Title: Self-correction of sex ratios in India. Evidence from the last four censuses

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Abstract

Sex ratios in India have become increasingly skewed over the past decades. We hypothesize that when sex ratios become very uneven, the shortage of girls would increase girls' future value in marriage and labor markets leading sex ratios to self-correct. Using data on children under five from the last four Indian censuses we examine the relationship between sex ratio at one point in time and the change in sex ratio over the next ten years by state. Indian states with skewed sex ratios became even more skewed between 1991 and 2001. However, analysis shows that states with the most skewed sex ratios in 2001 had larger corrections by 2011. Fixed effects models show that, accounting for unobserved state-level characteristics, sex ratios are now significantly negatively correlated with the change in sex ratio in the successive ten-year period. This suggests that self-corrective forces are at work on imbalanced sex ratios in India.

Introduction:

Uneven sex ratios at birth and throughout childhood have been noted for decades in India where the ratio is skewed in favor of boys (Jha et al., 2011). This is hypothesized to be due to a strong cultural preference for sons, combined with access to sex selective technologies and a falling fertility rate (Guilmoto, 2009). In India as a whole in 2011, there were 914 girls for every 1000 boys under 6 years old, compared to 927/1000 in 2001 and 945/1000 in 1991(Jha et al., 2011). Most of the increase in skewedness is thought to be due to increases in sex-selective abortion, rather than excess mortality for girls (Jha et al., 2011).

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

Biological Perspective

Some non-human species have the ability to shift their sex ratio in response to ecological factors that favor imbalance. The rationale, as advanced by Trivers and Willard (1973) is that in many species males born in good ecological conditions will out-reproduce females because strong males can produce offspring at a higher frequency. In poor ecological conditions, the females will out reproduce males (Trivers & Willard, 1973). From the evolutionary perspective of the mother, it is therefore advantageous to have sons in good times, and daughters when times are bad. This theory—the Trivers-Willard Hypothesis—has been shown to hold for population wide stresses due to environmental conditions, but to be mediated by individual specific factors due to an animal's position in a social hierarchy. For example, the Seychelles warbler has a higher proportion of female offspring during good ecological conditions being born to higher ranking females, while more male offspring are born during bad conditions or to less well established females (Jan; Komdeur, 2002 ; Jan Komdeur, Daan, Tinbergen, & Mateman, 1997). Higher ranking red deer have been shown to produce more male than female offspring (Clutton-Brock, Albon, & Guinness, 1984).

There are limits to the number of generations a Trivers-Willard gender imbalance can be sustained at a population level. 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 (13). Over the long run most species oscillate around a stable gender balance that is remarkably close to 1:1 (Fischer, 1930).

In human populations, there is evidence of a biological mechanism through which sex ratios are affected by stresses. 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, see below) is estimated at around 105 males born for every 100 females (Dyson, 2012).[1] There is evidence that stresses that the mother experiences while the fetus is in utero, such as terrorism, extreme temperatures, and economic instability, can lead to the spontaneous abortion of male fetuses and thus alter the sex ratio (Catalano, 2003; Catalano, Bruckner, Marks, & Eskenazi, 2006; Catalano, Bruckner, & Smith, 2008). Conversely, sex ratios after wars have at times been noted to favor males (James, 2009). Research into the life expectancies of males born in Sweden in cold years, when the sex ratio favored females, showed that those males who were born lived longer than males born in normal years, suggesting that pregnant females abort weaker male fetuses in times in stress (Catalano et al., 2008). 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, Li, & Feldman, 1995).

