Missing Girls

Women's Education and Declining Child Sex Ratios in India

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Sex ratios in India have been declining for decades, and "missing girls" are a serious social and political problem. Drawing on subdistrict-level data from the 2001 and 2011 Censuses and detailed data on women's education and fertility, we show that more-educated mothers have fewer girl children than less-educated mothers, but that these girls are also more likely to survive. The policy implication of these findings is that among uneducated mothers, the focus should be on child treatment and survival; among educated mothers, attitudinal campaigns that emphasise the value of having girl children are likely to be more successful.

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In 1990, Amartya Sen brought the palpable demographic, social, and political problem of "missing girls" to the world's attention (Sen 1990). Nearly 30 years later, on 21 January 2017, the *Economist* (2017) declared that "the war on baby girls is winding down." The *Economist* was not the first to trumpet India's sex ratio improvements: its report drew on data from the 2011 Census of India (GoI 2011), which showed that the country's overall female-to-male ratio had increased since the 2001 Census (GoI 2001). Sex ratio gains in the overall population are important, but there is a problem with relying on population-wide statistics: in India, the child sex ratio—the share of young girls to young boys in a population[1]—continued to decline over the same period, indicating that the "missing girls" problem has remained a pressing concern.

The underlying cause for declining child sex ratios across the world is well known: cultural preferences for sons have resulted in more girls than boys dying because of female infanticide and neglect. With the increasing availability of prenatal sex determination technologies, female foetuses can be (and are) selectively aborted more often than male foetuses (Bhalotra and Cochrane 2010; Guilmoto 2009; Jha et al 2011; Madan and Breuning 2014). How can we change cultural preferences for sons and, thereby, the trend of ever-declining child sex ratios?

Women's education has been held as a solution to the missing girls problem (Bourne and Walker 1991; Inchani and Lai 2008). In development literature, various education indicators—literacy in particular—are used as proxies for knowledge, women's bargaining power, and individual agency. Following Lalage Bown's (1990), *Women, Literacy and Development*, many excellent studies have demonstrated the relationship between women's literacy and positive development outcomes—in health (UN 1985), contraceptive use (Zaki and Johnson 1993; Ainsworth et al 1996; Samarakoon and Parinduri 2015), decreased fertility rate (Martin 1995; Samarakoon and Parinduri 2015), reduced child mortality (Mosley 1985; Das Gupta 2010; Blunch 2013), improvements in reproductive health (Samarakoon and Parinduri 2015), increased economic growth (Hill and King 1995; Behrman et al 1995),[2] and positive spillovers on the human capital of younger siblings (Qureshi 2018).

The host of positive outcomes associated with women's education leads one to assume that improvements in women's bargaining power (and in other areas) also foster more balanced sex ratios. However, as Bhalotra and Cochrane (2010) point out, studies on women's education and child sex ratios have reached contradictory conclusions. Moreover, more education for women has been found to worsen child sex ratios, because women with more education—who want to have fewer children overall, but want a son—are more likely to abort girl children (Mayer 1999; Das Gupta and Mari Bhat 1997). But other studies have predicted that educating women improves sex ratios because girl children of women who are educated are more likely to survive (Bourne and Walker 1991; Inchani and Lai 2008). Are both these trends, established some time ago, and often based on highly aggregated data, still prevalent in India? If so, which trend is stronger? What is the overall relationship between advances in women's education and child sex ratios in India?

Our analysis draws on more recent, comprehensive, and disaggregated data to make three points. We first establish the fairly obvious—but important—fact that although improvements between 2001 and 2011 in India's overall sex ratio (the number of women per 1,000 men) have led to claims that the war on baby girls is "winding down" (*Economist* 2017; UNFPA 2011), India's child sex ratio (the number of girls under six years of age for every 1,000 boys under six years of age) is still declining, even in areas considered culturally less prone to a preference for sons, such as locations with a large presence of tribal groups and parts of South India.

Second, we show that both these trends still seem to be present today: detailed data on the level of education of mothers show not only that more-educated mothers have fewer children overall (lower fertility rates) and give birth to far fewer daughters (lower female natality), but also that they seem to treat their daughters better, so that their daughters are as likely to survive as are their sons (higher girl survival). However, these data also reveal that the sex-selective abortion trend is stronger than the trend of more-educated mothers treating their daughters better. Thus, there are fewer girls among the children of educated women than among those of less-educated women, even though girls born to less-educated women are less likely to survive during the first six years of life. Finally, we draw on disaggregated subdistrict-level data to show that although there is only a weak association between literacy and sex ratios in the cross-sectional data when we control for confounding factors, a local-level increase in female literacy is strongly associated with a local-level decrease in the sex ratio. In India today, there is a clear overall negative relationship between improvements in women's education and changes in the share of girl children in the child population.

These findings have important implications for policies designed to combat declining sex ratios. For uneducated mothers, the focus should be on the treatment of children's diseases and improving child survival, whereas attitudinal campaigns focused on the value of having girl children are likely to be more successful among more-educated mothers.

