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Evidence of Self-correction of Child Sex Ratios in India: A District-Level Analysis of Child Sex Ratios From 1981 to 2011

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Abstract

Sex ratios in India have become increasingly imbalanced over the past decades. We hypothesize that when sex ratios become very uneven, the shortage of girls will increase girls' future value, leading sex ratios to self-correct. Using data on children under 5 from the last four Indian censuses, we examine the relationship between the sex ratio at one point in time and the change in sex ratio over the next 10 years by district. Fixed-effects models show that when accounting for unobserved district-level characteristics—including total fertility rate, infant mortality rate, percentage literate, percentage rural, percentage scheduled caste, percentage scheduled tribe, and a time trend variable—sex ratios are significantly negatively correlated with the change in sex ratio in the successive 10-year period. This suggests that self-corrective forces are at work on imbalanced sex ratios in India.

Keywords

India; Child sex ratios; Fertility; Fixed-effects models

Introduction

Uneven sex ratios at birth and throughout childhood have been noted for decades in India, where the ratio is imbalanced in favor of boys (Jha et al. 2011). This imbalance is hypothesized to be due to a strong cultural preference for sons, access to sex-selective technologies, and a declining fertility rate (Guilmoto 2009). In India as a whole in 2011, there were 914 girls for every 1,000 boys under six years old, compared with 927/1,000 in 2001 and 945/1,000 in 1991 (Jha et al. 2011). Most of the increase in imbalance is thought to be due to greater use of sex-selective abortion rather than excess mortality for girls, although both contribute to the imbalance in children under 6 (Jha et al. 2011). Desired sex ratios (as reported by individuals) in India are even higher than actual sex ratios in most

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states, suggesting that with increased access to sex-selective technologies in the future, sex ratios could become even more imbalanced (Bongaarts 2013).

Much media and scholarly attention over the past few years has been devoted to the increasingly imbalanced sex ratios in India, which may have dire consequences for marriage patterns, social stability, violence, and mental health (Guilmoto 2012; Hesketh 2011). Scholars have suggested that 40 million men will remain single between 2020 and 2080 in India (Guilmoto 2012). Men spending longer periods outside unions may increase their exposure to sex with prostitutes, thereby posing the threat of an increase of sexually transmitted diseases and HIV/AIDS, as has been evidenced in China (Tucker et al. 2006). Additionally, evidence from China has suggested that a more imbalanced sex ratio (by 0.01) increased violent and property crimes by 5 % to 6 % (Edlund et al. 2007). More imbalanced district-level sex ratios in India are associated with theft, breaking and entering, assault, and the perception that women are harassed more (South et al. 2014). Other research in India has found a relationship between sex ratios and both violence and homicide rates (as a whole, not only against women) (Hudson and Den Boer 2002). These authors also suggested that men who are unmarried are more likely to join military groups, which could lead to more domestic or regional violence. Other research has suggested that uneven sex ratios could increase sex trafficking (Hesketh and Xing 2006). These studies do not prove causality, but they do suggest that there may be negative social outcomes related to imbalanced sex ratios.

Increasingly imbalanced sex ratios are not sustainable in the long term at a population level because of biological, social, and economic factors. We expect that population-level sex ratios would begin to self-correct at some point, perhaps due to social forces such as the labor or marriage market. Recent research on the 2011 census has noted that the child sex ratio in three states appeared to have equalized slightly, although the country as a whole has become more imbalanced (Navaneetham and Dharmalingam 2011). No research to date, however, has looked at this phenomenon in more detail or at a district level. This article explores the changing pattern of Indian sex ratios at a district level, controlling for other social and demographic factors. By looking for evidence of previously very imbalanced districts beginning to balance out in more detail, we can understand whether it is occurring at a district level (not just state level), where in the country is it occurring, and what the main predictors of reduced imbalance may be.

Background

The “natural” sex ratio at birth (meaning the sex ratio in a population that is not using sex-selective technologies to alter its sex ratio or is not experiencing environmental stresses) is estimated at around 105 males born for every 100 females (Dyson 2012).[1] However, male neonates and infants have higher mortality rates than females. For example, diarrheal disease, tuberculosis, measles, diphtheria, pneumonia, syphilis, respiratory distress syndrome, and sudden infant death syndrome all show higher mortality in the postnatal period for males compared with females (Wells 2000). Overall, male infants show a higher

[1]The literature on sex ratios conventionally uses a ratio of the number of boys to the number of girls, whereas the discussion of sex ratios in India uses the reverse (the ratio of number of girls to the number of boys). In this article, we use the same standard as is customarily used for India (girls/boys), unless otherwise specified.

propensity to become malnourished and are less robust in general (Wells 2000). Therefore, there are biological contributors to uneven child sex ratios, which may be contributing to the imbalanced sex ratio observed in India today. However, we support the view of the majority of scholars in the field that the primary cause is sociocultural.

A great deal of past literature has focused on the causes and consequences of son preference in Asia, especially in India and China (Arnold et al. 1998; Das Gupta 2009). Not only is there a preference for sons, but there are also disadvantages to having daughters (Chakraborty and Kim 2012). Past qualitative research in southern India has shown that women are well aware of the economic benefit of boys and that families are actually averse to having girls due to the costs of marriage. However, girls do provide other important benefits in terms of emotional support and care. As one respondent described, “Two boys and one girl is enough because two boys will support themselves, and the girl will be more useful to me. When I am old with problems, she will come to help me” (Diamond-Smith et al. 2008:702).

Since Amartya Sen first described 100 million missing women in Asia in the 1990s, much attention has focused on understanding the causes, consequences, and magnitude of son preference and daughter discrimination (Sen 1990). Since Sen’s publication, other authors have tried to estimate the number of missing women in India in various periods. Research in the 1990s suggested that over 1 million girls were “missing” due to sex-selective abortion and female infanticide between 1981 and 1991 (Das Gupta and Bhat 1997). Recent work by Roy and Chattopadhyay (2012) projected the likely sex ratio at birth in India given historical trends in fertility decline and sex-selective behavior by parity as well as future projections about fertility decline. Their median projection of the peak sex ratio at birth for 2021–2026 (which is when fertility is projected to fall to replacement level in India) is 117 boys/100 girls (which is about 85.5 girls/100 boys in the reverse ratio form) (Roy and Chattopadhyay 2012). Much of this imbalance is due to son preference and sex selection in a select group of states mostly in northwest India. If son preference and sex selection spreads increasingly to other parts of the country where it is currently lower, such as the southeast, the authors estimated that the peak sex ratio at birth could be closer to 124 boys/100 girls (about 81 girls/100 boys). Other research looking at the spread of imbalanced sex ratios in India has suggested that areas with highly imbalanced sex ratios act as epicenters, from which imbalance spills outward over time. However, the opposite is also true: areas of relative equality affect their surrounding areas to lower imbalance over time (Kuzhiparambil and Rajani 2012).

From a biological perspective, there are limits to the number of generations that a gender imbalance can be sustained at a population level (Trivers and Willard 1973). Eventually, the scarcity of the rarer gender makes offspring of the superfluous gender a less rewarding reproductive strategy Fisher’s principle predicts long-term failure for any mutant-attempting reproductive success by consistently producing more male or female progeny (Fischer 1930). Over the long run, most species oscillate around a stable gender balance that is remarkably close to 1:1 (Fischer 1930). In human populations, cognitive mechanisms and social signaling could potentially recognize that one gender is in shortage and hence more valuable in terms of future wages and reproductive potential. Human populations that achieve surplus boys using stopping rules, sex-selective abortion, and differential child treatment can make choices to reduce these practices on the margin when they recognize an increased value of girls due to shortage. However, so far, there has been little evidence to suggest that human populations self-correct their sex ratios in response to marked imbalance (Judson 1994; Tuljapurkar et al. 1995).