As mentioned above, in a natural setting, the sex ratio at birth in humans is estimated to be about 105 boys for every 100 girls. However, male neonates and infants have higher mortality 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 post-natal period for males compared to females (Wells, 2000). Overall, male infants show a higher propensity to become malnourished, and are less robust in general (Wells, 2000). Wells (2000) suggests that rather than looking at the Trivers-Willard hypothesis in the narrow constraints of pregnancy, we should think about the whole period of parental investment (which he defines as through the end of breastfeeding) as a time when parents could be adjusting their sex ratio based on environmental conditions and information about the strength of the infant (Wells, 2000). Hence, he argues that the weakness of male infants is a method by which natural selection has allowed parents to be able to prolong the period for deciding whether to

[1] Note: The literature on sex ratios conventionally uses a ratio of the number of boys over the number of girls, however, the discussion of sex ratios in India uses the reverse (the ratio of number of girls over the number of boys). For the purposes of this paper, the same standard as is customarily used for India (girls/boys), unless otherwise specified.

invest in a certain infant. If times are bad, and it would be disadvantageous to have a male, the weaker male infants will be more at risk to disease and death, thereby conserving maternal fitness, and allowing the mother to have another pregnancy sooner.

Social and Cultural Perspective

In much of Asia, son preference is thought to be a manifestation of patrilineal social structures that favor males and which generally create situations in which boys are a better investment than girls (Monica Das Gupta, 2009). As in most agrarian societies, in rural India, sons traditionally have been a better investment because they work on the farms using the male advantage in aggression to protect rural property and other assets from theft. Agrarian sons, thus, can produce more income than daughters and provide security and support in old age (Arnold, Choe, & Roy, 1998). Another stated cause of son preference (especially for Hindus in India) is the religious role that son's play in funeral ceremonies (Arnold et al., 1998). Modernization and a reduction in the threat of violent threats may have reduced the physical advantages underlying income disparities, but culture and tradition can sustain son preference long after the economic rationale has declined.

Social factors are sometimes intertwined with the economic factors that lead to son preference. Where the kinship system is patrilineal, girls drain family resources because they require inputs (food, health care, dowry) and once they marry they no longer contribute (in terms of care or money) to the household, while boys remain with their families and contribute for the remainder of their lives (Chakraborty & Kim, 2012). Therefore, in the Indian context, it is not just that families prefer boys, but there are also disincentives to having girls. Past qualitative research in southern India showed 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." p.702 (Diamond-Smith, Luke, & McGarvey, 2008).

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 time other authors have tried to estimate the number of missing women in India at various time periods. Research in the 1990s suggested that over one million girls were "missing" due to sex selective abortion and female infanticide between 1981 and 1991 (Monica Das Gupta & Bhat, 1997). Recently, Anderson and Ray (2012) estimated that a total of over two million women are missing in India in a given year, with 12% missing at birth, 25% missing in childhood, 18% in reproductive ages and 45% in older ages (Anderson & Ray, 2012). Another way to think about this is that of the women who could be alive today, 25 million are missing (Anderson & Ray, 2012). Other work suggests that virtually all of the gender imbalance in India is due to excess mortality under the age of five, and mostly between ages two to five years (Oster, 2009). Given the lack of conclusive evidence about whether the imbalance sex ratio imbalance is due predominantly to sex selective abortion or to excess mortality, this paper will look at the sex ratio in children five and under, to capture information about both of these factors.

Excess mortality for girl children

There are many ways that son preference can be expressed. It can be expressed in uneven investment in children by gender, for example, sending boys to school longer than girls, seeking health care for boys sooner than girls, and/or giving boys better nutrition than girls (Arnold et al., 1998; Mishra, Roy, & Retherford, 2004). These practices can be described as discrimination against girls, which can lead to excess mortality for girls, and subsequent uneven sex ratios post-birth.

Mortality for girls in childhood once exceeded mortality for boys in childhood by 43% in India in the 1990s (Arnold et al., 1998). This excess mortality was due to discrimination against girls in terms of food allocation, nutritional level, care-seeking behavior when the child is ill and preventative services (vaccinations, etc.) (Mishra et al., 2004). Sons have also been shown to be breastfed longer, receive more vitamin supplements, partially due to the fact that girls more often end up in larger families (due to stopping behavior described above) (Barcellos, Carvalho, & Lleras-Muney, 2012). Oster (2009) looked at the impact of specific types of biases on mortality, and found that uneven vaccination rates explain about 20-30% of the sex imbalance, malnutrition explains 20%, respiratory infections and diarrhea combined explain 5%, and the remaining roughly 50% is unexplained by these factors (Oster, 2009).

