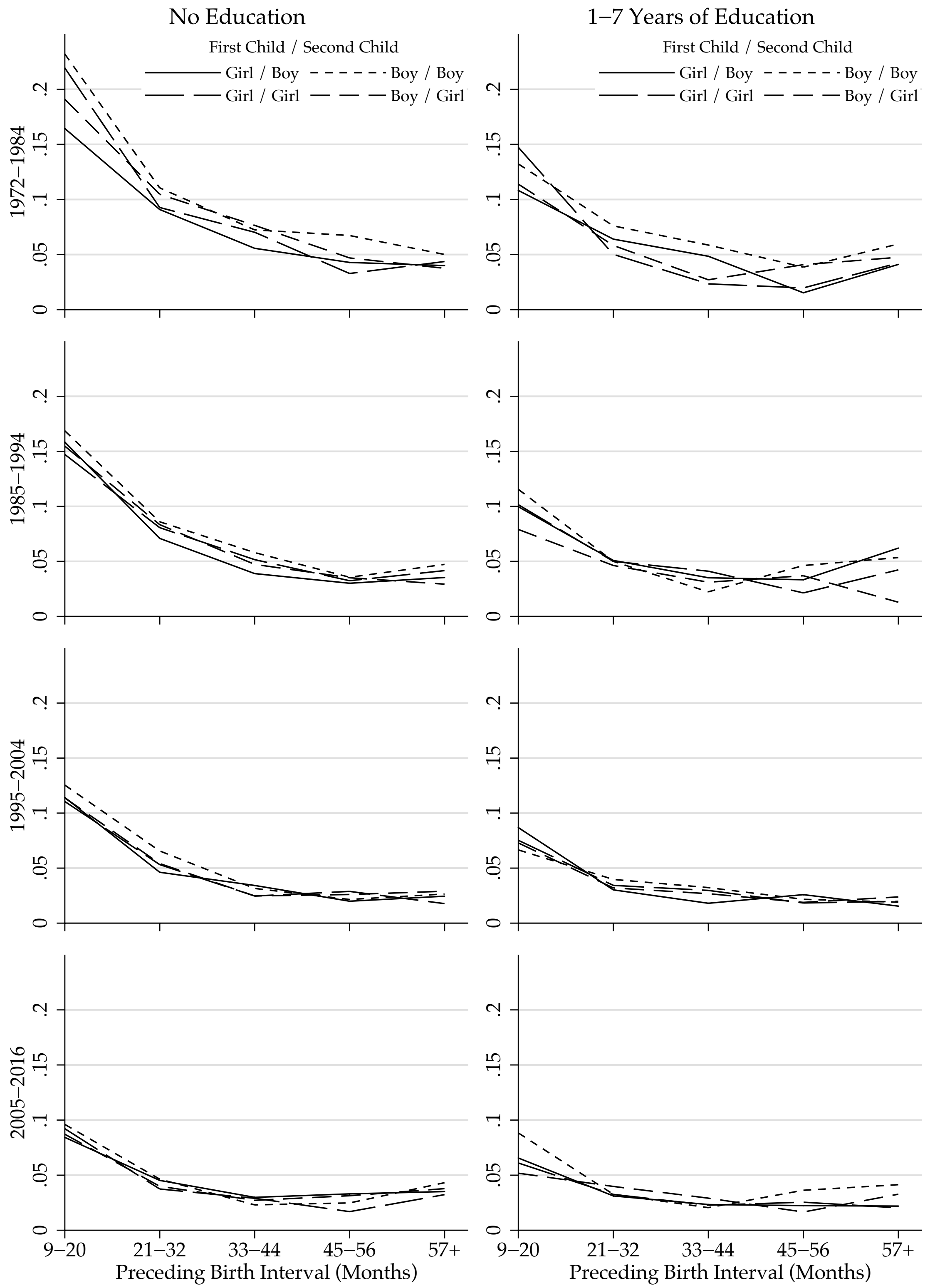


Figure 8: Infant mortality by preceding birth interval length across periods for second child of women with no education and women with 1–7 years of education