We hypothesize that when we control for other factors associated with changing sex ratios, populations with more imbalanced sex ratios will see proportionately greater corrective change in the subsequent sex ratios over time, compared with districts with less imbalanced sex ratios. We use census data from 1981 to 2011 to investigate the plausibility of the self-correction process by analyzing the correlation between sex ratios in Indian districts and the subsequent change in sex ratios over the next 10 years.

Data and Methods

Data

District-level data from the 1981–2011 censuses are collected from various sources of the Indian Census Bureau (see Table 6 in the appendix for data sources). Because infant mortality rates are not yet available at a district level for the 2011 censuses, data from Annual Health Survey 2010 and Sample Registration System of 2010 are used for the major states (available at the district level), and state-level infant mortality rates from the 2011 census are used for non-major states (Registrar General and Census Commissioner 2012; Registrar General of India 2011).

District boundaries in India have changed significantly over the past 40 years, with some districts split into smaller districts and new states created. Districts that were split into new, smaller districts kept information about the full districts that they came from for the older years. For example, if a district was split into smaller districts in 1995, the same data from the original district in 1981 and 1991 are used in the model (entered twice), and then the individual data for the two new districts are used for 2001 and 2011. In some cases, new districts were created from more than one former district; in that case, the new district used information from the original district that constituted the largest proportion of the new district. Much of the information about changing district boundaries came from Kumar and Somanathan (2009). Jammu, Kashmir, and Assam are dropped from the analysis because of civil strife that interfered with census data collection at various times between 1981 and 2011.

Methods

The dependent variable of this analysis is the change in child sex ratio between two censuses (for example, between 1981 and 1991). This is calculated by subtracting the child sex ratio in the prior period from the child sex ratio in the later period. The main predictor of interest is the child sex ratio in the earlier period (in this case, periods are 10 years between each census). The child sex ratio is the ratio of the count of living girls to living boys under age six in each district. Control variables (for each census year from 1981 to 2011) include the total fertility rate (TFR), the infant mortality rate (IMR), the percentage of adults in each district who were literate, the percentage of female adults who were literate, the percentage of each district that was Scheduled Caste and Scheduled Tribe, and the percentage of each district that is rural. Scheduled Caste (SC) refers to the castes at the bottom of the caste hierarchy in India, and Scheduled Tribe (ST) refers to the tribal populations, which live mostly in the northern Indian states of Bihar, Gujarat, Maharashtra, Madhya Pradesh, Orissa, Rajasthan, and West Bengal, as well as in North-East India (Gang et al. 2008). SC and ST populations make up about 25 % of the country's total population, but almost 50 % of India's poor are in these groups (Gang et al. 2008). Additionally, a time trend variable and an interaction term between time trend and sex ratio lagged 10 years are included. To account for the fact that the populations of states and territories differ substantially, all models are weight-adjusted by the mean population size of that district over the 30-year period.

Rational for Control Variables Included—Choice of control variables was based on variables included in models in previous literature in the long history of research on declining child sex ratios (e.g., Murthi et al. 1995). The TFR is strongly associated with son preference and sex ratios. As people are choosing to have fewer children, they are more pressured to have the gender of children they want in a narrower window (Guilmoto 2009). Fertility has been declining rapidly in India, heightening son preference because families are more pressured to have their desired number of sons as soon as possible (Basu 1999). Many studies have explored the relationship between IMR and TFR given that they often fall in similar periods. Some literature suggests that a decline in IMR allows families to feel safe having fewer children (they have more assurance that some children will live to adulthood) and therefore precedes a decline in TFR; this is consistent with the general idea of the demographic transition theory (for a summary, see Kirk 1996). Other research is not as conclusive that IMR falls before TFR, and suggests that by having smaller families, parents are better able to care for and invest in the children they have, thereby lowering IMR (Bongaarts 1987; Rosenzweig and Schultz 1983). Evidence also suggests that other changes (such as improvements in sanitation) have an impact on both of these factors, but they themselves are not causally related (Newell and Gazeley 2012).

Past research has found that child sex ratios were more imbalanced in urban areas than rural areas (Jha et al. 2011). Although ultrasounds and abortions are available in rural areas, their use usually begins in urban areas and moves to rural areas, and therefore may be less accessible in rural areas (Akbulut-Yuksel and Rosenblum 2012). Also, fertility tends to be lower in urban areas, thereby heightening the pressure to have sons as soon as possible where son preference exists (Guilmoto and Rajan 2001). More-educated and wealthier families (and therefore those more likely to live in urban areas) are more likely to have imbalanced sex ratios (Subramanian and Selvaraj 2009).

Literacy rates are used as a proxy for educational status, as has been done in other studies in this setting. Echavarri and Ezcurra (2010), for example, modeled both the percentage literate and square of percentage literate of all adults, just women, and just men in their models looking at sex ratios. Few differences arose in this analysis (and in ours) for the different measures of literacy (all, female, and male); therefore, we use percentage of adults literate and the square of this in our models.

There is a long history of poorer educational attainment, occupational choices and income, and health outcomes for ST/SC populations compared with non-ST/SC populations in India. For example, infants, children, and the elderly from ST and SC groups had higher mortality than nonscheduled populations (Subramanian et al. 2006). However, there is evidence of a reduction in the gap in education and wages in recent years, although states with larger ST populations have shown less convergence in wages and education compared with SC and non-scheduled populations (Hnatkovskay and Lahiri 2012). Other work has found that the causes of poverty for ST and SC populations differ, with the social constrictions created by the caste system being more important for SC population, while the occupational structure is more important for ST populations (Gang et al. 2008). These findings suggest that SC and ST populations should be accounted for in the model separately.

Unfortunately, we were unable to include other variables revolving around socioeconomic indicators, such as per capita income and access to health care, as has been used by past scholars, because these data are not in the census data (Murthi et al. 1995).

Models—We estimate a series of fixed-effects models to account for unobservable district-level factors that we hypothesize do not change over time. The fixed-effects models are run multiple times. Models 1A–F test for robustness by adding and removing different variables. Model 1A includes only the change in sex ratio over 10 years and the lagged sex ratio (10 years prior). Model 1B adds covariates for time trend and an interaction term for time trend and the sex ratio lagged 10 years. Model 1C includes covariates for the TFR and the IMR in each period but without the time trend variables in Model 1B. Model 1D includes variables about rural/urban percentage, literacy, and SC/ST percentage, again without the time trend variables. Model 1E combines both Models 1C and 1D. Model 1F extends Model 1E to include the time trend variables.

The fixed-effects model is then run separately in different regions of India: north, south, east, west, and northeast (see Table 3 for the states included in each region) (Model 1G). This is done to test for any differences in different regions of the country, which have different patterns of gender preference, cultural practices in general, fertility, child mortality, development, and so on.

Finally, a series of robustness tests are run on the full model. First, we test a child sex ratio lagged by 20 years instead of 10 years on the outcome of the change in child sex ratio (Model 1H). Second, we rerun the model with dummy variables for the time trend, as opposed to a single time trend variable. Because there are three actual periods (even though there are four time points of data collection), we include dummy variables for time for periods 2 and 3 (Model 1I). Finally, we run a new model (Model 2) with the main outcome of interest being the child sex ratio, rather the change in the child sex ratio between the two times. In this model, we are regressing the child sex ratio in one time point on the child sex ratio in the next time point.

