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Sex ratio and fertility preferences in India: A longitudinal analysis

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ABSTRACT

Birth control policies and entrenched patriarchal norms have contributed to a highly imbalanced male/female ratio in India. While the impact of son preference on the sex ratio is largely studied, the consequences of a male-skewed sex ratio on women's fertility preferences remain underexplored. Merging different longitudinal datasets (Indian Census and IHDS panel household survey), this article provides an original empirical analysis of the effect of district-level sex ratios on women's fertility preferences and the nested pathways of this relationship. Individual and time fixed-effects regressions show that district-level surplus of men negatively affects women's desired number of sons. The robustness of these findings is confirmed after conducting multiple checks, including controlling for endogeneity by leveraging temperature data from the India meteorological department (1952–2011). The investigation of potential pathways shows that a higher district male/female ratio may make gender norms and the marriage market more favorable to women (via an increase in decision-making power and age of marriage, and a decrease in the dowry price and domestic violence acceptance). We conclude that this self-corrective process which shapes the relationship between sex ratio and son preference in contexts of entrenched patriarchal norms, hinders gender equality.

1. Introduction

In the early 1990 s, Nobel prize winning Amartya Sen highlighted the alarming issue of *missing women*, referring to the number of women who would have been part of the population if the sex ratio was balanced (Sen, 1990, 1992). Three decades later, the United Nations Population Fund estimates that there are 142.6 million *missing women* in the world, a number that has more than doubled in the past 50 years (UNFPA, 2020). Although registration issues at birth may partly account for the missing women phenomenon, as shown by Bulte et al. (2021) in the case of China, there is little doubt that many regions face a relative scarcity of women. This includes countries in East and South Asia (i.e., China, India, South Korea, and Vietnam) and Eastern Europe and Central Asia (i.e., Armenia, Azerbaijan, Georgia, and Albania) (Guilmoto, 2009).

A growing literature has shown that a range of factors including infanticide (Croll, 2002; George, 1997), sex-selective abortions (Nandi & Deolalikar, 2013), the neglect of girls (Sahni et al., 2008) and the neglect of elderly women (Calvi, 2020) contribute to the growing number of missing women in the world. The motivation underlying these behaviors is the preference for sons. This deeply rooted practice exists in many patrilineal communities, particularly in Asia (e.g., South Korea, China, Vietnam, India and Pakistan) (Tafuro & Guilmoto, 2020). To a lesser extent, a preference for sons has also been observed in the USA (Dahl & Moretti, 2008), especially among immigrant communities (Blau et al., 2020), illustrating the stickiness of this preference.

A large and converging literature highlights the crucial role of the preference for sons in explaining male-skewed sex ratios, as expressed, for instance, by Guilmoto & Tove (2015: 208): "The central cause of the rise in the sex ratio at birth is naturally connected to son preference". Yet, only a few studies analyze how imbalanced sex ratios may in return reshape fertility preferences and rebalance abnormal sex ratios. According to Kolk & Jebari (2022), in the analysis of cultural evolution, a distinction should be made between demographic phenomena that are self-reinforcing (i.e. increasing in prevalence over time) and others that are self-limiting (i.e. producing outcomes that make them less prevalent). For non-human species, there is a consensus in the literature on the existence of a self-correction process related to abnormal sex ratios (Diamond-Smith & Bishai, 2015). Among Humans, limited evidence indicates that self-regulating mechanisms to normalize the sex ratio exist in China (Li et al., 2016), India (Diamond-Smith & Bishai, 2015), South

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Korea (Yoo et al., 2017) and Taiwan (Francis, 2011). One of the mechanisms through which a self-limiting process might operate is the reshaping of fertility preferences. In the Chinese context, Dong et al. (2021) and Song et al. (2022) find a negative effect of sex ratios on the preference for sons, suggesting that the relative scarcity of women may reshape fertility preferences.

The case of India is particularly relevant for analyzing the relationship between the sex ratio and son preference. According to Pew Research Center's estimates (Tong, 2022), the sex ratio at birth has continuously increased from 105 male births for 100 female births in the 1970 s (i.e., its approximate natural level) to more than 111 males in 2015–2016. The legalization of abortion in 1971 as well as the generalization of prenatal tests have been identified as the direct drivers of this increase. There is a strong spatial heterogeneity of the sex ratio in India, with the most male-skewed ratios observed in the northern part of the country (especially in the States of Punjab and Haryana). Since the 2010 s, the overall sex ratio at birth has begun to decline, reaching 108 in 2019–2021. This process of normalization was potentially driven by a decline in the preference for son and sex selection, following the increase in education and income levels and the implementation of specific public policies (e.g., the ban on prenatal sex tests and the "Save the Girl Child" campaign).