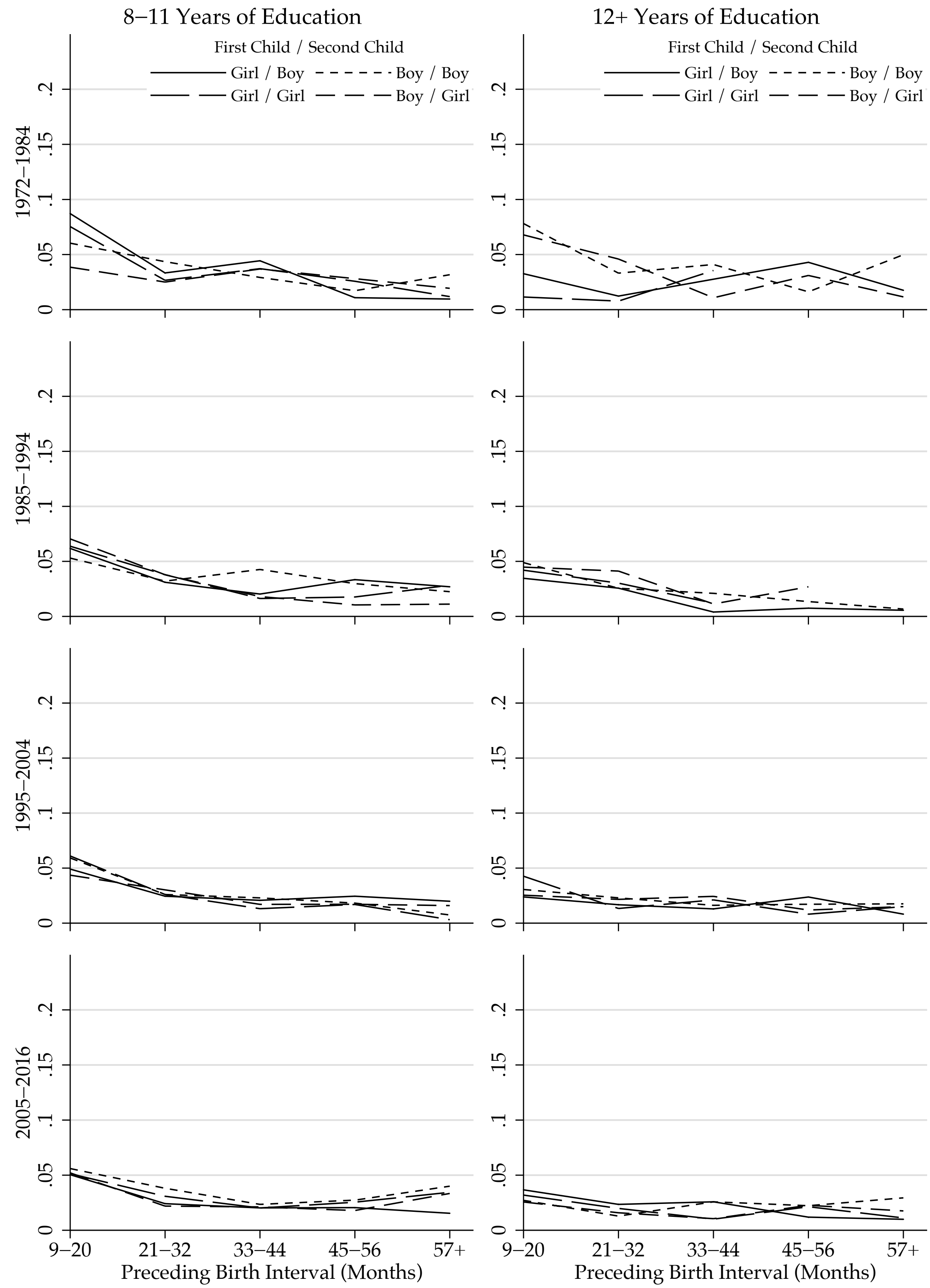


Figure 9: Infant mortality by preceding birth interval length across periods for second child of women with 8–11 and 12 and above years of education

interval, and none died in the 57-month+ interval.

8 Conclusion

Over the past four decades, India saw a dramatic increase in the male-to-female sex ratio at birth as access to sex selection spread and son preference remained high. Simultaneously, economic growth was strong, schooling increased, and the total fertility rate declined to almost replacement level.

The main question I address in this paper is how birth spacing responded to the significant changes in India between 1972 and 2016, particularly the spread of sex selection. I also examine two related questions. First, did changes in birth spacing make us overestimate the decline in cohort fertility? Second, what is the relationship between infant mortality and the changes in birth spacing and sex selection?