As mentioned above, in populations without gender preference, male infants have higher rates of mortality than female infants in general, especially in the neonatal period (Wells, 2000). Hill and Upchurch (1995) used Demographic and Health Survey data from around the world to look at gender differences in child mortality. With development, mortality in the neonatal period generally declines (most of which is due to infectious diseases), thereby placing more of the mortality in children under five in ages one to four. Therefore, the female advantage in the neonatal/infant period may decline with the changing cause of death structure. The authors find that when male child mortality declines, female advantage increases (Hill & Upchurch, 1995). Therefore, even in the absence of gender preference and uneven care-giving practices, with development, we would expect the situation for girls to appear to improve.

Uneven sex ratios at birth

As people are choosing to have fewer children, they are more pressured (squeezed) 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). Sex-selective abortion is technically illegal in India since 1994, although abortion itself has been legal since the 1970s (Naqvi & Shiva Kumar, 2012). There has been a proliferation of mobile ultrasound clinics, which offer (and even advertise aggressively) relatively inexpensive way of finding out the sex of a fetus (Retherford & Roy, 2003). Once the sex has been determined, people have little trouble obtaining an abortion under the pretense of other reasons. Much of the skewed in sex ratios at birth today is thought to be due to sex selective abortion, but sex ratios at birth were manipulates (and continue to be today) through “stopping rules.” (Jha et al., 2011)

“Stopping rules” is the concept that a family continues having children until they have reached some goal (such as having one son), and then they stop childbearing (Andersson, Hank, Rønsen, & Vikat, 2006). As was put eloquently by a woman in northern India "I myself would like one son. And I don't want many children. But it isn't a question of what I want. Until I have a son, I won't stop having children" p.96 (Jeffery & Jeffery, 1996). In the absence of sex selective technologies, stopping rules lead to more girls in a family than boys, which further impoverishes girls, as they are more often in larger households competing for household resources. In India, girls with older sisters have been shown to have the highest risk of mortality (Arnold et al., 1998).

Some authors have argued that access to pre-natal sex determination and abortion should allow those girls that are born to be more “wanted” and therefore excess girl-child mortality would decrease with increasing sex selective abortion. Evidence of this effect has been found by some authors in India (Sudha & Rajan, 2003). Others have argued that sex-selective abortion and girl-child neglect are additive, or even re-enforce and strengthen each other, and that additivity has increasingly skewed sex ratios in parts of Asia in recent years (Goodkind, 1996). More research is needed to understand this relationship.

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, and 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 & Chattopadhyay, 2012). Much of this skew 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 estimate that the peak sex ratio at birth could be closer to 124 boys/100 girls (about 81 girls/100 boys). Perhaps hearteningly, or perhaps dishearteningly, other research looking at the spread of skewed sex ratios in India has suggested that areas with highly skewed sex ratios act as epicenters, from which skewedness spills outwards over time, however, the opposite is also true, where areas of relative equality effect their surrounding areas to lower skewdness over time (Kuzhiparambil & Rajani, 2012).

This paper uses census data from 1981 to 2011 to check for self-correction by examining the correlation between sex ratios in Indian States and Territories to the subsequent change in sex ratios over the next ten years. We hypothesize that populations with more skewed sex ratios will see proportionately greater corrective change in the subsequent sex ratios, compared to states with less skewed sex ratios.