Despite its recent decline (Tong, 2022), the preference for sons remains deeply anchored in the Indian society. Its cultural roots are related to various factors, many of which have an economic nature, with sons being considered as better investments than daughters. One of the most commonly researched reasons for son preference is the need for a woman's parents to pay a dowry for her marriage (Robitaille, 2013). Moreover, it is considered inauspicious for married daughters to provide in-kind or financial support to their families (Das Gupta, 1987). Other structural factors such as religion also play a role in son preference. Sons have a primordial role in funeral rites among Hindus who represent most of the Indian population (Vlassoff, 1990). Finally, women are likely to prefer having a son to a daughter as a means to increase their mobility and autonomy. Indeed, for households that practice seclusion or *purdah* to limit interactions of women with non-household members, women are more likely to get permission to go outside of their households if they are accompanied by their sons (Robitaille, 2013).

This study analyzes the effect of male-skewed sex ratios on women's fertility preferences for sons or daughters in India and proposes an empirical identification of potential pathways of this effect.[1] Two pathways are explored: gender norms and the "marriageability" of women defined as the extent to which women are valued in the marriage market. The analysis draws on district-level data from the 2001 and 2011 censuses and longitudinal household survey data from the 2005 and 2011–2012 waves of the Indian Human Development Survey (IHDS). From a methodological perspective, we rely on fixed-effects estimations and address the potential endogeneity of the relationship between male-skewed sex ratios and fertility preferences with an instrumental variables (IV) strategy leveraging temperature data from the India Meteorological Department (1952–2011). Moreover, we carry out additional robustness checks to rule out the risk of a selection bias by replicating the analysis on a restricted sample and implementing a placebo test.

Individual and time fixed-effects regressions, conducted using a representative sample of ever-married women, show a negative impact of the district-level surplus of men on women's desired number of sons. These findings are confirmed after controlling for endogeneity and conducting further robustness checks. The investigation of potential pathways shows that a higher district male/female ratio may make gender norms and the marriage market more favorable to women via changes in gender norms and women's marriageability (an increase in decision-making power in the household and in the age of marriage respectively, and a decrease in the tolerance for domestic violence against women in the community and in the dowry price paid by the wife's family respectively). We conclude that a self-corrective process shapes the relationship between sex ratio and son preference in patriarchal countries such as India, with alternating periods of growth and decline of the imbalance. When son preference is high, the relative number of women decreases. However, when the sex ratio becomes too imbalanced, son preference decreases. This contributes to re-balancing the sex ratio, but potentially reshapes preferences for sons in turn. Consequently, we argue that these demographic changes should be accompanied by ambitious public policy measures targeting both outcomes and beliefs to ensure gender equality as the sex ratio fluctuates. This study contributes to the literature by shedding light on this self-corrective process using a robust analysis and drawing from rich data. To our knowledge, this is the first study focusing on the relationship between local sex ratios and son preference using panel data and robust identification methods.

The rest of the paper is structured as follows. Section 2 reviews the theoretical and empirical literature and presents the conceptual framework. Section 3 lays out the empirical methodology. Section 4 describes the data and provides descriptive evidence whereas Section 5 presents the results. Finally, Section 6 discusses the findings and concludes.

2. Literature review and conceptual framework

2.1. Empirical evidence

A substantial body of empirical literature addresses the risks and negative consequences (both for men and women) associated with male-skewed sex ratios, particularly in China and India. These consequences, which vary depending on the context and indicators measured, include increased violence against women (D'Alessio & Stolzenberg, 2010; Hudson & Den Boer, 2002), deteriorating male mental and physical health (South & Trent, 2010; Zhou et al., 2013), male suicides (Conner et al., 2007; Zhou et al., 2013), risky sexual behavior of men (South & Trent, 2010), family disruption (Hudson & Den Boer, 2002), and reduced female labor force participation (Amuedo-Dorantes & Grossbard, 2007; Angrist, 2002; Cardoso & Morin, 2023).

Surprisingly, however, few empirical studies have explored whether and through which transmission mechanisms imbalanced sex ratios are likely to impact fertility preferences and whether this contributes to further perpetuating or mitigating the initial gender imbalance. Most studies examining this relationship, at least partially, focus on the Chinese context. Using the Chinese Census data from 2000, Li et al. (2016) emphasize that the male-skewed sex ratio in the marriage market negatively impacts the proportion of male births, thereby reducing the preference for sons. Using data from the Chinese General Social Survey and the Population Census of China, Dong et al. (2021) highlight that an increase in the sex ratio at the local level is correlated with a decrease in the preference for sons. Also focusing on China and based on an original survey on the consequences of gender imbalance, Song et al. (2022) show that when individuals perceive the risks related to an imbalanced sex ratio (difficulties for men to find spouses, high marriage expenses, tensions around old age support, violence, etc.), two opposing mechanisms take place: stated son preference diminishes but, simultaneously, the gender norms that underpin son preference are reinforced. Finally, in the Taiwanese context, during the post-Chinese Communist Revolution period, Francis (2011) shows that an increase in the marriage market sex ratio is associated with an increase in the proportion of female children in a family.