The most substantial lengthening of birth intervals occurred among the best-educated women, likely because of substantial use of sex selection combined with falling fertility. Take, for example, women with 12 or more years of education who had two girls. As the sex ratio reached almost 80% boys, the expected median birth interval length increased by almost 15 months, and the 75th percentile interval length increased by 21 months. Most of the lengthening in the long intervals came immediately after the introduction of sex selection in India.

For some groups, the lengthening in birth intervals was so substantial that it led to a reversal of the traditional spacing pattern: In the absence of sons, these groups now show statistically significant longer, rather than statistically significant shorter, birth intervals than if there is at least one son.

The women who are the least likely to use sex selection, as indicated by their sex ratios at birth, still show the traditional spacing pattern with short spacing in the absence of sons.

Son preference continues to show in fertility decisions. Fertility has declined for all groups, but the likelihood of having an additional child still depends strongly on the number of sons, with women with no sons having the highest parity progression probabilities.

Birth intervals also lengthened in cases when sex selection appears to be less used. However, compared to other countries with similar declines in fertility, the median spacing increases were smaller at three to six months over the period. Most of the median intervals when sex ratios are close to normal are still short at 36 months or below. Furthermore, many women still have very short birth intervals. More than 25% of women have their next child within 24 months of the previous birth in many cases.

Despite predictions that the use of sex selection would decline, there is no clear evidence of this. The most likely users of sex selection continue to show substantial male-biased sex ratios, although there may be some leveling off. More concerning, the increasingly male-biased sex ratios among less-educated women suggest that sex selection use appears to be spreading as fertility falls.

The increases in spacing make the total fertility rate a more biased measure of cohort fertility. This bias was most prominent early in the spread of access to sex selection when the fertility rate was up to one child lower than the predicted cohort fertility. However, it is still present, with the predicted cohort fertility 10%–20% higher than the fertility rate. At 1.8 children, the best-educated urban women are the only group for whom the predicted cohort fertility is below replacement.

Tempo effects are studied extensively in the literature (see, for example, Bongaarts, 1999). Still, there are, to my knowledge, no other cases where there has been as substantial an increase in birth interval lengths and associated bias in fertility rates as for India. It is conceivable that we might see increases in the total fertility rate as birth spacing stabilizes or even shortens again if interventions against sex selection are successful.

There has been a substantial reduction in infant mortality over time, and the size of the reductions is inversely related to the mother's education. Hence, there is now little difference in mortality risk across education groups if the birth took place more than 21 months after the previous birth. Short birth spacing is still associated with higher mortality, although the effect is small for the best-educated women. There is no evidence that repeated abortions are associated with higher infant mortality for the child eventually born; boys born after long birth intervals to families with well-educated mothers, only daughters, and high predicted sex ratios—the combination of which suggests repeated sex-selective abortions—have no higher infant mortality than other children.

The results here paint a less rosy picture of India's prospects for a continued reduction in population growth than generally accepted. With predicted cohort fertility still substantially higher than the period fertility rate, India's total fertility rate will likely stabilize or even increase as birth intervals slow their lengthening. The more successful the attempts at combatting sex selection are, the more likely an increase in the total fertility rate will be. Furthermore, the rapid decline in infant mortality risk, combined with likely future declines as the proportion of very short birth intervals falls, may also slow the reduction in population growth.

There are two crucial questions that future research should address.

First, what is behind the improvements in girls' health status? Access to sex selection means that girls-only families are less likely to have very short birth intervals, which may reduce sibling competition. Hence, better health outcomes for girls with sex selection is available could be an unintended side-effect, rather than the result of girls becoming more valued as is often assumed (Hu and Schlosser, 2015). Comparing prior children's outcomes across sex composition and the sex of the next child could be a way to understand why girls' health outcomes improve in the presence of sex selection.

Second, what is the relationship between female labor force participation and sex selection? Women may be staying out of the labor market precisely because sex selection makes them more likely to have a boy and increases the expected birth spacing. Better job opportunities for women could reduce sex selection use for two reasons. First, it becomes more expensive to be out of the labor market for long periods. Second, the differential in potential earnings between husband and wife would decline, making it relatively more attractive to invest in daughters' human capital. This approach could, however, be a double-edged sword. If better job opportunities further lower fertility, the use of sex selection may increase, everything else being equal. Understanding the trade-off between long-term benefits from improvements in women's labor force participation and short-term costs from potential increases in sex selection is of paramount importance.

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