Data and Methods:

Data on the sex of children under six in states and territories of India is uses from the four most recent Indian censuses (1981, 1991, 2001, 2011). We define sex ratio as the ratio of the count of living boys to living girls under age six in each state or territory. The outcome of interest is the change in sex ratio in a 10 year interval (between censuses). The main predictor of interest is the sex ratio lagged 10 years. Other variables included are a time trend variable, and interaction term between time trend and sex ratio lagged 10 years, total fertility rate and infant mortality rate. The last two variables are included because, as discussed above, previous research has shown these to be associated with changes in the sex ratio in children under five.

In the past 40 years, there have been some territorial changes is India, specifically, the creation of new states and territories, which has made finding complete data on all states impossible, especially for Total Fertility and Infant Mortality Rates. New states that were clearly formed from existing states were included in the analysis (Chhattisgarh from Madhya Pradesh in 2000, Jharkhand from Bihar in 2000, Mizoram from Assam in 1987, and Uttarakhand from Uttar Pradesh in 2000). Values for missing data before the states became independent were calculated by taking the ratio of the indicator of interest (say, infant mortality rate) in the first year that data was available, and then using that ratio to estimate the value for infant mortality for that region when it was still part of the mother-state. This was done by multiplying the ratio by the value in the mother-state in the years prior to independence. Andaman and Nicobar Islands, Dadra and Nagar Haveli, Daman and Diu, Lakshadweep, Puducherry, Jammu and Kashmir, and Nagaland were dropped from the analysis because of incomplete or inconsistent data.

We first regress the change in sex ratio over ten years against the sex ratio ten years prior using a series of models. To account for the fact that the population of states and territories differ substantially, we adjusted the regression with population weighting using the population of each state or territory in the 2001 census. We then estimated a series of fixed effects models to account for unobservable state-level factors that we hypothesize do not change over time. The first model included only the change in sex ratio over ten years and the lagged sex ratio (10 years prior). The second model added covariates for time trend and an interaction term for time trend and the sex ratio lagged ten years. The third model included covariates for the total fertility rate and the infant mortality rate in each time period, without the time trend variables in model 2, and the fourth model included the time trend variables.

Results:

Figures 1,2,3 show the relationship between sex ratio lagged by ten years and the change in sex ratio in the subsequent time period for each state and territory in three time periods (1981-1991, 1991-2001, 2001-2010). Figure 1 (1981-1991) shows no real relationship between the sex ratio in 1981 and the change in sex ratio between 1981-1991. Figure 2 (1991-2001) demonstrates that for a certain subset of regions with very skewed sex ratios (many more boys than girls) those with a higher sex ratio in 1991 had a proportionately greater rise in sex ratio that resulted in even more surplus boys between 1991 and 2001. The most affected areas are Punjab, Haryana, Chandigarh, and Delhi. The most recent data shown in Figure 3 indicates that states/territories with higher sex ratios in 2001 experienced proportionately greater corrective changes in sex ratios between 2001 and 2011 which favored girls.

<Fig 1, 2, and 3>

The successive columns of Table 1 show (A) no statistically significant relationship in 1991, (B), a significant positive relationship in 2001(p-value> 0·0001) , and (C) a significant negative relationship in 2011 between the change in sex ratio and sex ratio ten years prior (p-value=0·005).

<Table 1>

Pooling all the data from 1981 to 2011 together and removing state-specific fixed effects, Table 2 shows that the self-corrective pattern is dominant for the thirty year period studied. After controlling for time trend, and infant mortality and total fertility rate in each time period, and increase in sex ratio is strongly associated with a decrease in sex ratio in the future. The total fertility rate and infant mortality rate were not associated with the change in sex ratio between two periods, nor was the interaction between time period and lagged sex ratio, or the time trend variable itself. In the final model, about 91% of the variation in the model is due to differences between states (rho=0·91).