The scarce literature examining the case of India also provides some evidence on the existence of a self-correction process in sex ratios, even though these studies do not specifically focus on son preference. These

[1] While the focus on women's fertility preferences provides an important contribution to the literature, examining how skewed sex ratios affect men's preferences would also offer important insights. Unfortunately, data limitations restrict our analysis to women's fertility preferences only.

studies are based on the hypothesis that strongly male-skewed sex ratios and the shortage of women increase the future marriageability of women and their prospects in labor markets, which subsequently leads to re-balancing the sex ratio. For instance, Diamond-Smith & Bishai (2015) show that in Indian districts, sex ratios at a given time are negatively associated with changes in sex ratio over the following decade, suggesting the presence of self-corrective mechanisms. Diamond-Smith et al. (2020) extend these investigations by exploring potential transmission mechanisms. They find that most of the improvements in sex ratios are associated with the decline in sex-selective abortions.

Overall, these findings suggest that a high scarcity of women can contribute to altering son preference. However, a robust empirical analysis of the extent to which son preference is reshaped in societies experiencing imbalanced sex ratios, as well as an investigation of the potential pathways of this mechanism, is needed, especially in the context of India which remains understudied.

2.2. Conceptual framework

Two main theoretical frameworks have been used to study the behavioral consequences of imbalanced sex ratios: the sexual selection framework and the social exchange framework (Pedersen, 1991).

The sexual selection framework developed by Trivers (1972) and Emlen & Oring (1977) is linked to the evolutionary theory and focuses on intrasexual competition (D'Alessio & Stolzenberg, 2010; South et al., 2014). The underlying idea is that the relative oversupply of men in the marriage market (cf., the 'marriage squeeze') is expected to create intense intra-male competition to secure a partner. In other words, men might adjust their behavior to align with women's preferences, leading to greater parental investment and commitment to securing economic resources. Women on the other side are likely to choose men for their willingness to invest. This may result in higher family stability (higher marital rates, lower divorce rates, etc.) and increased fertility (Schacht & Kramer, 2016; Stone, 2019). The sexual selection framework also predicts that the intense intra-male competition may increase levels of violence (between men and against women). It should be noted that the conclusions of the sexual selection framework are similar to those of the demographic-opportunity hypothesis (e.g., South et al., 2016), which posits that an excess of members of the opposite sex in the mating market increases the likelihood of finding an attractive partner and consequently leads to earlier marriages.

The social exchange framework developed by Guttentag & Secord (1983) shifts the focus to gender norms and societal structures. When sex ratios are high (i.e., indicating a relative undersupply of women), women are less dependent on their partners and hence have a greater intra-family power (i.e., the dyadic power) translating into greater autonomy and influence in family decision-making. Nevertheless, the social exchange theory emphasizes a potentially antagonistic phenomenon which is the influence of structural power related to the economic, political, social and legal structures in a society. Men could use their structural power to constrain women's behavior to their advantage, even when gender dyadic norms are less male-biased. This may result in traditional beliefs regarding what a family should look like and women's roles: early age of marriage, lower divorce rates, higher fertility, greater commitment of women to domestic and care work, etc. (Pedersen, 1991; South & Trent, 1988). Therefore, in strongly patriarchal systems, these two antagonistic mechanisms are at play leading either to a perpetuation of the system or, as suggested by Guilmoto (2009: 535), the greater autonomy and self-reliance of women (i.e., more gender-balanced dyadic norms) "may undermine the foundations of a patriarchal system". In addition, the relative surplus of men can reduce population growth and mitigate the global impact of the structural male-biased norms (Kolk & Jebari, 2022).

To our knowledge, these two frameworks have not explored how male-skewed sex ratios influence fertility preferences. Moreover, both of these frameworks have been criticized for ignoring or under-estimating women's agency in fertility decisions (Gowaty, 1997; Himmelweit, 2000). Nevertheless, they highlight interesting dynamics this study draws on to construct a conceptual framework and formulate research hypotheses focusing on women's preferences. This framework is presented in Fig. 1 and must be viewed as a reduced-form model since the mechanisms described are embedded in complex dynamics of structural norms. Following Guilmoto (2009) and Kolk & Jebari (2022), our central assumption is that high sex ratios may contribute to the disruption of patriarchal sociocultural norms (i.e., less male-biased structural gender norms) and especially to the alteration of fertility preferences (decrease in son preference and increase in daughter preference). Two potential mediating channels may account for this general effect.