Results

The change over time in the main covariates of interest at the district level is shown in Table 1. The national child sex ratio fell from 978.86 girls per 1,000 boys to 921.58 girls per 1,000 boys under age 6 between 1981 and 2011. The TRF fell from 5.12 to 2.81, and the IMR rate decreased from 116/1,000 to 47/1,000, which is a remarkable change in 30 years. The percentage of literate adults increased more than twofold, from about 35 % to 74 %, and rate of literacy among adult females increased from 24 % to 65 %. The percentage rural decreased over time (from 79 % to 75 %), and there was little change in the percentage of each district that was SC or ST (about 15 % and 17 %, respectively).

Figures 1–3 show the relationship between the change in sex ratio (y-axis) and the sex ratio 10 years prior at the state level (x-axis). Anything below 0 on the y-axis means that the sex ratio became more uneven in the intervening 10-year period. As shown in Fig. 1, there does not seem to be much of a relationship between the sex ratio in 1981 and the change in sex ratio in the next period.

In Fig. 2, we can see that the states that were the most uneven in 1991 became even more uneven in 2001. However, Fig. 3 shows the opposite trend: districts that were more imbalanced in 2001 showed positive change (became less imbalanced in 2011), whereas districts that were less imbalanced in 2001 became more imbalanced in 2011. From these three graphs, we can see that most of the improvement is centered in a few states and territories (Punjab, Haryana, Gujarat, Delhi, and Chandigarh).

Fixed-Effects Models

As can be seen in Table 2, TFR, percentage total literacy and female literacy, percentage SC, and percentage ST were positively and significantly associated with the main outcome of interest: the change in child sex ratio. IMR and percentage rural were negatively and significantly associated with change in child sex ratio.

In the bivariate fixed-effects model of the main predictor of interest on the change in child sex ratio, the higher the sex ratio in the previous period, the more it declined in the next period (Model 1A, −0.617, $p < .01$) (Table 3). Thus, in districts where the sex ratio was lower, the change in sex ratio became less imbalanced than in districts where the sex ratio was higher, suggesting that as sex ratios fall, the pace of their fall lessens. In other words, a higher starting sex ratio (a less-imbalanced sex ratio) leads to more imbalance; however, having an already imbalanced sex ratio leads to less imbalance in the following period. This is consistent with a deceleration model.

This effect became larger after the time trend variables were controlled for, and the interaction term between time and district was significantly associated with the outcome (Model 1B, $p < .01$). When only TFR and IMR were controlled for (without the time trend variables, Model 1C), the main effect remained significant and larger than in the basic model, and an increase in TFR was associated with an increase in the change in sex ratio (10.115, $p < .01$). In Model 1D, when percentage rural, female literacy, female literacy squared, and caste were taken into account, the main effect remained significant and was larger than in the basic model. An increase in the percentage of female adults who were literate increased the change in child sex ratio (more imbalance) ($p < .01$), and the squared female literacy was associated with a change in the sex ratio (less imbalance) ($p < .01$). The larger the percentage of the district that was ST, the higher the sex ratio change ($p < .10$). The percentage rural and percentage SC were not significantly associated.

In Model 1E, where all covariates except for the time trend variables were added, all the aforementioned factors remained significantly associated with the sex ratio change to the same significance level and similar magnitude. The final model, Model 1F, includes all the aforementioned covariates; and again, all covariates that were significant remain significant in the same direction, with similar magnitude, and with the same level of significance. This suggests that the model is robust and provides strong evidence that a more unbalanced sex ratio in an earlier period is associated with more equality in the sex ratio in the next period. The R squared value improves with the addition of more variables, and the final model with all covariates has the largest R squared (.641).

Regional Differences

Figure 4 shows the districts in which child sex ratios became less imbalanced between 2001 and 2011 (shaded districts in the figure). In all other districts, the child sex ratio fell between the two time points. Some of the districts that equalized are clustered in four regions, and the rest are scattered. Starting at the north, many of the districts that showed equalization are in Haryana, Punjab, Himachal Pradesh, and the territories of Delhi and Chandigarh. There is some spillover into Rajasthan and Uttrakhand. Of the 21 districts in Haryana, 17 showed equalization; 20 of the 22 districts in Punjab showed equalization. This cluster also includes much of New Delhi and Chandigarh.

The second cluster of districts is in Gujarat, in western India. Of the 32 districts in Gujarat, 12 showed equalization, and these are clustered around the capital of Gujarat, Ahmedabad. The third cluster is in the south, mostly occurring in Tamil Nadu and Karnataka, with some spillover into Kerala and Maharashtra, although not all districts in these states have shown equalization. The fourth cluster is the northeastern region, on the eastern side of Bangladesh, and includes districts in Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, and Nagaland; however, not all districts are in any one of these states.

As shown in Figs. 5, 6, 7, 8 and 9, the pattern of improvement in 2011 among the most uneven districts in 2001 can be most strongly seen in the north, south, west, and northeast, and less so in the east. The strong downward trend between 1991 and 2001 is most clearly visible in the north and west. (See Fig. 6.)

The fixed-effects model was run on different regions of the country: north, south, east, west, and northeast region (Model 1G, Table 4). The lagged sex ratio was statistically significantly associated with the sex ratio in all models, with a less uneven sex ratio in the earlier period associated with a more uneven sex ratio in the following period. The TFR was positively and significantly associated in the north and northeast ($p < .05$). Infant mortality was negatively and significantly associated with the change in child sex ratio in the north. Female literacy and literacy squared acted differently in different regions: female literacy was positively associated in the north and negatively related in the south, west, or northeast; and female literacy squared was negatively associated in the north and east and positively associated in the south and west. Percentage rural was not significantly associated for any regions. Percentage SC and percentage ST were negatively associated in the northeast region. The time trend and interaction between time trend and lagged sex ratio were significant in the north, south and northeast region. The time trend and district interaction variable was significantly positively associated in the north, south, and east, and negatively association in the west and northeast.

Robustness Checks

We ran three alterations on the model to test for robustness (Table 5). First, we regressed the sex ratio lagged 20 years on the main outcome of the change in child sex ratio. In this model, a less-imbalanced child sex ratio 20 years before was associated with a positive change in the child sex ratio. The IMR was significantly associated, with a higher IMR being associated with a positive change in child sex ratio. TFR, female literacy, and the three time trend variables were significantly associated with the outcome.

Second, we included time dummy variables rather than a single time trend variable (Model 1I, Table 5). Because there are only three measures of differences in time, we included two time dummy variables (Time Dummy Variable and Time Dummy Variable 3). Using dummy variables did not change the significance or direction of any of the variables compared with the full model (Model 1F).

We next ran another model regressing the lagged child sex ratio on the child sex ratio in the next period, rather than the change in child sex ratio (Model 2, Table 5). In this model, a higher lagged child sex ratio was associated with a higher child sex ratio in the next period ($p < .01$). All other covariates had the same significance and direction as in the full model (Model 1F).

Discussion

Overall, the sex ratio in children has fallen in India over the past 30 years. This has been concurrent with a fall in the TFR from 5.12 to 2.81 and the IMR from 115.7/1000 to 46.55/1000. Literacy for the population as a whole and for women specifically has risen over the 30-year period. A smaller proportion of districts are rural, and about the same percentage of the population of districts are ST and SC. All these changes are in the direction expected for a rapidly developing country, although India does lag behind other countries, especially in female literacy rates (for example, China's female literacy rate in 2007 was 88.5 %).[2]

Our models find that when other demographic factors are controlled for, districts in India that have historically had increasingly imbalanced sex ratios are beginning to decelerate their decline and, in some cases, have even begun to equalize in their sex ratios. This suggests that as sex ratios become increasingly imbalanced, people begin to adjust their

[2]Data were retrieved from the CIA World Factbook (https://www.cia.gov/library/publications/the-worldfactbook/).

behavior to avoid discriminating against their female children as much. In other words, the situation for girls begins to improve as girls become increasingly scarce.