Women's Education and Child Sex Ratios

In a normal population, more boys than girls will be born; sex ratios in the United States (US) and Western Europe have remained stable at about 952 females born for every 1,000 males. The biological literature on sex ratio variations in humans provides a range of explanations for non-voluntary variations (James 1987). However, in India and elsewhere, there is also considerable evidence of voluntary variations in sex ratios.

Child sex ratios (female/male) across India have experienced a secular decline since records became available. By the early 1900s, there were fewer women than men in India, and the situation has only worsened since. In 1991, India's child sex ratio was 945/1,000; by 2001, it had dropped to 927, and by 2011 to 918. In some regions, it is much lower. This trend has been attributed to female infanticide and to boy children being prioritised in contexts marked by food or medical care scarcity (Agarwal 1986; Bhaskar and Gupta 2007). Access to prenatal sex determination and abortion have deepened sex ratio imbalances (Bhalotra and Cochrane 2010; Jha et al 2011; Madan and Breuning 2014). Multiple explanations for the imbalance have been offered, including kinship structures (Dyson and Moore 1983), socio-economic status (Das Gupta 1987; Krishnaji 1987; Miller 1997), employment opportunities for adult women and their increased economic value (Rosenzweig and Schultz 1984; Berik and Bilginsoy 2000), overall fertility decline (Das Gupta and Mari Bhat 1997; Jayachandran 2017; Malhotra et al 1995), low female labour force participation (Agnihotri et al 2002; Kishor 1993), trade openness (Chakraborty 2015), development/urbanisation (Murthi et al 1995; Sudha and Rajan 1999), and female inheritance rights (Bhalotra et al 2020).

Does educating women lead to improved child sex ratios? The theoretical expectations are contradictory, and the empirical evidence is mixed. Some studies indicate that educating women can reverse declining sex ratios by improving women's social status and, consequently, the treatment of girl children (Bourne and Walker 1991; Inchani and Lai 2008). However, other research finds that women's education is negatively associated with sex ratios, as more-educated women have fewer girl children (Mayer 1999). This is thought to be, at least in part, because of an "intensification effect": more-educated women desire fewer children but often feel pressured to have a male child (Das Gupta and Mari Bhat 1997). Yet, other studies indicate that increased female literacy, once it passes a certain threshold, is associated with initial sex ratio declines, followed by subsequent increases (Echávarri and Ezcurra 2010).

Empirical studies assessing the relationship between female literacy and child sex ratios in India have used national-level longitudinal data (Mayer 1999), cross-sectional state-level data (Das Gupta and Mari Bhat 1997), or district-level data (Echavarri and Ezcurra 2010). However, a challenge when trying to infer associations from these data is that the established relationships could be influenced by a whole host of confounding factors. Several of the main findings, such as those by Mayer (1999) and Das Gupta and Mari Bhat (1997), are also quite dated. To deal with these inferential concerns and to determine whether previously identified trends are still present in India today, we employ more recent and disaggregated data than those used in earlier studies. We rely on subdistrict-level data and examine cross-sectional patterns and the association between local-level changes in female literacy and child sex ratios.

Data Sources and Measures

Our study relies on data from the Indian Censuses of 2001 and 2011. The Census covers the entire country, thereby offering the most up-to-date and comprehensive snapshot of Indian reproductive behaviour possible. Our main data set comprises subdistrict-level census data. At the time of the most recent census, in 2011, India was divided into 28 states and seven union territories, which were in turn subdivided into 640 districts and 5,960 subdistricts. Each subdistrict is home to an average of about 1,95,000 people.[3] The Censuses of 2001 and 2011 are of particular interest because they allow us to examine local-level changes over time. We can link subdistrict-level data from one census to the next—this was challenging when working with older data.

To identify local-level changes over time, we linked subdistrict-level data from the 2011 Census to corresponding subdistricts in the 2001 Census.[4] Of the 5,958 subdistricts for which 2011 data are available, 5,939 subdistricts were linked to the 2001 data. Data were missing for two subdistricts in the 2011 data and three in the 2001 data. In addition, the subdistricts in the city of Hyderabad differed between the data sets and could not be linked. Some 512 subdistricts from 2001 were linked to more than one 2011 subdistrict; this was because these subdistricts had split during the 10-year interval between censuses. For these cases, we used the old subdistrict as the match for both of the new subdistricts in 2011. We could have also split the values for the old subdistricts between the new ones (evenly or weighted by population), but as the variables used in this study are proportional in nature (literacy rates, sex ratios, and so on), the results would not have been different if we had.[5]

We had access to census data for villages and towns, which are units below the subdistrict-level. However, there are advantages to working with subdistrict-level data. First, subdistrict-level data are already highly disaggregated. Second, it is much easier to link subdistricts than villages and towns over time, as fewer subdistricts change names, split or merge, or change status (for example, when villages become towns). Therefore, subdistrict level data is more reliable than village- or town-level data. Using subdistrict-level data has a further advantage: information on several important covariates—including the religious composition of the population—is not available below the subdistrict level.