The first pathway is linked to the marriage market. Drawing from the sexual selection framework, we hypothesize that the relative scarcity of women increases their relative marriageability compared to men in the marriage market. In the Indian context, this can lead to a decline in the dowry amount or in the prevalence of arranged or forced marriages, for instance, and thus contribute to undermining patriarchal norms at the societal scale and especially the preference for sons. Empirical evidence is in line with this assumption. In Taiwan, Francis (2011) finds that the relative scarcity of women tends to increase the bride price (paid by the husband's family) relative to the dowry (paid by the wife's family) and the proportion of female children in a family. This may lead parents to increase their savings to strengthen the attractiveness of their son, as evidenced by Wei & Zhang (2011). In India, Robitaille (2020) concludes that the increase in marriage expenses by the husband's family tends to undermine son preference. Larsen & Kaur (2013) confirm that the shortage of women in the mating market in India is negatively correlated with the demand for dowry. They also provide evidence that the shortage of women on the marriage market is associated with higher acceptance of husbands living with their wives' parents, greater awareness of women's inheritance rights, and decreased son preference, thus indicating that high sex ratios may alter male-biased structural gender norms. In addition, from an intertemporal perspective, the perception of risks also matters. If there is a high perception of marriage-related risks for males (e.g., involuntary bachelorhood, increased marriage expenses and bride price paid by the husband's family, vulnerability at old-age for men who never marry or uncertainty to the future marriage perspective of sons), structural gender norms and the preference for sons may be affected, as evidenced for instance by Song et al. (2022) in the Chinese context. It is worth noting, however, that the effect of the increased relative marriageability of women in the mating market on structural gender norms is still debated in the literature. As previously explained, from the sexual selection framework perspective, this increased marriageability of women in the marriage market may paradoxically contribute to entrenching women in their traditional gender roles, aligning with a conservative picture of marriage. This could contribute to maintaining male-biased structural norms.

Second, the relative undersupply of women may also increase their power in the intra-familial bargaining process (i.e., dyadic gender norms in the social exchange framework). High sex ratios can increase women's decision-making power, mobility autonomy, education and labor market perspectives and thus decrease the prevalence of male-biased structural norms such as the preference for sons. Several empirical studies support this assumption. Bulte et al. (2015) highlight a positive association between sex ratios and different measures of female bargaining power in China. Still in China, Porter (2017) finds that male-skewed sex ratios tend to decrease the household bargaining power of the husband's family and suggests that this may reverse the preference for sons. Nonetheless, this effect can be mitigated by the strength of patriarchal norms. A strong male structural power may constrain women (even when dyadic gender norms are less male-biased) and maintain them in traditional gender roles, thus limiting the potential for changes in fertility preferences (Pedersen, 1991; South & Trent, 1988).

The framework therefore presents how sex ratios can impact

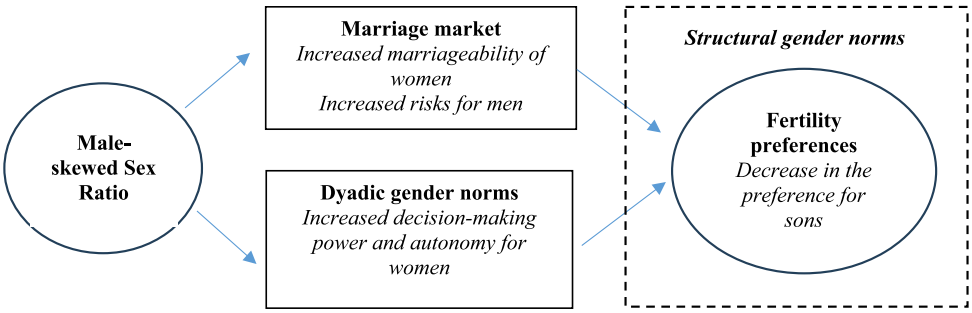

Fig. 1. Potential pathways of the impact of district-level male-skewed sex ratio on women's fertility preferences. .
Source: Authors

marriage market mechanisms and intra-household norms to in turn have an effect on a more structural gender norm: the fertility preferences of women regarding their child's gender. In both hypotheses, opposing mechanisms can mitigate this impact, making an empirical exercise particularly relevant in order to assess whether male-biased sex ratios are self-reinforcing or self-regulating.