Theoretically, a decline in TFR should accompany an increasingly imbalanced sex ratio, as discussed earlier (Basu 1999; Guilmoto 2009). When families have fewer children and son preference still exists, they are more pressured to have the desired number of sons in a smaller number of child “slots.” Therefore, the sex ratio in children is expected to become more imbalanced. As expected, TFR is significantly associated with the change in child sex ratio in the fixed-effects model, with a lower TFR being associated with more imbalanced sex ratios.

We expected that the percentage of the population that was rural would have been associated with the changing child sex ratio because past research suggested that sex ratios are more uneven in urban areas. The relationship between rural percentage and sex ratio in this study might have been subsumed under the other factors related to rural populations, such as TFR and literacy, which were significantly associated.

The percentage of the population that was ST was associated with the change in child sex ratio, although percentage SC was not. This supports other research that SC and ST are different and thus should not be clumped together. More research could explore what differentiates ST and SC populations in terms of their preference for sons or use of sex-selective technologies, and why larger ST populations might be associated with more equalization in sex ratios as they become more imbalanced.

Extensive literature has explored and argued about the relationship between education and sex ratios in India (Echavarri and Ezcurra 2010). The debate revolves around whether more education will lead people to change their values to have lower levels of son preference, thereby leading to less sex discrimination; or instead whether more highly educated individuals are better able to act on their desires and to use sex-selective technology, thereby increasing imbalanced sex ratios (Bhat and Zavier 2003; Clark 2000). Recent work has suggested that the relationship between education and sex ratios follows an inverted U-shaped pattern, where initially with increasing education, sex ratios become more imbalanced, and then sex ratios begin to fall at higher levels of educational attainment (Echavarri and Ezcurra 2010). We ran our models for both female literacy and female literacy squared, and overall literacy and overall literacy squared: there were not substantive differences. Therefore, only female literacy is shown here. Our analysis supported the findings that female education acts in a U-shape: female education at first makes the child sex ratio more uneven, but then when it is higher, it acts in the opposite direction.

The districts in which child sex ratios equalized between 2001 and 2011 were mostly clustered in four regions: the north around Punjab, Haryana, Delhi, and Chandigarh; the west around the capital for Gujarat; the south extending contiguously from southern Tamil Nadu up through Karnataka; and the northeastern region, east of Bangladesh. The north and west clusters are similar in that their child sex ratios had become extremely low (very imbalanced). They were, in fact, two of the most imbalanced regions in the country in 2001. Child sex ratios in the south and northeastern clusters were not as imbalanced in 2001 (or

2011); they were higher than the national average. These areas have traditionally had much lower rates of son preference and less imbalanced sex ratios (or not imbalanced at all) compared with the rest of the country (Dyson and Moore 1983).

The pattern of the southern cluster is interesting because it is fairly narrow and follows the contours of the West Ghats, which are a north-to-south mountain range separating much of Kerala and Tamil Nadu. Past literature has described an “infanticide belt” in Tamil Nadu, which is very similar to the stretch of equalizing districts found in this analysis in the south (Chunkath and Athreya 1997; Vella and Oliveau 2005). Vella and Oliveau (2005) argued that infanticide spread from a few specific areas in Tamil Nadu to contiguous districts through social diffusion. Specifically, they suggested that the Kongu Vellalar Gounders caste had high son preference and infanticide because of their work in agriculture; and because this is a high caste, these practices were spread via social propagation to lower castes in nearby districts (Vella and Oliveau 2005). Much attention has been devoted to the high levels of infanticide in this region, and therefore many programs and government efforts have focused on reducing female infanticide in this region (Athreya and Chunkath 2000). Perhaps, therefore, the equalization in the child sex ratio in this area is due to reductions in infanticide following the same diffusion pattern along the “infanticide belt” as in the past (Srinivasan and Bedi 2008; Vella and Oliveau 2005). More research on this is needed.

In northeast India, the districts that have shown equalization are not as contiguous as the other clusters and are scattered among a number of states. It is possible that this does not actually represent a cluster of equalization. These states have a very different culture than the rest of India, have higher proportions of tribal populations, and have experienced political unrest and violence in the recent decades due to a separatist movement (Shimray 2004). Due to the unrest, conducting research in this area has been difficult, and very little research on gender preference or child sex ratios has occurred in this region. Interestingly, some states in the northeast, such as Meghalaya, have a tradition of daughter preference, which could help explain the rebound from the slightly imbalanced sex ratios seen in the past (Narzary and Sharma 2013). More research on gender preferences in this part of the country could help us understand the trends in child sex ratios seen today.

In the fixed-effects models, regional differences exist, although all regions showed the same relationship between the lagged child sex ratio and the change in child sex ratio in the next period as the full country model. The relationships found in the full model between the main outcome and TFR and literacy were most strongly replicated in the north and northeast, which has the states and territories that have shown the largest decline in child sex ratio and subsequent improvement (Haryana, Punjab, Chandigarh, and Delhi). The northeast region has a higher percentage of SC and ST than other regions, which perhaps explains the significance of these two variables in that region compared with others. Overall, most of the variables in the east and west regions that we were able to include in the model from the census data were not significant, perhaps suggesting that other factors are more importantly associated with changing child sex ratios in these regions.

The relationship between the most recent lagged child sex ratio and the change in child sex ratio switches direction when that outcome is modeled on a 20-year lagged sex ratio, although it is still significant. This could suggest that the level of the child sex ratio in an earlier period is reflective of the level that it will rebound to, even after a dip into unevenness in intervening years. Using time dummy variables rather than a single variable for the time trend did not change the relationships in the model. Therefore, we are confident in using a single variable to account for the period in all the other models in this analysis.

When child sex ratio in one year is regressed on itself in the next period, we see that a higher child sex ratio in an earlier period is associated with a higher child sex ratio in the later period. This seems contrary to our findings in the first model that a higher change in child sex ratio in an earlier period is associated with more decline in the next period. However, we do not think these are in conflict, but rather that they are measuring different phenomena. This model is really identifying that there are districts with less imbalanced sex ratios, and even though they might decline some, they are still going to be in a subset of higher and less imbalanced sex ratio districts. In other words, it is a measure of magnitude at both time points. When we take away the influence of the magnitude, we are able to focus on change itself and thereby measure something beyond the fact that higher sex ratio districts remain higher, and lower remain lower. Additionally, the districts that have started to become less imbalanced are doing so only slightly, especially compared with the rate and magnitude of change in the districts that are becoming more imbalanced. This is hidden when the model considers only magnitude, but can be picked up on in the model looking at change.

This study uses four decades of census data and controls for other factors that are associated with changing child sex ratios, such as fertility and infant mortality, to look at trends in child sex ratios over time. It highlights a yet unexplored phenomenon of improving child sex ratios in some of the districts that previously had the most skewed child sex ratios. The richness of census data (large sample size, covering the whole population) also brings some challenges and limitations. The changing district and state boundaries over the past 30 years in India created challenges for merging the data from the censuses of each year. Newly created districts were given information about past indicators of the entire districts from which they were formed. It is possible that when a district divided, the portion of the original district from which the new district was formed had different levels of the covariates of interest than the district as a whole. If this is the case, then applying the full district rates of the original district for the newly formed district is problematic. However, there is limited (or no) information about the covariates of the subportion of the original district from which the new district was formed.