Table 1 provides summary statistics for the variables used in the analysis. Following the convention for analysing sex ratios in India, we calculate the sex ratio as the number of females per 1,000 males.[6] The child sex ratio is the number of girls (age 0–6 years) per 1,000 boys (age 0–6 years). In 2001, the sex ratio in the full population was approximately 10 points higher than that among children; by 2011, the gap had grown to almost 30 points. The average subdistrict-level child sex ratio was 942 in 2001 and 932 in 2011. These values are higher than the all-India figures, as they are unweighted averages across all subdistricts, and child sex ratios are often lower in subdistricts with larger than average populations. However, the change over time in the average child sex ratio in our data is similar to the change in the national average—a drop of about 10 points over these years.

Again, following the conventional method in India, we calculated female literacy as the number of literate women in a subdistrict, divided by the number of women in the population above six years of age. Between 2001 and 2011, subdistrict-level female literacy increased by about 12 percentage points on average. Importantly, only a few subdistricts were close to achieving full literacy at the time the census data was collected, so increases in literacy were possible across most subdistricts. For example, in 2001, 1.1% of subdistricts had a literacy rate above 90%; by 2011, this had increased only to 2.3% of subdistricts. We use census data to calculate the percentage of the working female population in a subdistrict; the percentage of agricultural labourers; and the percentages of Scheduled Tribes (STs), Scheduled Castes (SCs), and Muslims. These are the control variables in our models.

Table 1: Summary Statistics of Key Variables from the Indian Censuses of 2001 and 2011

	Mean	Standard Div	Minimum	Median	Maximum	N
Child sex ratio, 2001	942.3	47.8	555.6	949.2	1,309.9	5,455
Child sex ratio, 2011	932.3	47	569.3	937.4	1,461.5	5,958
Change in child sex ratio, 2001–11	-10.6	43.5	-466.5	-10	586.5	5,939
Female literacy, 2001	47.8	16.4	3.6	47.1	97.2	5,455
Female literacy, 2011	59.8	13.7	9.6	59.3	98.5	5,958
Change in female literacy, 2001–11	12	7.2	-34.3	11.8	53.8	5,939
% of women working, 2001	32.7	14.4	3.4	33.9	72.6	5,455
% of women working, 2011	32.7	14.3	3.7	33.2	79.1	5,958
Change in women working, 2001–11	0.1	7.8	-45.2	0.4	53	5,939
% of women agriculture labourers, 2001	8.3	6.7	0	6.9	36.6	5,455
% of SC, 2001	15.7	9.5	0	15.5	74.6	5,455
% of ST, 2001	16.5	26.8	0	3.5	100	5,455
% of Muslims, 2001	10.1	14.7	0	5.3	99.6	5,455

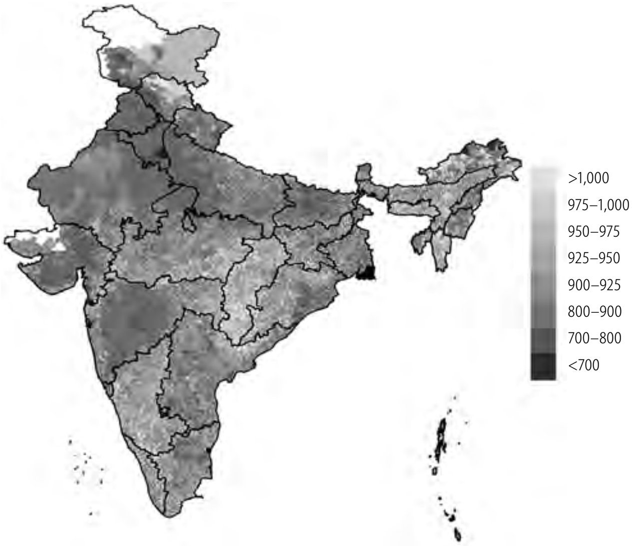
Source: GoI (2001, 2011).

Our other primary source is the 2011 Census F-series (Fertility Tables; GOI 2011). Data include information about all women in India, subdivided into age groups ranging from <15 to 80+ years, in five-year intervals, and into seven educational attainment levels, ranging from “illiterate” to “graduate and above.” For each group, data include the number of girl and boy children ever born to a female respondent (Census Table F-3) and the number of these who survive (Census Table F-7). These data are described further in the paper.

India’s Declining Child Sex Ratios

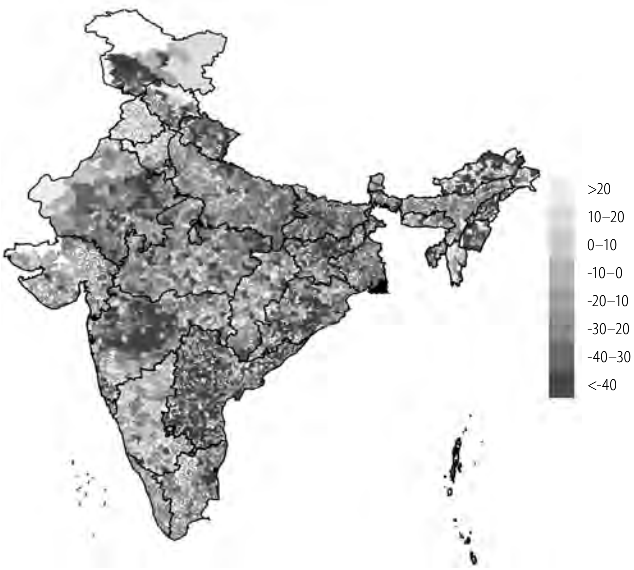
The *Economist* (2017) recently declared that the “war on baby girls is winding down.” Similarly, a 2011 United Nations (UN) report stated that the imbalance between boys and girls in some countries (including India) seems to be “levelling off” (UNFPA 2011). These findings are accurate as regards the