3. Methodology

3.1. Baseline model

To analyze the relationship between district-level sex ratios and fertility preferences of women, along with the pathways through which this relationship potentially operates, we first use an individual and time fixed-effect model. This approach allows us to control for time-invariant heterogeneity across individuals and for time dynamics in fertility preference.

$$y_{idt} = \alpha + \beta_1 SexRatio_{dt} + \beta_2 X_{idt} + \beta_3 X_{dt} + \alpha_i + \gamma_t + \epsilon_{idt} \quad (1)$$

For each ever-married adult woman i at a time t ($t = 1$ for 2005 and $t = 2$ for 2011–12), in a district d, Y_{it} refers to dependent variables of women's fertility preferences (i.e., the ideal number of sons and daughters) and a set of proxies illustrating two transmission pathways: the dyadic gender norms pathway (decision-making power; mobility restriction; domestic violence acceptance)[2] and the marriage market pathway (dowry price; age of marriage). The independent variable of interest, $SexRatio_{dt}$, refers to the ratio of men to women per district. In this study, we consider two sex ratio measurements based on different age groups: (i) the ratio of all men to all women (referred to as the all-age male/female ratio); (ii) the ratio of 15–49 y.o. men to 15–49 y.o. women (referred to as the adult male/female ratio). In addition, we control for several individual and household (X_{it}) as well as district-level (X_{dt}) characteristics such as age groups, caste/religion, marital status, contraception use, years of education, newspaper exposure (i.e., reading or not), employment status, number of children, the logarithm of per capita income, farm household, the perceived risk of harassment faced by women in the area, and district-level deprivation and migration indicators (i.e., total number of immigrants by district and share of women immigrants by district). Finally, ϵ_{it} is the error term. Summary statistics of each variable are available in Table S1 of Supplementary Materials.

3.2. Identification strategy

3.2.1. Potential sources of endogeneity

Potential endogeneity in the relationship between the sex ratio and women's fertility preferences can bias the fixed effect estimates described above. The first source of possible endogeneity is the reverse causality underlying the sex ratio and fertility preferences nexus, since, as discussed earlier, the strong prevalence of son preference is one major determinant of unbalanced sex ratios in some Asian countries (Guilmoto, 2009; Guilmoto & Tove, 2015). Second, although the panel specification of Eq. (1) controls for time-invariant individual heterogeneity, the existence of time-varying unobserved factors simultaneously correlated to son preference and the sex ratio, such as the establishment and implementation of family planning policies between the two waves of the IHDS survey, may also alter our estimates. One can assume that the most conservative Indian States that had a wider prevalence of son preference were also more willing to adopt one-child or two-child restriction policies, and thus more likely to have a male-skewed sex ratio. Multiple forms of conservative birth control measures limiting the number of authorized children by women (i.e., two-children birth policies) have been implemented by some Indian States since 1992 (Mandal & Wu, 2023). As observed in China, such birth control policies contribute to an imbalance in the local sex ratio by decreasing the number of female births (Tang et al., 2022). Likewise, the ideal number of daughters is expected to be lower in Indian States that have applied a birth control policy. This fact might contribute to understating the negative impact of the scarcity of women on son preference.

Even if both sources of endogeneity (i.e., reverse causality and omitted time-varying individual factors) are potential concerns in this study, the model specification using the adult sex ratio (calculated from the frequency of women and men that were between 15 and 49 y.o. in the censuses of 2001 and 2011) is less likely to be prone to such biases compared to the all-age sex ratio. Indeed, when using the adult sex ratio, birth events occurred at least 15 years before the measurement of fertility preferences through IDHS data. Nevertheless, we conduct three types of robustness checks to ensure the validity of our results: an instrumental variables' (IV) method, an estimation restricted to States where birth policies were not implemented and a placebo test.

3.2.2. Instrumental variables strategy

To further ensure the robustness of our estimates, we perform an endogeneity-correction model relying on an IV strategy. Specifically, we use average maximum and minimum temperature data of the years of birth of individuals in the sample for each district as instruments,

[2] Following Alvarez-Saavedra et al. (2023), we measure these transmission pathways using dummy variables from the IHDS survey which we aggregate to create scores. Decision-making power is a [0;5] score summing whether women have a say in cooking, big purchases, number of children, seeking medical care for an ill child or children's marriage arrangements. Mobility restriction is a [0; 3] composite index summing whether women need to ask permission to go to health centres, grocery shopping or visit a friend or family member. Domestic violence acceptance is a [0;5] score summing whether violence of husbands towards wives in the following contexts are considered as usual in the community: wife going out without permission, dowry not respected by her family, neglect of the house or children, not cooking properly or having an extra-marital relationship.

assuming that climate is exogenous to women's fertility preferences but highly correlated to the district sex ratio.[3] The empirical literature in human biology and demography exhibits significant correlations between higher temperatures just before conception and the odds of giving birth to boys rather than girls, potentially because warmer temperatures tend to cause more damage to the X than the Y chromosome contained in the sperm during its maturation (Lerchl, 1998a, 1998b, 1999). This indicates that children conceived in hot summers are more likely to be boys (Cagnacci et al., 2003; Helle et al., 2008; Pongou, 2013). Hence, we assume that the average maximum temperature at the time of conception will be positively correlated to the male/female ratio. In contrast, climate change and related extreme events like very cold winters may also affect the sex ratio but in the reverse direction, increasing male fetal and newborn mortality given the greater fragility of male versus female pregnancies (Catalano et al., 2008; Fukuda et al., 2014). Male fetuses are biologically more vulnerable and more frequently eliminated in unfavorable climate conditions, thus explaining that the average minimum temperature at the time of birth will be negatively correlated to the male/female ratio.