A vast body of literature has looked at the quality of the data collected in the census and Sample Registration System. There is evidence of underreporting of births, deaths, and age misreporting throughout the country, with heterogeneity in quality between states (Retherford and Mishra 2001). Larger states have been found to have better-quality data. Using demographic estimation methods to test the quality of the data, other work has suggested that the quality was fairly good in the 1970s and 1980s but deteriorated in the 1990s. For example, Bhat (2002) found that underenumeration for men was 0.7 % worse in the 1991 census compared with the 1981 census, and 1.4 % worse for females. The most recent 2011 census made a specific effort to improve enumeration of women (Navaneetham and Dharmalingam 2011). Despite problems in the Indian censuses, it is the only source for district-level estimates of our variables of interest and is therefore our only source for answering these questions at a district level (Guilmoto and Rajan 2013).

Most likely, the underenumeration is in more disadvantaged populations (poorer, more rural, more likely to be ST/SC). Because this analysis finds that sex ratios are more imbalanced in urban, wealthier, more-educated populations, imbalance may actually be underrepresented. Assuming that whatever makes the data quality poorer in one state is consistent over time, then the fixed-effects model helps control for these state-/district-level factors.

Fertility starting in 1981 was estimated at the district level and has, for the last four censuses, taken into account potential age misreporting and corrected for poor-quality data on morality (Guilmoto and Rajan 2001, 2013). Evidence suggests that reporting for children aged 6 and under in the censuses is fairly high quality (Bhat 1996); therefore, the computation of the child sex ratio is straightforward (a ratio of girls to boys taken from the population age structure). Infant mortality has been estimated from the 1981–2001 censuses at a district level. Research double-checking the quality of the IMR trends calculated from the census by using the Brass method to calculate IMR (which takes into account problems in age misreporting and misreporting of infant and child mortality) found that the census estimates were fairly strong (Sarma and Choudhury 2012). This article does not attempt to correct for possible data-quality problems using demographic estimation techniques.

Conclusions

Child sex ratios in India as a whole have become increasingly imbalanced in recent decades. However, this analysis provides evidence that a subset of the districts and states that have been on the steepest downward slope in imbalance appear to be decelerating their decline and are beginning to see equalization in their child sex ratios. This suggests that the districts that had the most imbalanced sex ratios hit some type of inflection point from which they have begun to rebound; sex ratios do not appear to fall indefinitely. Additionally, although child sex ratios in this subset of districts have begun to improve, the child sex ratios in many of these districts still remain very skewed.

Although this is a promising trend that is important to understand more in depth, as this analysis has begun to do, these findings by no means suggest that we should be complacent or that skewed sex ratios will "fix themselves." First, the question remains as to whether the remaining (majority) of the districts in India will have to fall to the same level of imbalance before beginning to equalize. If this is the case, there would likely be many more years of increasingly imbalanced sex ratios before the country as a whole begins moving upward, and even longer before sex ratios become close to normal (even). This would mean many more years of discrimination against girls, owing to both sex-selective abortions and excess mortality for girls. Of course, there still is no evidence that this deceleration and upward trend will be sustained permanently or even temporarily. Understanding which of the components that makes up the child sex ratio (abortion and excess girl mortality) is responsible for the equalization seen in some districts and states is key to both reducing these practices and knowing how the trend will change in the future.

Evidence from this analysis helps us understand which populations might be at risk in future years of having increasingly imbalanced sex ratios. These findings suggest that as women's literacy rate rises, we are likely to see increasingly imbalanced sex ratios, but as it becomes even higher, this slope will decline and perhaps reverse. Declining fertility is unsurprisingly associated with sex ratio imbalance. Interestingly, states with larger ST populations showed more deceleration in their sex ratio imbalance, and this finding deserves more careful exploration.

Further work needs to explore what factors are associated with the selfcorrection in sex ratios. A shortage of women in the marriage market or the labor market (therefore driving up women's wages) may be mechanisms for this change. Also possible is that laws or programs aimed to decrease sex-selective abortion or improve the status of girls have had an effect on this trend. Some evidence has suggested that the Pre-natal Diagnostic Technique Act of 1996, which aimed to regulate and eliminate the misuse of sex-selective technologies, did not have an impact on the probability of a family having a boy (Subramanian and Selvaraj 2009). A variety of schemes have attempted to improve the welfare of Indian girls, but data on the extent and quality of their implementation and impact are of poor quality (Sekher 2010, 2012).

At first glance, the findings of this analysis are optimistic in that sex ratio imbalance does not appear to continue downward forever. However, if all states had to reach such an imbalanced sex ratio as is seen in the more imbalanced districts of India before beginning to equalize, the situation for girls in India would remain dire. Raising the threshold at which states decelerate and reverse could potentially save the lives of millions of girls and reduce sex-selective abortions. This analysis helps us understand the factors associated with this very nascent trend, and the next steps are to explore its components and potential mechanisms for change.

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Appendix

Table 6

Data sources

	1981	1991	2001	2011
CSR	E	E	B	B
IMR	D	D	F	G
TFR	D	D	H	H
Population Size	A	A	B	B
% SC	A	A	C	C

	1981	1991	2001	2011
% ST	A	A	C	C
Literacy (total and female)	A	A	B	B
% Rural	A	A	C	C

A: Directly from the Indian Census, sent in a STATA file by Vinod Mishra (Office of the Registrar General 1981, 1991).

B: 2011 Indian census: Primary census abstract (online) (Office of the Registrar General 2013a).

C: Census of India website (Office of the Registrar General 2013c)

D: Office of Registrar General (1997).

E: Hand entered from census records in University of California, Berkeley library (Office of the Registrar General 1981, 1991).

F: Office of the Registrar General (2009).

G: For Andhra Pradesh, Gujarat, Haryana, Karnataka, Kerala, Maharashtra, Punjab, Tamil Nadu, West Bengal, and Himachal Pradesh, Office of the Registrar General (2013b), For Daman and Diu, Dadra and Nagar, and Chandigarh, Office of the Registrar General (2013d), or state-level census data for 2011, where we could not find district-level estimates (Goa, Mizoram, Meghalaya, Manipur, Sikkim, Tripura, Arunachal Pradesh) (Office of the Registrar General 2013c).

H: Guilmoto and Rajan (2013).

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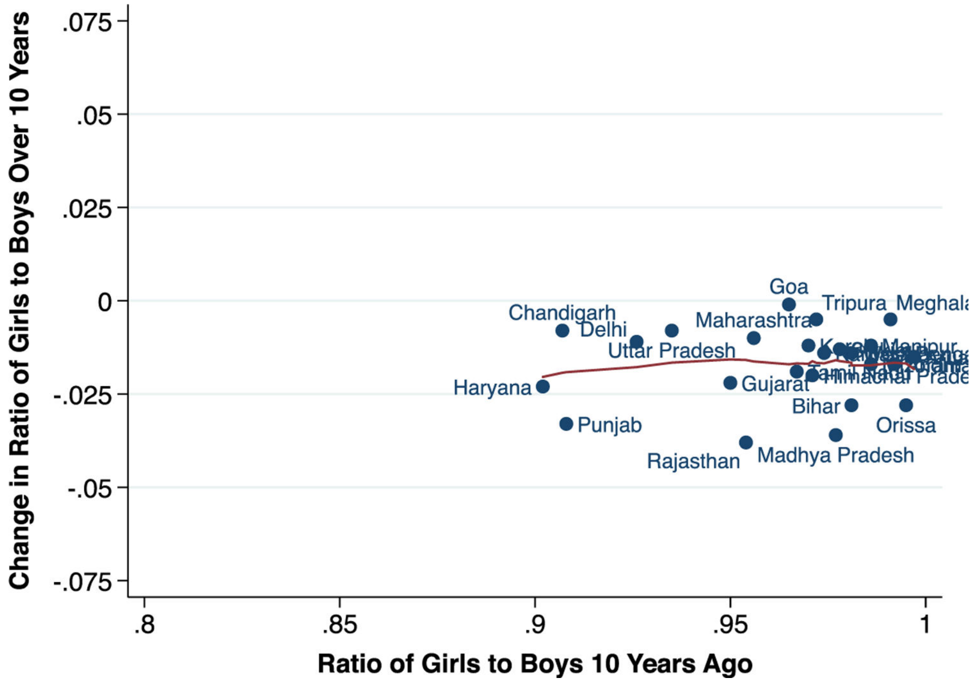

Fig. 1.