Figure 1: Subdistrict-level Child Sex Ratio (F/M, Aged 0–6 Years) across India in 2011



Authors' calculations based on primary census abstract data from 2011. Map shapefiles from ML-info.
Source: Government of India (2011).

Figure 2: Change in Child Sex Ratios (F/M, Aged 0–6 Years) across India, 2001–11



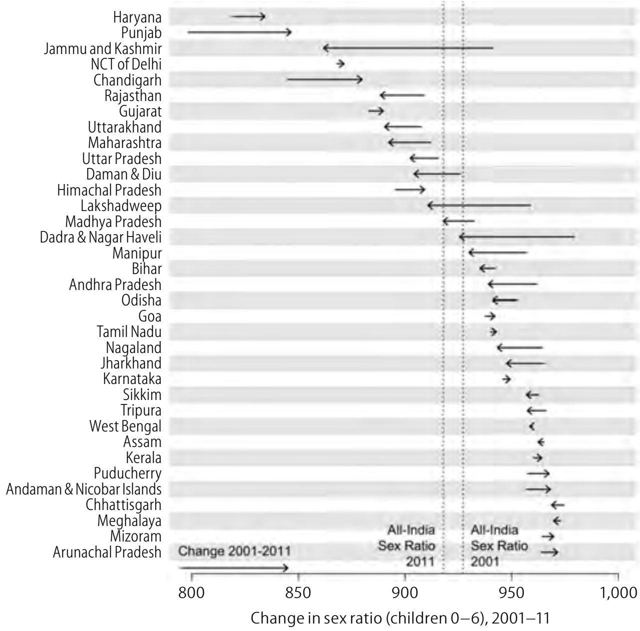
Authors' calculations based on primary census abstract data from 2001 and 2011. Map shapefiles from ML-info.
Source: GoI (2001, 2011).

overall sex ratio in India, which improved between 2001 and 2011—probably due to better health services for adult women.[7] However, the child sex ratio (aged 0–6 years) is still declining.

The map in Figure 1 shows the 2011 sex ratio among children aged 0–6 years across India's subdistricts. The areas in light gray—those with sex ratios greater than 975—are clustered in Andhra Pradesh (AP), Chhattisgarh, Odisha, and the North East. The areas in dark gray are mostly in the north and west, in states infamous for their low sex ratios, like Haryana and Punjab, but also in other large states, like Gujarat, Maharashtra, Rajasthan, and Uttar Pradesh (UP).

To some extent, this pattern confirms the north–south divide that Dyson and Moore (1983) established using 1901–81 Census

Figure 3: Statewise Changes in Child Sex Ratios, 2001–11



Source: Authors' analysis based on GoI (2001, 2011).

data. However, the pattern has been weakened by current trends, as shown in the map in Figure 2. The worst offender states have improved since 2001: both Haryana and Punjab had higher child sex ratios in 2011 than in 2001. However, there were significant declines elsewhere—AP, Maharashtra, Madhya Pradesh, Rajasthan, and UP. It is also no longer true that the south does not have a missing girls problem.

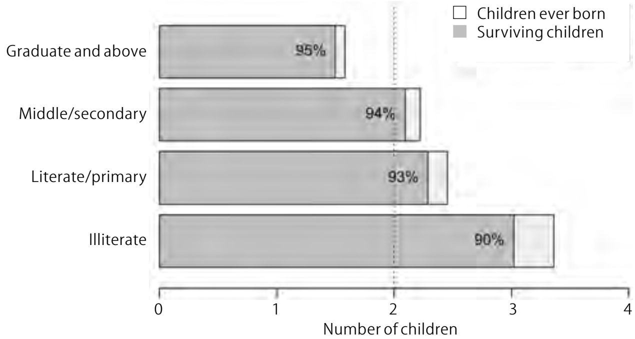
Differences between communities have also reduced over time. While there are small variations in the sex ratios of the children of Hindus and Muslims, the main outliers are Christians (with a higher-than-average sex ratio) and Sikhs (with a lower-than-average sex ratio).[8]

Statewise changes in child sex ratios between 2001 and 2011 are clearly evident in Figure 3. Here, the grey dotted lines indicate the average statewise sex ratio of 927 in 2001 and 918 in 2011, showing an overall decline in this 10-year period of about nine points. For each state, we show the change between 2001 and 2011 with an arrow. The starting point of the arrow indicates the value in 2001 and the arrowhead shows the value in 2011. The states are arranged in ascending order according to the values they had in 2011—Haryana on top with a sex ratio of 834 in 2011 (up from 819 in 2001) and Punjab in second place, with a sex ratio of 846 (up from 798 in 2001). Figure 3 demonstrates how sex ratios have worsened in states like Jammu and Kashmir, Rajasthan, AP, and several north-eastern states. None of the large states other than Haryana, Punjab, and Himachal Pradesh experienced major improvements over this period.