Theoretically, the amplitude of the impact of temperature on the sex ratio is expected to be higher in countries where the vulnerability to climate events is higher and where the seasonal variation of air temperature is exacerbated (Melnikov, 2015). Therefore, given the large size and diversity of the Indian territory, the correlation between district average temperatures and the male-skewed sex ratio is potentially strong. Equation (2) describes the first-stage equation of IV regressions. Using an individual and time fixed-effect two-stage least squares (2SLS) estimator, fitted values of district-level sex ratios estimated in Eq.2 are injected in Eq.1 to provide non-biased estimates of the impact of the district sex ratio on women's fertility preferences.

$$\boldsymbol{SexRatio}_{dt} = \alpha + \beta_1 \boldsymbol{Temperatures}_{dt} + \beta_2 \boldsymbol{X}_{dt} + \alpha_d + \gamma_t + \varepsilon_{dt} \quad (2)$$

3.3. Further robustness checks

To test how exposure to birth-control policies influence our individual and time fixed-effect estimates, we replicate the model relying on a restricted sample excluding Indian States that have applied a two-children birth policy following Mandal & Wu (2023): i.e., Rajasthan, Odisha, Andhra Pradesh, Haryana, Himachal Pradesh, Madhya Pradesh, Chhattisgarh, Uttarakhand, Maharashtra, Gujarat, and Bihar.[4] As explained earlier, a significant change in the results, once we exclude these States, would challenge the robustness of our fixed-effect estimates.

Moreover, we also test the sensitivity of our estimates to potential heterogeneity in district-level demographic trajectories. Indeed, it may be argued that conservative districts where women's rights were more often violated have been concerned by higher distortion in their sex-ratio trajectory across time, compared to less-conservative districts with more balanced sex-ratio. Such a selection bias might contribute to understating the negative impact of the scarcity of women on son preference. To reject this potential source of bias, we thus carry out a placebo test on an outcome that is assumed to be unrelated to district-level sex ratio dynamics, but potentially correlated to the initial presence of gender inequality, i.e., female height in 2011–12 (Human height being determined from the intrauterine environment to the 4th year of life). A significant association between this predetermined outcome and the shift of the sex ratio across time would also cast doubt on the validity of our fixed-effect estimates, suggesting potential correlations between initial population characteristics and district-specific demographic trajectories. This placebo test relies on an OLS estimator as follows:

$$\boldsymbol{Height}_{id,2011} = \alpha' + \beta'_1 \Delta \boldsymbol{SexRatio}_d + \beta'_2 \boldsymbol{X}_{id,2011} + \beta'_3 \boldsymbol{X}_{d,2011} + \varepsilon'_{id} \quad (3)$$

4. Data and descriptive statistics

Our empirical investigations are based on the combination of data from the Indian Census (2001 and 2011) and from the India Human Development Survey panel data (IHDS 2004–05 and 2011–12). The IHDS is a nationally representative longitudinal dataset administered by the University of Maryland and the National Council of Applied Economic Research. From IHDS, we exploit individual-level data from the women's questionnaire on fertility decisions, bargaining power, gender norms, marriage-related indicators, as well as other individual and household economic and sociodemographic characteristics. From the Census, we retrieve district-level sex ratios, a deprivation index and migration indicators (the size of the immigrant population in each district, and the share of women immigrants). We merge the datasets longitudinally to attribute the relevant demographic information sourced from the closest Census wave to each IHDS wave, i.e., the 2001 census was merged with the 2004–05 IHDS and the 2011 census was merged with the 2011–12 IHDS. To perform our IV strategy, we also longitudinally merge data from the India Meteorological Department to measure instruments relying on average maximum and minimum temperatures at the district level (see footnote 2).

Table 1 shows the stated preference of women in terms of their ideal number of sons and daughters. On average, women want 1.40 sons and 1.09 daughters in 2004–05 compared to 1.42 and 1.17 respectively in 2011–12. These differences between the preference for sons and daughters are significant at the 1 % level in both survey waves.