Sex ratio change 1981–1991 versus sex ratio in 1981

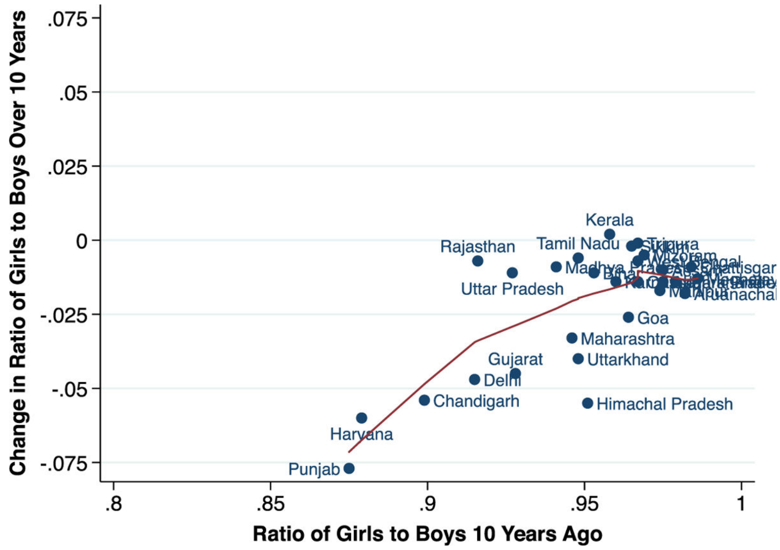

Fig. 2.

Sex ratio change 1991–2001 versus sex ratio in 1991

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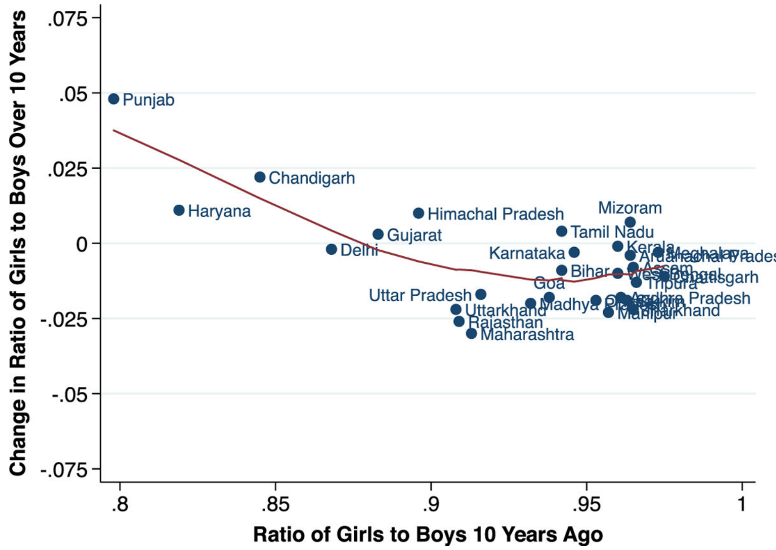

Fig. 3.

Sex ratio change 2001–2011 versus sex ratio in 2001

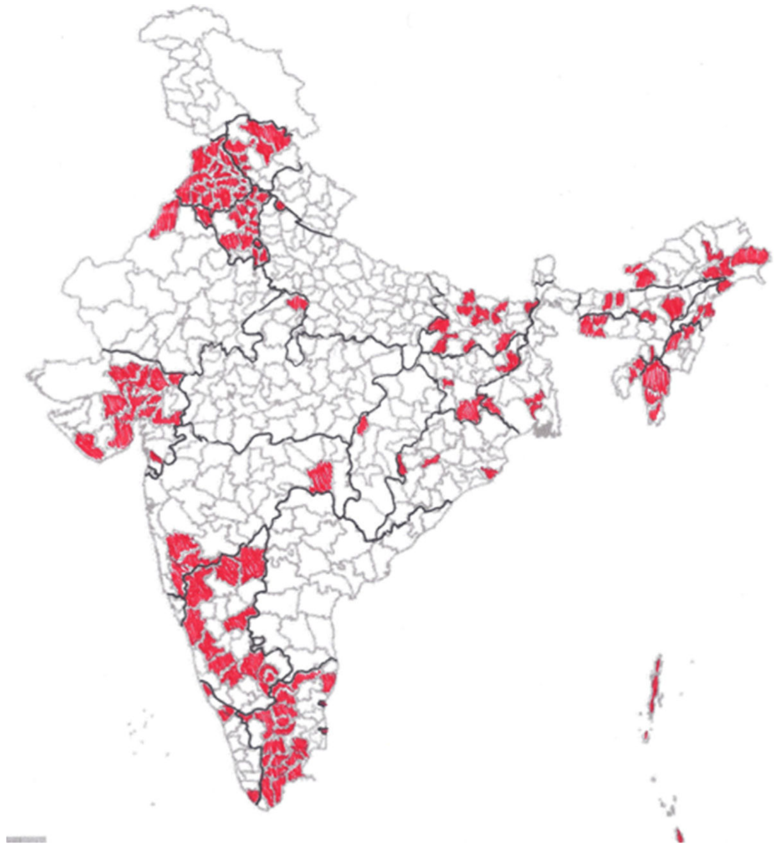

Fig. 4.
Map of India, with shaded districts being those in which the child sex ratio equalized between 2001 and 2011

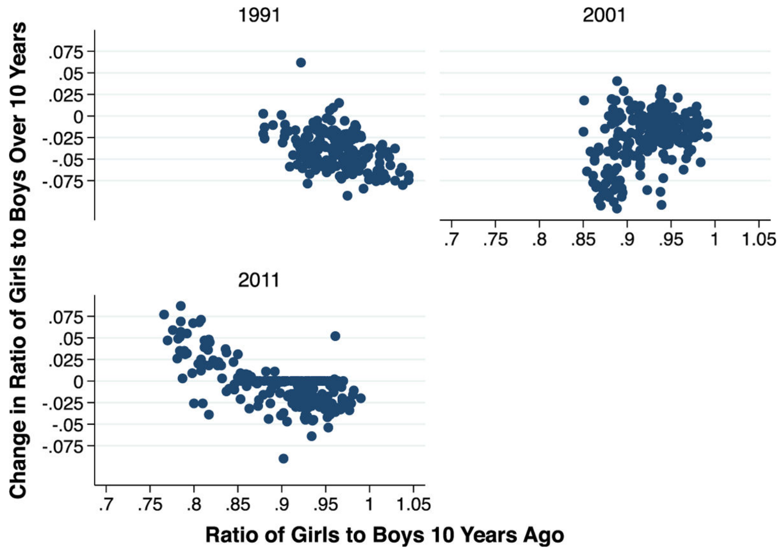

Fig. 5.