Female Education, Natality, and Survival

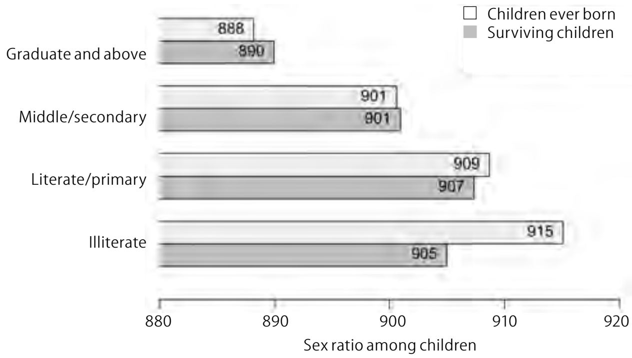
The literature from the past few decades provides evidence that female education in India is associated with lower female fertility (Reddy 2003) and higher female mortality (Mayer 1999; Das Gupta and Mari Bhat 1997). To explore

Figure 4: Number of Children of Mothers Aged 30–44 Years, All-India Data, 2011



Source: Authors' analysis based on GoI (2011).

Figure 5: Sex Ratio of Children of Mothers Aged 30–44 Years, All-India Data, 2011



Source: Authors' analysis based on GoI (2011).

whether these trends are still present, we examine data from the Fertility Series of the Census of 2011. These data provide information about the number of children born to women with different levels of education and include information about all women in India (some 58,75,84,719 individuals). As it was not obvious how to rank-order all of the original educational categories, we collapsed the information about women's educational attainment into four categories that could easily be rank-ordered: "illiterate," "literate or completed primary school," "completed middle school, secondary school, or entered university without graduating," and "graduate or above."

Figure 4 shows the average number of children born to married women, aged 30–44 years, of various education levels, and the number of these children who were still alive at the time of data collection. We chose to present data for women aged 30–44 years because they had entered their childbearing years after sex-selective abortion had become widely available in India, but were also old enough to have had several children. These criteria reduced the data set to 12,10,48,306 women. Consistent with previous findings, we find a strong association between women's education level and the number of children they have (fertility) and how many of their children survive (mortality).

Figure 5 shows the sex ratios of all children born to mothers aged 30–44 years, and the sex ratios of their surviving children. Here, we see quite clearly both the positive and negative associations between female education and sex ratios indicated earlier (Bourne and Walker 1991; Bhalotra and Cochrane 2010; Echávarri and Ezcurra 2010; Mayer 1999; Murthi et al 1995). The light grey bars indicate a strong negative relationship between a mother's educational attainment and the sex ratio of the children born to her, with educated women—university graduates in particular—having fewer girl children. Importantly, the difference is not only between literate and illiterate women: the higher the educational level of the mother, the fewer girls she bears.

The patterns shown in Figures 4 and 5 are consistent with the "intensification effect" that Das Gupta and Mari Bhat (1997) explained based on 1981 and 1991 Census data. As the education level among women rises, they tend to have fewer children overall and, therefore, are less likely to give birth to a son naturally. Given the strong cultural preferences for sons (Guilmoto 2009), better access to healthcare and enhanced knowledge of sex-selection technologies seem to make sex-selective abortion more common (Bhalotra and Cochrane 2010; Madan and Breuning 2014).

As the differences between each pair of bars in Figure 5 demonstrate quite plainly, there is also a positive association between womens' education and the survival of the woman's female children. Educated women have fewer girl children, but these girls are as likely to survive as their brothers. Here, the differences between women with varying levels of education are not so large. Among illiterate women, however, we note a large drop in the sex ratios of children ever born and surviving children, which suggests that female infanticide and neglect are issues of particular concern in the case of illiterate mothers. This pattern is consistent with the findings of Jayachandran and Kuziemko (2011), which are that the number of years of schooling a woman has is negatively associated with other aspects of parenting, such as breastfeeding.

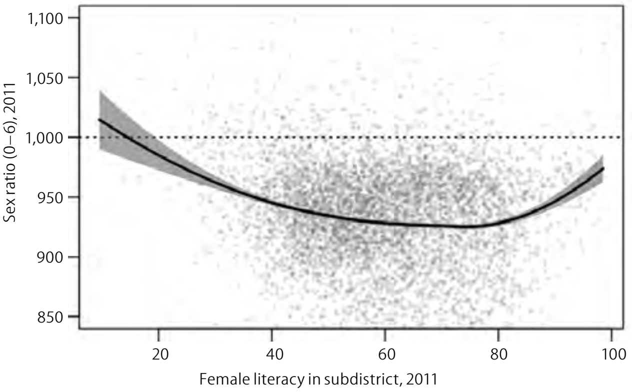
Female Literacy and Sex Ratios

The previous section confirmed that female education is strongly associated with lower female natality and higher female survival. But what has been the overall association between changes in women's education and child sex ratios in India between 2001 and 2011?