As shown in summary statistics reported in Table S1 of Supplementary Materials, sex ratio was relatively stable on average in India between 2001 and 2011; although observing a slight decrease from + 8 % of men in 2001 to + 6 % of men, on average on the whole Indian territory. However, these national level statistics hidden rural–urban and regional specificities. Fig. 2 shows all-age sex ratio maps by district and time in urban and rural areas.[5] The figure shows that sex ratios differ across districts both in urban and rural areas, with similar trends in 2001 and 2011. Northern districts have more imbalanced sex ratios than Southern districts in both waves and rural and urban areas, although slightly more so in urban districts than rural ones. The higher sex ratio imbalance in the Northeastern regions reflects the strongly rooted son preference in States where the Brahmanical tradition is highly present such as Uttar Pradesh and Bihar (Kumar & Rohtak, 2018; Lawrence & Hensly, 2023).

Table 1
Preference for sons and daughters across time.

Variable	Mean	SD	Min	Max	N
Ideal number of sons (2004–05)	1.40	0.64	0	8	21,504
Ideal number of daughters (2004–05)	1.09	0.47	0	6	21,324
Ideal number of sons (2011–12)	1.42	0.62	0	11	22,469
Ideal number of daughters (2011–12)	1.17	0.51	0	15	22,297

Source: IHDS (2004–05 and 2011–12).

[3] To instrument the all-age male/female ratio, we calculated district-level average minimum and maximum temperatures in °C from 1952 to 2001 for the 2001 Indian census and from 1962 to 2011 for the 2011 Indian census. To instrument the adult male/female ratio, we calculated district-level average minimum and maximum temperatures from 1952 to 1986 for the 2001 Indian census and from 1962 to 1996 for the 2011 Indian census. Temperature data are provided by the India Meteorological Department from this open access website: https://www.imdpune.gov.in/lrfindex.php.The data provides 961 measurement points per day disseminated in all the Indian territory. The nearest measurement point to the district centroid was attributed to each district.

[4] See Mandal & Wu (2023) for a detailed summary of the policy implementation.

[5] Fig. S1 in Supplementary Materials shows the same maps for adult sex ratio.