<Table 2>

Discussion:

These findings indicate that between 2001 and 2011 Indian populations with skewed sex ratios experienced corrective forces that were proportionate to the degree of prior imbalance in the local sex ratio. Corrective forces were not evident between 1991 and 2001. Indeed, there was proportional accentuation of skewed sex-ratios in the 1991-2001 interval. Historically, the 1990s brought a boom in the availability of pre-natal ultrasound scans in India. The introduction of this technology and its use for self-selection abortion may have been differentially embraced by populations in proportion to their pre-existing son-preferences. The market for ultrasound-assisted sex selective abortion may have achieved saturation by 2001. Our data suggest that the incidence of surplus boys in the most affected populations of India may have passed its zenith. Other states in India that are still experiencing increasingly uneven sex ratios (extreme cases are, for example, Maharashtra, Rajasthan and Uttarkhand) may also reach this turn-around point in the decade to come.

The changes in the most recent decade are consistent with Fisher's principle as applied to human populations. There were self-corrective forces at work in the most gender imbalanced populations of India between 2001 and 2011. Future research should explore potential drivers of this self-correction. For example, it is possible that an increase in women's wages due to a shortage of women to fill female-dominated occupations changes people's perceived value of having a girl. Another possibility is that tightening of the marriage market (due to shortage of brides, compounded by falling fertility) is changing the value of having a girl child. Research into the reduction of previously skewed sex ratios in South Korea showed that both the marriage market and employment rates of males compared to females were associated with improvements in the sex ratio (Edlund & Lee, 2013). Other factors, such as the impact of regulations and laws, governmental programs or media aimed to discourage discriminating against girls could be playing a role. It is yet to be seen how far back towards normal sex ratios will fall, and whether the decline in sex ratios will persist in the decades to follow. Time will tell.