To answer this question, we turn to the subdistrict-level data from the Censuses of 2001 and 2011. From these data, we have access to information about the number of boys and girls, aged 0–6 years, the share of literate women in the population, and the changes seen between 2001 and 2011 in these variables. The bivariate association between these variables is shown in Figure 6 (p 57), where each of the grey dots represents the value for one of the subdistricts in the data; the black line is a trend line based on a LOESS regression model, and the grey area around it is the 95% confidence interval. We see a clear curvilinear association in these raw data, with the highest sex ratios found in subdistricts that have very low or very high female literacy.

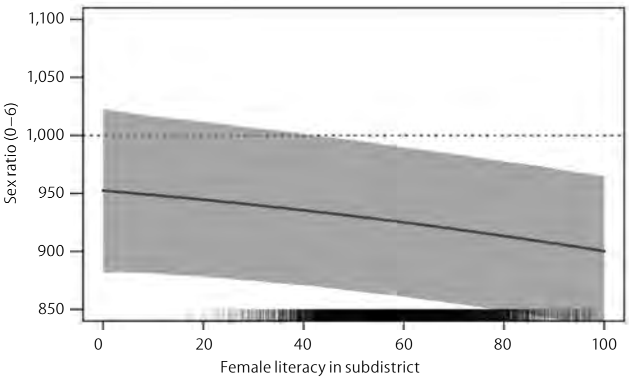
This bivariate pattern is likely to be confounded by other differences between subdistricts. To explore this relationship further, we look at multivariate regression models that allow us to control for some of these other factors.

Figure 6: Female Literacy and Sex Ratios across India's Subdistricts in 2011



Source: Authors' analysis based on GoI (2011).

Figure 7: Female Literacy and Sex Ratios in India in 2011—Predictions from a Multivariate Model



Source: Authors' analysis.

Our baseline model for examining the association between the subdistrict-level child sex ratio and female literacy in 2011 is

$$SR_i = \beta_0 + \beta_1 FL_i + \beta_2 FL_i^2 + \varepsilon_i \quad \text{... (1)}$$

where SR_i is the child sex ratio in 2011 in each subdistrict I; FL_i is the subdistrict-level female literacy in 2011; FL_i^2 is the squared term of female literacy to account for the curvilinearity we observed in the raw data; and ε_i is an error term.

To control for potential confounding factors, we also added district fixed effects and control variables to this baseline model: the percentage of the female population in a subdistrict that was working, since employment status could be associated with the social standing of women; the percentage of agricultural labourers, which is indicative of the overall socio-economic status of the population; and the percentage of STs and SCs in the subdistrict, as these are considered particularly vulnerable communities and are known to have higher sex ratios.

Table 2: Regression Models of Subdistrict Level Child Sex Ratio (F/M) in 2011, Explained by Female Literacy in 2011

	Model 1	Model 2	Model 3	Model 4
Intercept	1,052.85***	915.50***	900.21***	861.90***
	(10.36)	(17.18)	(18.23)	(19.55)
Female literacy	-3.79**	-0.63	-0.35	-0.38
	(0.35)	(0.49)	(0.50)	(0.50)
Female literacy squared	0.03***	-0.00	-0.00	-0.00
	(0.00)	(0.00)	(0.00)	(0.00)
Percentage of women working, 2011			-0.08	0.02
			(0.10)	(0.11)
Percentage of agriculture labourers, 2011			0.07	0.05
			(0.11)	(0.11)
Percentage of SC, 2011			0.22*	0.36***
			(0.09)	(0.09)
Percentage of ST, 2011			0.37***	0.42***
			(0.05)	(0.05)
Percentage of Muslims, 2011				0.38***
				(0.06)
District fixed effects	No	Yes	Yes	Yes
N	5,958	5,958	5,958	5,958
R^2	0.03	0.60	0.61	0.61
adj R^2	0.03	0.55	0.56	0.56
Resid sd	46.20	31.39	31.17	31.08

Linear regression models of child sex ratios in 2011 on female literacy in 2011 (cross-sectional). Robust (heteroscedasticity-consistent) standard errors in parentheses.
† significant at $p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$.

Table 2 shows the output from the models regressing the child sex ratio in 2011 with female literacy in the same subdistrict in 2011. Model 1 is a bivariate specification; Model 2 includes district fixed effects; Model 3 includes the control variables just described; and Model 4 also includes the percentage of Muslims in the subdistrict, as this is considered an important sex ratio predictor (Guillot and Allendorf 2010; Bhalotra et al 2010). As this last variable is from the 2001 Census, it reduces the sample size (the 2011 values have not been released). The association between female literacy and sex ratios is negative across all specifications. However, the size of the female literacy coefficient is much lower when we include district fixed effects (and it is no longer statistically significant). The coefficient for female literacy squared is significant in the bivariate model but not in the models that include district fixed effects.