North: Sex ratio change by region: sex ratio change 1981–1991 versus sex ratio in 1981; sex ratio change 1991–2001 versus sex ratio in 1991; and sex ratio change 2001–2011 versus sex ratio in 2001

Fig. 6.
South: Sex ratio change by region: sex ratio change 1981–1991 versus sex ratio in 1981; sex ratio change 1991–2001 versus sex ratio in 1991; and sex ratio change 2001–2011 versus sex ratio in 2001

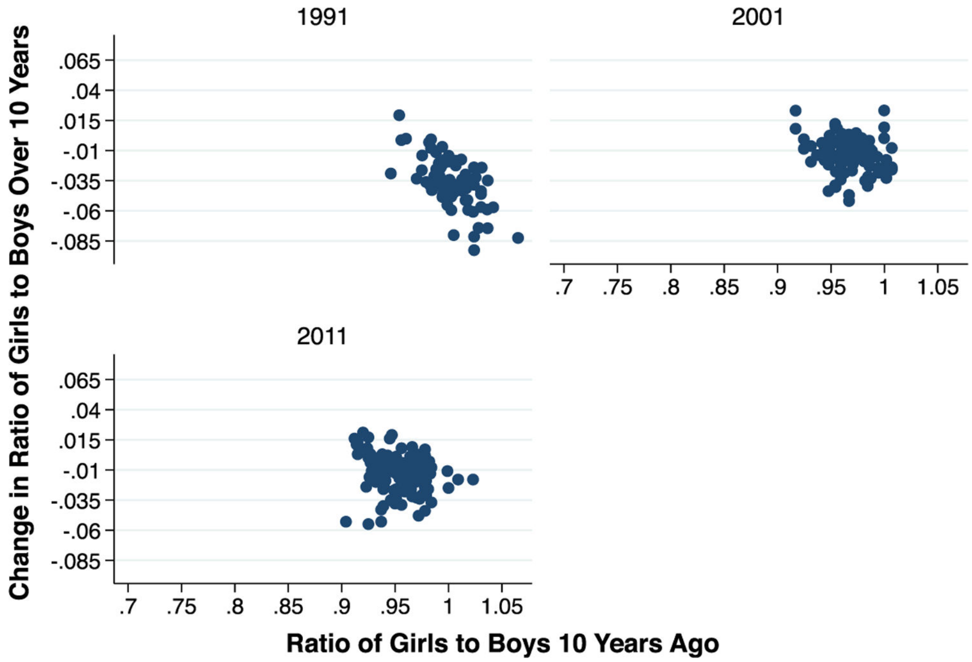

Fig. 7.

East: Sex ratio change by region: sex ratio change 1981–1991 versus sex ratio in 1981; sex ratio −2001 versus sex ratio in 1991; and sex ratio change 2001–2011 versus sex ratio in 2001

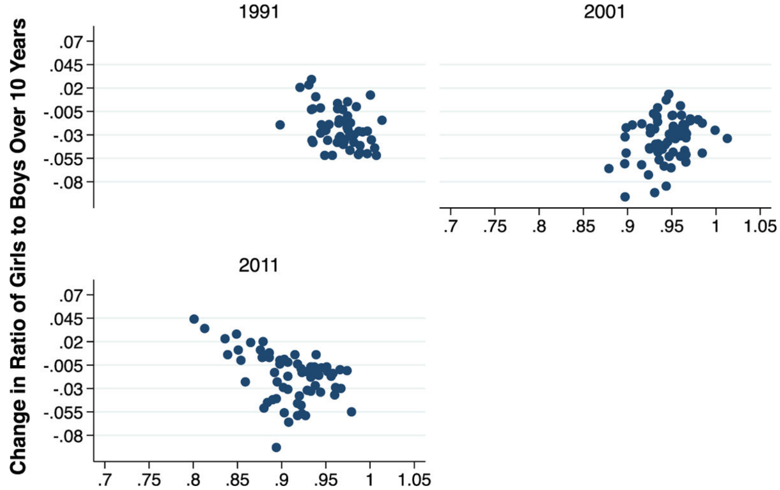

Fig. 8.

West: Sex ratio change by region: sex ratio change 1981–1991 versus sex ratio in 1981; sex ratio change 1991–2001 versus sex ratio in 1991; and sex ratio change 2001–2011 versus sex ratio in 2001

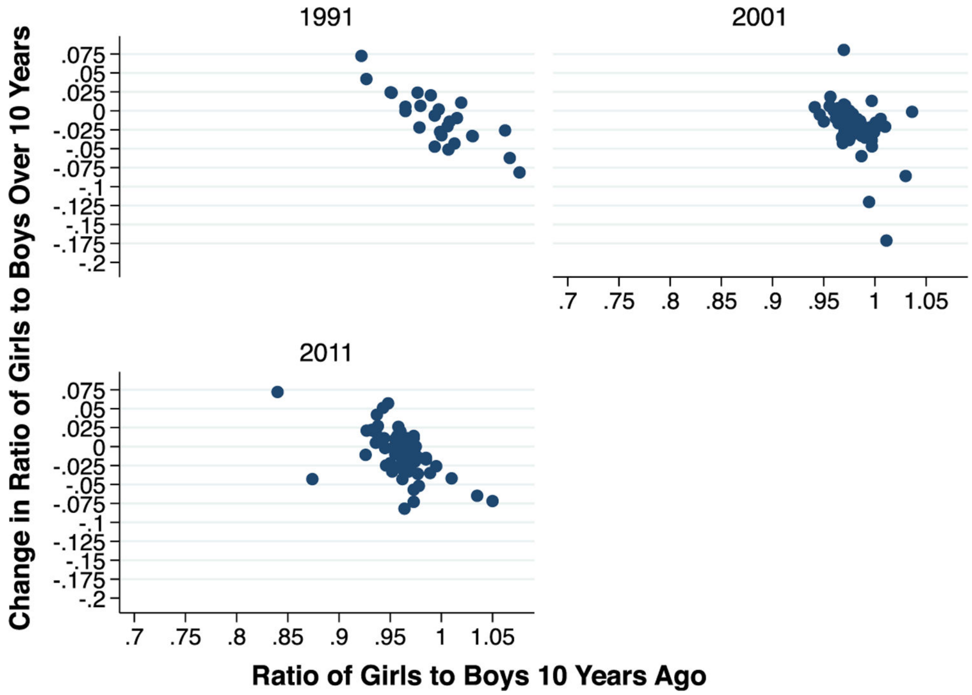

Fig. 9.

Northeast: Sex ratio change by region: sex ratio change 1981–1991 versus sex ratio in 1981; sex ratio change 1991–2001 versus sex ratio in 1991; and sex ratio change 2001–2011 versus sex ratio in 2001

Table 1

Mean and range of covariates in 1981, 1991, 2001, and 2011 (N = 590 per year)

	Total Missing (over all four periods)	1981	1991	2001	2011
Child Sex Ratio	44	978.86 (878.9, 1,076.4)	948.42 (848.6, 1,036.3)	929.76 (766, 150)	921.58 (774, 1,013)
Total Fertility Rate	30	5.12 (2.5, 9.1)	4.47 (1.85, 7.08)	3.32 (1.3, 5.8)	2.81 (1.2, 5.8)
Infant Mortality Rate	30	115.7 (12, 257)	78.90 (22, 204)	60.16 (6, 151)	46.55 (11, 103)
% of Adults Literate	27	34.93 (7.73, 81.66)	51.16 (19.01, 95.72)	63.82 (25.74, 96.51)	73.59 (37.22, 98.76)
% of Female Adults Literate	27	23.50 (2.88, 79.35)	38.09 (7.68, 94)	52.49 (17.45, 96.26)	64.91 (30.97, 98.28)
% Rural	63	79.03 (0, 100)	77.37 (0, 100)	75.97 (0, 100)	73.46 (0, 100)
% Scheduled Caste	34	14.37 (0, 49.85)	14.77 (0, 51.76)	15.61 (0, 82.58)	15.24 (0, 56.27)
% Scheduled Tribe	33	16.27 (0, 97.17)	16.37 (0, 98.11)	16.70 (0, 98.10)	17.5 (0, 99.64)