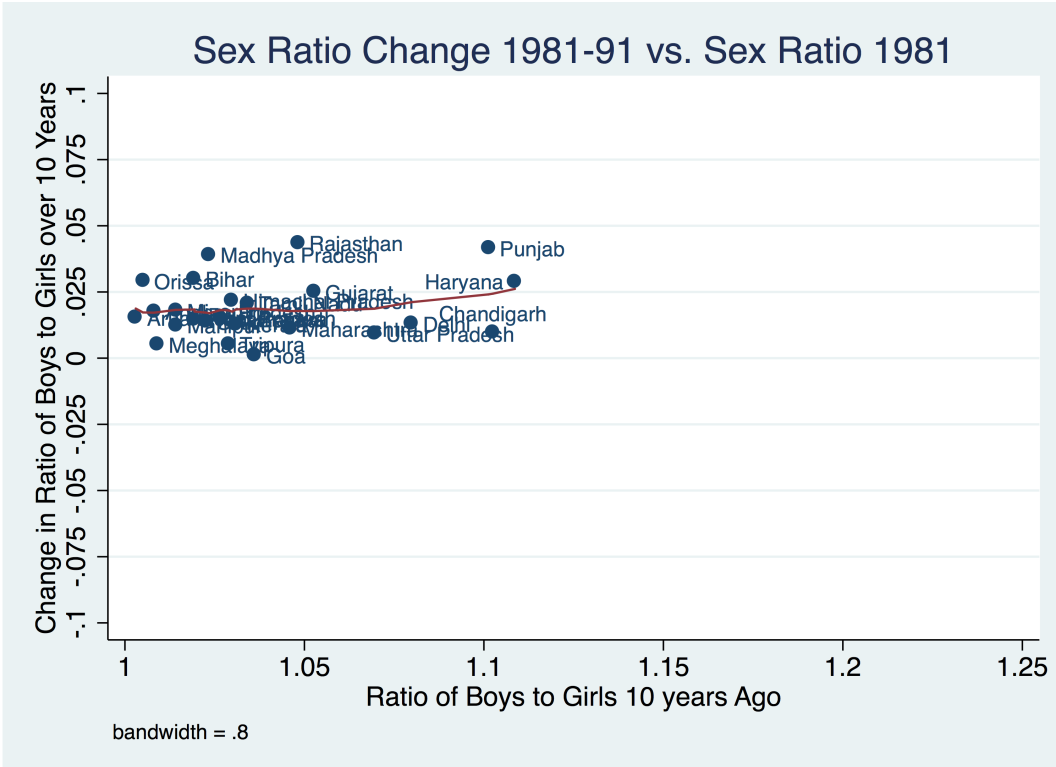

Fig 1. Sex Ratio Change from 1981-1991 versus Sex Ratio in 1981

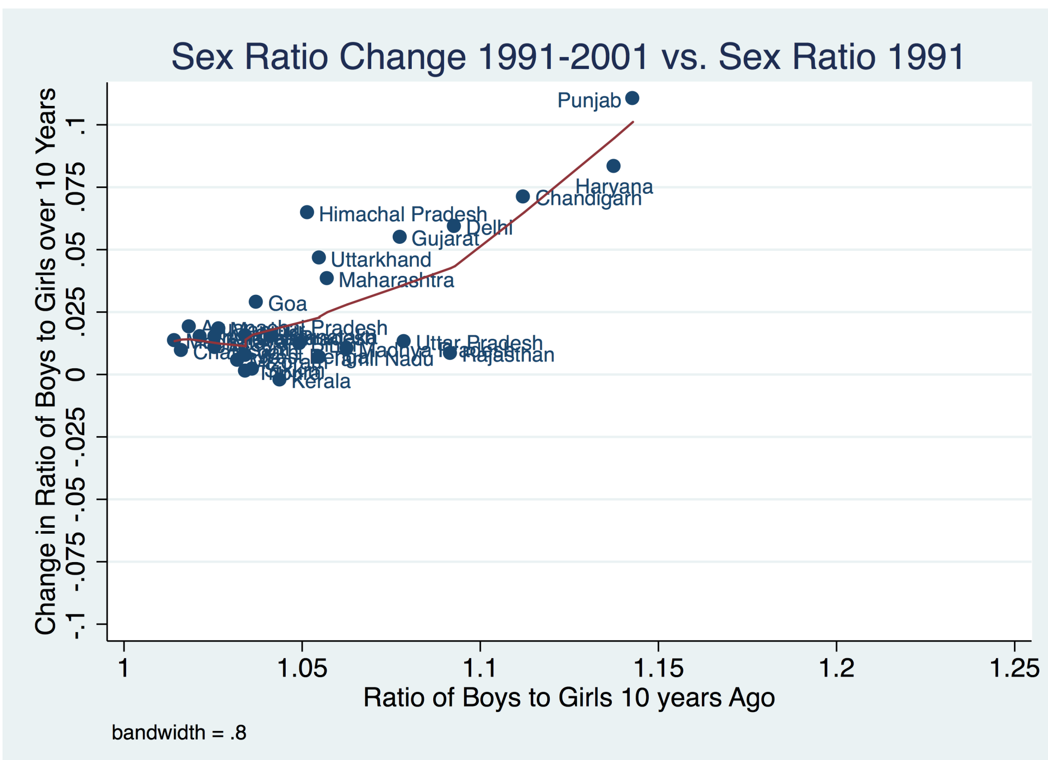

Fig 2. Sex Ratio Change from 1991-2001 versus Sex Ratio in 1991

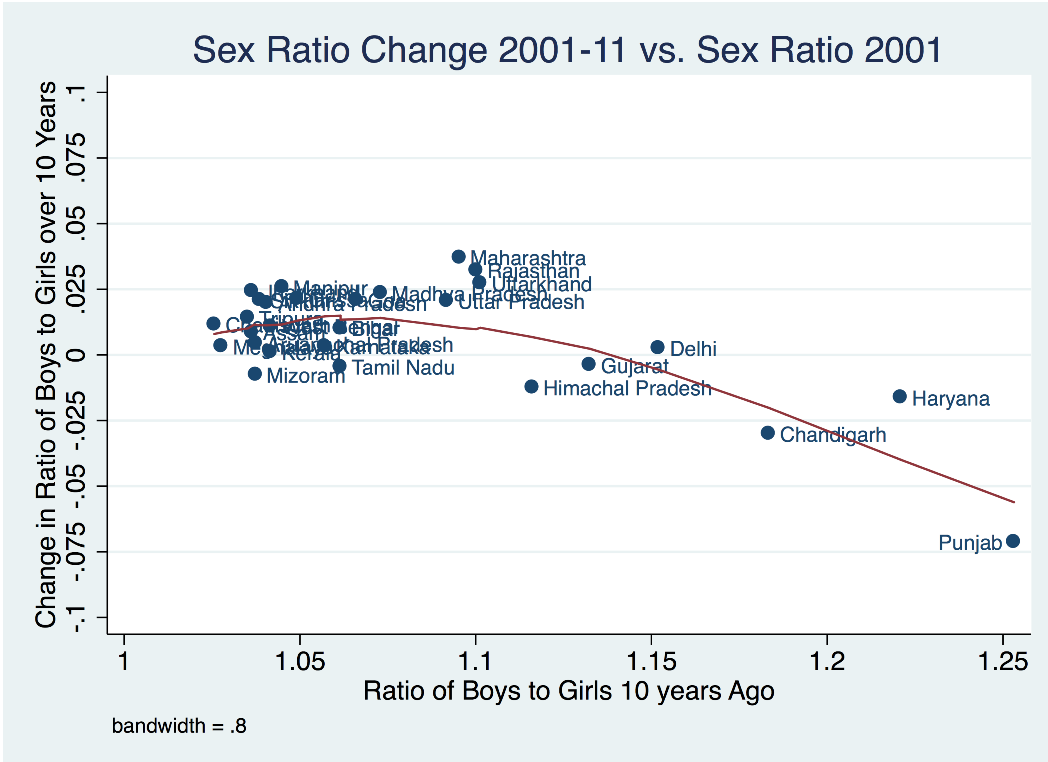

Fig 3. Sex Ratio Change from 2001-2011 versus Sex Ratio in 2001

Table 1: Ordinary least squares regression of the change in sex ratio in a 10 year period and the sex ratio 10 years prior. Indian children under 6 (Source: Indian Census)

	Change in Boy:Girl Sex Ratio		
	A: 1981-1991	B: 1991-2001	C: 2001-2011
Boy:Girl Sex Ratio 10 yrs prior	-0.048 (-0.091)	0.497*** (0.123)	-0.204*** (0.070)
Constant	0.071 (0.096)	-0.505 (0.130)	0.232 (0.76)
N (States of India)	24	28	28
R-squared	0.01	0.39	0.24

***=p-value<0.001
Coefficient (Standard Error)

Table 2: Fixed effects model of the change in sex ratio in a 10 year period and the sex ratio 10 years prior. Indian children under 6, 1981-2011 (Source: Indian Census and Sample Registration System)

	Change in Boy:Girl Sex Ratio			
	Model (1)	Model (2)	Model (3)	Model (4)
Sex Ratio Lagged 10 years	-0.441*** (0.095)	-1.182*** (0.314)	-0.800*** (0.136)	-1.102*** (0.357)
Time Trend		-0.005 (0.008)		-0.002 (0.009)
Time Trend*Sex Ratio Lagged		0.006 (0.008)		0.004 (0.009)
Infant mortality Rate			-0.000 (0.000)	0.000 (0.000)
Total Fertility Rate			-0.010 (0.007)	-0.005 (0.007)
Constant	0.485*** (0.100)	1.233*** (0.324)	0.907*** (0.153)	1.153*** (0.364)
N (States of India)	28	28	28	28
R-squared	0.298	0.510	0.476	0.529

***=p-value<0.001
Coefficient (Standard Error)

Acknowledgments: The authors would like to acknowledge Caroline Moreau, Stan Becker and Nan Astone for their advice and feedback on this research.

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