Figure 7 shows the output from Model 3 in Table 2. The vertical lines at the bottom of the plot indicate the location of the underlying subdistrict-level observations. The shaded area represents a 95% confidence interval based on robust (heteroscedasticity-consistent) standard errors. As shown clearly in Figure 7, there is a weak, negative association between female literacy and sex ratios at the subdistrict level in the 2011 data. It is important to note that the curvilinearity observed in the raw data disappears when we include control variables.

To further control for possible confounding factors, we turn to the relationship between the subdistrict-level change in both women's literacy and sex ratios. Our change score model, a variation on our baseline model, is

$$\Delta SR_i = \beta_0 + \beta_1 \Delta FL_i + \beta_2 \Delta FL_i^2 + \varepsilon_i \quad \text{... (2)}$$

where i stands for subdistrict, ΔSR_i is the subdistrict-level change in the child sex ratio between 2001 and 2011, ΔFL_i is the subdistrict-level change in the female literacy between 2001 and 2011, ΔFL_i^2 is the squared term of this change, and ε_i is an error term. We also add district fixed effects and subdistrict-level control variables to this baseline model.

Table 3 (p 58) shows the output from the regression models of the association between the change in child sex ratio and female literacy between 2001 and 2011. Model 1 is bivariate; Model 2 includes district fixed effects; Model 3 includes control variables related to the share of women working and the overall socio-economic situation in the subdistrict; and Model 4 has demographic characteristics including the share of SCs, STs, and Muslims in the population.

Table 3: Regression Models of Changes in Subdistrict Level Child Sex Ratios (F/M) between 2001 and 2011, Explained by Change in Female Literacy

	Model 1	Model 2	Model 3	Model 4
Intercept	-4.98***	-100.96***	-102.58***	-116.04***
	(1.16)	(23.91)	(25.73)	(26.19)
Change female literacy	-0.63***	-0.80***	-0.93***	-0.93***
	(0.13)	(0.23)	(0.25)	(0.25)
Change female literacy squared	0.01†	0.01	0.01	0.01
	(0.01)	(0.01)	(0.01)	(0.01)
Change women working			-0.42**	-0.40**
			(0.15)	(0.15)
Female literacy, 2001			0.04	0.11
			(0.01)	(0.11)
Percentage of agriculture labourers, 2001			0.27	0.21
			(0.17)	(0.18)
Percentage of SC, 2001				0.33***
				(0.10)
Percentage of ST, 2001				0.16*
				(0.06)
Percentage of Muslims, 2001				0.10†
				(0.06)
District fixed effects	No	Yes	Yes	Yes
N	5,939	5,939	5,939	5,939
R^2	0.01	0.27	0.28	0.28
adj R^2	0.01	0.19	0.19	0.19
Resid sd	43.41	39.28	39.20	39.16

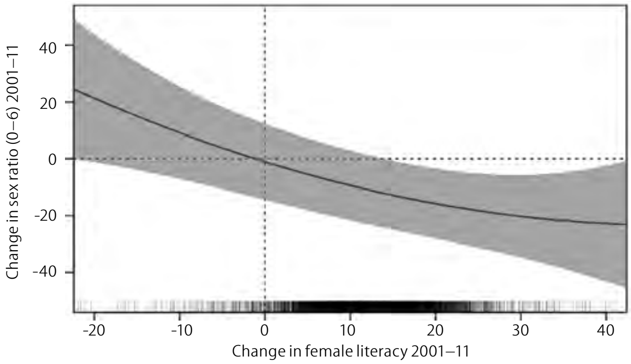
Linear regression models of child sex ratios 2001–11 on change in female literacy 2001–11 (change score models). Robust (heteroscedasticity-consistent) standard errors in parentheses.
† significant at $p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$.

The coefficient for the change in female literacy is substantively large and significant across the specifications. This means that subdistricts in India that experienced an increase in female literacy from 2001 to 2011 were also, on average, more likely to show a decrease in their sex ratio during the same period. The coefficient of -0.93 in the last model suggests that subdistricts, on average, experienced decreases in their sex ratios that were proportional to the increases they experienced in female literacy.

Figure 8 shows predictions from the change score model (Model 4) presented in Table 3. The vertical lines at the bottom of the plots indicate the location of the underlying subdistrict-level observations. The shaded areas represent 95% confidence intervals based on robust (heteroscedasticity-consistent) standard errors. Here, we see a strong negative association between changes in female literacy and sex ratios—whereas literacy for women increased between 2001 and 2011, the share of girls born dropped dramatically.