Table 2

Bivariate fixed-effect models of the main controls on the change in child sex ratio (coefficients, with standard errors in parentheses)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TFR	−11.530** (0.788)							
IMR		−0.39** (0.034)						
Total % Literate			1.003** (0.057)					
Total % Literate, Females				0.829** (0.048)				
Total % Literate, Males					1.205** (0.067)			
% Rural						−0.48** (0.120)		
% Scheduled Caste							0.601** (0.214)	
% Scheduled Tribe								0.409† (0.212)
Constant	19.66** (2.754)	3.738† (2.148)	−83.48** (3.654)	−63.26** (2.577)		13.765 (8.464)	−29.99** (3.714)	−23.41** (1.991)
Observations	1,745	1,747	1,748	1,748		1,720	1,742	1,743
R^2	.157	.101	.212	.205		.014	.007	.003
Number of Districts	590	590	590	590		590	590	590

† $p < .10$;

** $p < .01$

Table 3

Population-weighted fixed-effects models: Testing robustness by adding and removing variables, Models A–F (coefficients, with standard errors in parentheses)

	A	B	C	D	E	F
Sex Ratio Lagged	−0.617** (0.016)	−0.843** (0.042)	−0.839** (0.023)	−0.832** (0.025)	−0.854** (0.025)	−0.822** (0.044)
Time Trend		−0.138 (1.239)				1.555 (1.319)
Time Trend × Sex Ratio Lagged		−0.001 (0.001)				−0.002 (0.001)
Time Trend × District		0.001** (0.000)				0.002** (0.000)
Total Fertility Rate			10.115** (0.890)		6.849** (1.272)	7.165** (1.347)
Infant Mortality Rate			0.023 (0.030)		0.016 (0.031)	0.030 (0.031)
% of Female Adults Literate				0.367** (0.137)	0.411** (0.137)	0.508** (0.145)
% of Female Adults Literate Squared				−0.011** (0.001)	−0.007** (0.002)	−0.009** (0.002)
% Rural				−0.138 (0.087)	−0.121 (0.086)	−0.163† (0.084)
% Scheduled Caste				0.144 (0.249)	0.162 (0.246)	0.123 (0.242)
Percentage Scheduled Tribe				0.276† (0.149)	0.342* (0.148)	0.369* (0.147)
Constant	566.000** (15.470)	800.418** (40.793)	741.491** (19.909)	789.334** (26.973)	770.899** (26.957)	739.571** (44.582)
Observations	1,748	1,748	1,744	1,718	1,715	1,715
R^2	.554	.612	.610	.611	.622	.641
Number of Districts	590	590	590	590	590	590

† $p < .10$;

* $p < .05$;

** $p < .01$

Table 4

Model 1G: Region-specific population weighted fixed-effects models[a] (coefficients, with standard errors in parentheses)

	North	South	East	West	Northeast
Sex Ratio Lagged	−0.624** (0.066)	−0.461** (0.098)	−0.929** (0.075)	−0.852** (0.205)	−0.880** (0.186)
Time Trend	9.348** (2.122)	27.750** (3.718)	3.075 (3.677)	0.671 (6.069)	16.998* (7.820)
Time Trend × Sex Ratio Lagged	−0.011** (0.002)	−0.029** (0.004)	−0.004 (0.004)	−0.000 (0.007)	−0.016* (0.008)
Time Trend × District	0.003** (0.001)	0.001* (0.001)	0.001** (0.000)	−0.007** (0.002)	−0.004† (0.002)
Total Fertility Rate	14.130** (2.678)	−2.698 (2.211)	2.854 (2.140)	7.501 (5.655)	10.964** (3.885)
Infant Mortality Rate	−0.118* (0.049)	0.126† (0.067)	0.040 (0.045)	0.108 (0.124)	0.237† (0.133)
% of Female Adults Literate	1.289** (0.294)	−1.455** (0.377)	0.359 (0.274)	−2.824** (0.887)	−1.437† (0.818)
% of Female Adults Literate Squared	−0.012** (0.003)	0.009* (0.004)	−0.006* (0.003)	0.026** (0.009)	0.012 (0.008)
% Rural	−0.089 (0.145)	0.107 (0.110)	0.020 (0.177)	0.753 (0.495)	0.265 (0.270)
% Scheduled Caste	0.305 (0.328)	−0.804 (0.564)	−0.064 (0.373)	−0.577 (0.910)	−4.284* (2.021)
% Scheduled Tribe	0.437 (0.372)	0.043 (0.675)	0.303† (0.160)	−0.025 (0.395)	−1.136* (0.474)
Constant	474.335** (68.897)	492.041** (96.312)	877.505** (73.147)	808.333** (204.928)	897.176** (191.171)
Observations	679	290	373	197	142
R^2	.749	.743	.793	.581	.772
Number of Districts	230	99	128	66	55

Note: Standard errors are shown in parentheses.

[a]North = Haryana, Punjab, Chandigarh, Delhi, Rajasthan, Himachal Pradesh, Uttar Pradesh, Madhya Pradesh, and Uttarakhand; South = Karnataka, Tamil Nadu, Kerala, and Andhra Pradesh; West = Gujarat, Dadra and Nagar Haveli, Daman and Diu, Maharashtra, and Goa; East = West Bengal, Jharkhand, Orissa, Chhattisgarh, and Bihar; and Northeast = Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, and Tripura.

† $p < .10$;

* $p < .05$;

** $p < .01$

Table 5

Robustness tests of Model H (sex ratio lagged 20 years), Model I (dummy variables for time periods), and Model 2 (regression of lagged sex ratio on sex ratio rather than change in sex ratio)

	H: Sex Ratio Lagged 20 years	I: Time Trend Dummy Variables	Model 2: Outcome: Child Sex Ratio
Sex Ratio Lagged 20 Years	0.080 * (0.040)		
Sex Ratio Lagged		−0.893 ** (0.049)	0.178 ** (0.044)
Time Trend	33.242 ** (0.964)		1.555 (1.319)
Time Trend × Sex Ratio Lagged	−0.036 ** (0.001)	−0.000 (0.001)	−0.002 (0.001)
Time Trend × District	0.001 * (0.000)	0.002 ** (0.000)	0.002 ** (0.000)
Total Fertility Rate	17.971 ** (2.952)	4.506 ** (1.579)	7.165 ** (1.347)
Infant Mortality Rate	0.111 ** (0.041)	0.023 (0.031)	0.030 (0.031)
% of Female Adults Literate	0.731 * (0.298)	0.570 ** (0.146)	0.508 ** (0.145)
% of Female Adults Literate Squared	−0.002 (0.003)	−0.010 ** (0.002)	−0.009 ** (0.002)
% Rural	−0.142 (0.119)	−0.169 * (0.084)	−0.163 † (0.084)
% Scheduled Caste	−0.449 (0.316)	0.071 (0.241)	0.123 (0.242)
% Scheduled Tribe	0.196 (0.303)	0.352 * (0.146)	0.369 * (0.147)
Time Dummy Variable 2		−7.721 (15.025)	
Time Dummy Variable 3		8.290 (29.025)	
Constant	−171.038 ** (47.541)	739.571 ** (44.582)	820.582 ** (40.429)
Observations	1,126	1,715	1,715
R^2	.758	.644	.461
Number of Districts	585	590	590

† $p < .10$;

* $p < .05$;

** $p < .01$