In Table 3, we present the output from the change score models. A regressor variable model (or lagged dependent variable model) is another common model for examining change over time. Based on the discussion in Allison's (1990) paper, a change score model seems most appropriate given our data. However, noting the discussion in Diamond-Smith and Bishai's (2015) article, we also present regressor variable models to check the robustness of our results. Our regressor variable

Figure 8: Changes in Female Literacy and Sex Ratios in India, 2001–2011—Predictions from a Multivariate Model



Source: Authors' analysis.

model, in which the sex ratio in 2011 is regressed on the sex ratio in the same subdistrict in 2001, is as follows:

$$SR_{2011i} = \beta_0 + \beta_1 \Delta FL_i + \beta_2 \Delta FL_i^2 + SR_{2011i} + \varepsilon_i \quad \text{... (3)}$$

Results based upon regressor variable models are shown in Table 4. Except for the lagged dependent variable model, all specifications are the same as those shown in Table 3. Here too, the coefficient for the change in female literacy is substantively large and significant across the specifications, showing that our main finding is robust to this alternative model specification.

Table 4: Regression Models of Subdistrict Level Child Sex Ratio (F/M) in 2011, Explained by Change in Female Literacy and Child Sex Ratio (F/M) in 2001

	Model 1	Model 2	Model 3	Model 4
Intercept	402.43***	676.21***	731.49***	705.80***
	(16.41)	(32.92)	(34.79)	(34.40)
Change female literacy	-0.66***	-0.19	-0.76***	-0.71***
	(0.12)	(0.20)	(0.20)	(0.21)
Change female literacy squared	0.03***	0.01	0.00	0.00
	(0.00)	(0.01)	(0.01)	(0.01)
Sex ratio 2001	0.57***	0.21***	0.18***	0.17***
	(0.02)	(0.03)	(0.03)	(0.03)
Change women working			-0.20†	-0.16
			(0.10)	(0.10)
Female literacy, 2001			-0.63***	-0.41)***
			(0.09)	(0.09)
Percentage of agriculture labourers, 2001			0.01	0.07
			(0.14)	(0.14)
Percentage of SC, 2001				0.34***
				(0.08)
Percentage of ST, 2001				0.39***
				(0.05)
Percentage of Muslims, 2001				0.29***
				(0.05)
District fixed effects	No	Yes	Yes	Yes
N	5,939	5,939	5,939	5,939
R^2	0.34	0.61	0.61	0.62
adj R^2	0.34	0.56	0.57	0.58
Resid sd	38.24	31.27	30.92	30.66

Linear regression models of child sex ratios 2001 on change in female literacy 2001–11 and child sex ratio (F/M) in 2001 (regressor variable models). Robust (heteroscedasticity-consistent) standard errors in parentheses.
† significant at $p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$.
Source: Authors' analysis.

Concluding Discussion

Our analysis shows that, overall, local-level increases in female literacy are negatively associated with child sex ratios. Although the survival rate of girls born to educated women is higher, this positive trend does not offset the negative trend of educated mothers choosing to abort girl children. These findings serve as an important reminder that development is not free of perverse consequences and that those who engage in its promotion need to be sensitive to its complexities. The objectives and measures of development can sometimes undercut other aspects of the process. In this case, a type of development that is generally considered positive and has many desirable effects—increase in women's education—is negatively associated with perhaps the most basic human right: the right to life.

Importantly, a fuller understanding of the nuances of this association can help us develop better policies to combat the dwindling numbers of girls. It appears that more-educated women are more likely to select the sex of their child, but if they do have girls, it is because they want them, so they do not neglect them after birth. As many educated women are well-off financially, our findings cast doubt on the efficacy of economic incentives—such as the 2015 campaign Aapki Beti Humari Beti (Your Daughter is Our Daughter) or the longer-standing Devi Rupak campaign in Haryana to space childbirth, which were examined recently by Anukriti (2018)—in improving child sex ratios. Such programmes may be ineffective among educated women who are most likely to sex-selectively abort while rewarding impoverished, less-educated women, who are likely not to have aborted anyway.

Our findings indicate the need for at least two distinct policy approaches to combat the problem of missing girls: among educated women, printed materials and the educational system might be used to challenge cultural preferences for sons since the main goal should be to discourage sex-selective abortions. However, among less-educated populations, particularly illiterate ones, governments should focus on economic or—in light of Anukriti's (2018) work—other rewards for better treatment of girls in order to increase their survival rates.

NOTES

1 Our data cover children aged 0–6.

2 However, others have found a complex relationship beween the literacy of girl children and women's labour force participation in India (Sundaram and Vanneman 2008).

3 A new state, Telangana, was carved out of Andhra Pradesh in 2014; in the 2011 data, Telangana was still a part of Andhra Pradesh.

4 This could, to some extent, be done using link codes purchased from the Census of India office in New Delhi. However, as there were many errors in these files, several of the links were created by manually identifying subdistricts across the two data sets using their names and various geographic information system (GIS) maps.

5 These subdistrict-level data included territories that are home to about 95% of the Indian population. The remaining areas were not organised under any subdistrict. We included some remote territories and the four fully urban districts of Kolkata, Mumbai suburban, Mumbai, and Chennai. The findings and conclusions are robust; they include district-level data for these four districts.

6 This is distinct from the convention in demographics literature, which generally uses the ratio of men to women.

7 Improved healthcare for some adult women, however, does not necessarily balance out the other perverse consequences of the preference for sons: negative fertility behaviours that affect health outcomes for adult women (Milazzo 2018).

8 The subdistrict-level analysis by community is available upon request.

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