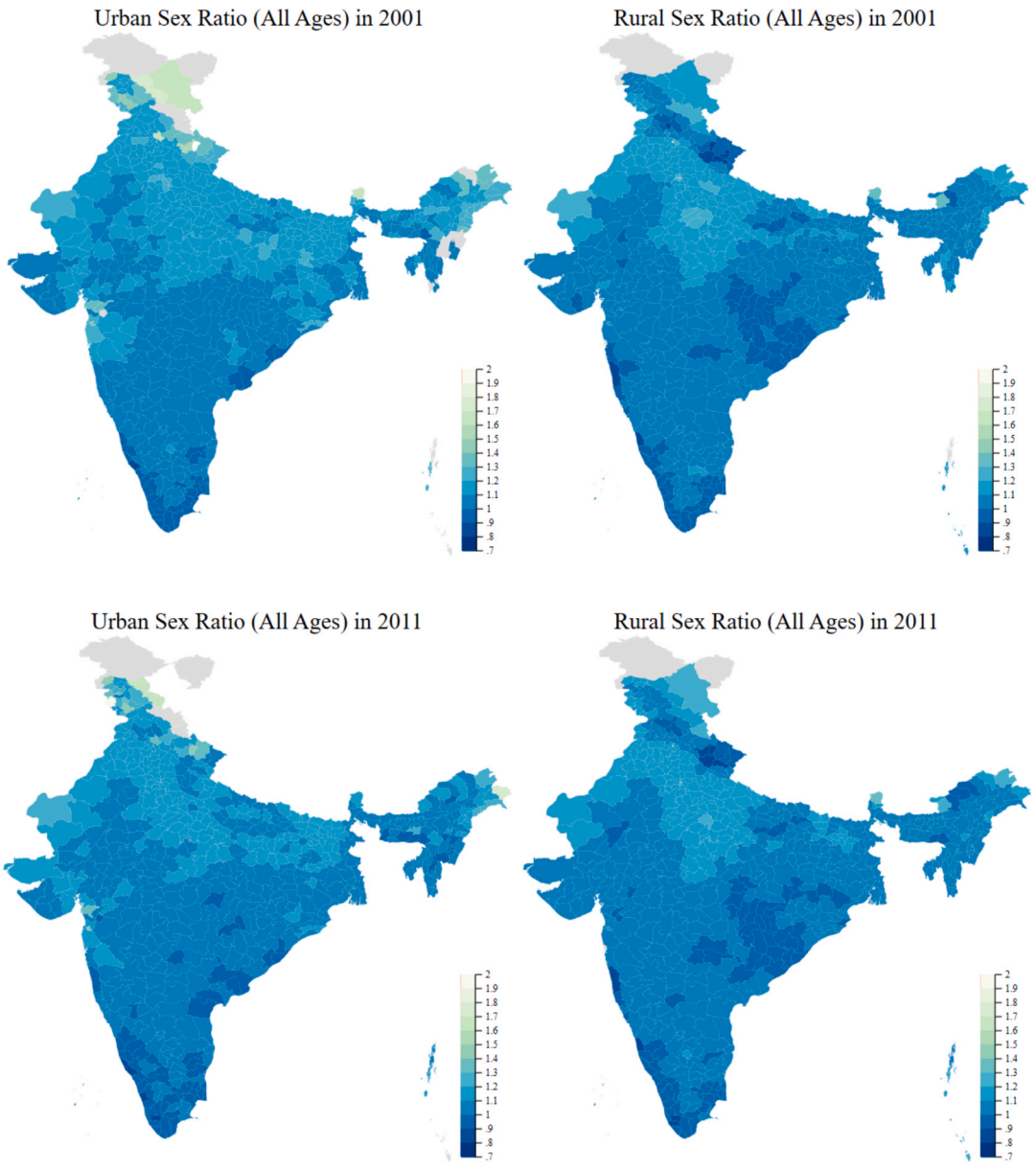

Fig. 2. All-age sex ratio by district and time. .
Source: Authors' calculations from Indian Census (2001 and 2011)

5. Results

5.1. Impact of sex ratio on women's fertility preferences

Table 2 reports our baseline estimates for the individual and time fixed-effect regressions of fertility preferences by women (15–49 y.o.) on district sex ratio, controlling for a comprehensive set of covariates (cf., section 3.1). Full regression results including all the covariates are presented in Table S2 and S3 of Supplementary Materials. We find that an increase in the district-level all-age sex ratio contributes to decreasing women's ideal number of total children (at the 10 % level), ideal number of sons (at the 1 % level) and the share of sons among all children desired (at the 1 % level). A 0.1 unit increase in the sex ratio (+10 % of men compared to women) is associated with a 0.06 decrease in the number of children wanted, a 0.07 decrease in the number of sons wanted and a decrease of 1 percentage point in the share of sons wanted. As expected, the sign of the coefficient on the sex ratio is positive for the ideal number of daughters, even if the effect is not significant. We find similar results with the adult sex ratio, which is more closely related to the marriage market sex ratio. As shown in Tables S2 and S3, these results remain significant even when the sample is split into rural and urban districts.

To address potential simultaneity bias and persisting time-varying individual heterogeneity that could understate the impact of women scarcity on fertility preference (cf., section 3.2), we employ an IV strategy instrumenting the district sex ratio using average minimal and maximal temperatures (in °C). Full first-stage and second-stage IV regression tables are available in Tables S4 and S5 of Supplementary Materials, respectively. In Table S4, first-stage regressions indicate that the instruments are highly correlated to sex ratio indicators and consequently can be considered as strong (i.e., high values of the F-statistics on excluded instruments). As assumed, district average maximal temperatures are positively and significantly (at the 1 % level) correlated to the sex ratio, potentially due to damage of X chromosomes in the sperm during hot waves at the time of conception, meanwhile district average minimal temperatures are negatively correlated with the sex ratio, potentially due to a higher risk of mortality among male fetus and

Table 2
Fixed-effects regressions of women's fertility preferences on district sex ratio.

	Ideal # of children	Ideal # of sons	Ideal # of daughters	Ideal share of sons
All-age male/female ratio in the district				
Fitted coefficients	−0.568*	−0.652***	0.082	−0.122***
Standard errors	(0.290)	(0.203)	(0.172)	(0.045)
Observations	*39,097*	*39,464*	*39,149*	*38,835*
R-square	*0.751*	*0.735*	*0.693*	*0.658*
Adult male/female ratio in the district				
Fitted coefficients	−0.252	−0.374***	0.121	−0.080***
Standard errors	(0.170)	(0.119)	(0.100)	(0.026)
Observations	*39,097*	*39,464*	*39,149*	*38,835*
R-square	*0.751*	*0.735*	*0.693*	*0.658*

Notes: Time fixed-effects regressions with control variables: age groups, caste/religion, marital status, contraception use, years of education, newspaper exposure, employment status, number of children, logarithm of per capita income, farm household, area girl harassment risk, district deprivation index, number of immigrants in the district, share of women immigrants in the district (among all immigrants), survey years. Significance levels of fitted coefficients are: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: Indian census (2001 and 2011), IHDS (2004–05 and 2011–12).

newborns when climate conditions are less favorable like cold waves or storms. More details on these assumptions are available in Section 3.2.2. Table 3 sums up our second-stage IV results. Although the signs of instrumented fitted coefficients are the same as those observed in Table 2, we highlight some differences regarding their level of significance. Considering the all-age male/female ratio, only the negative effect on the ideal number of sons is significant (at the 5 % level). Considering the adult male/female ratio, Table 3 also reveals significant (at the 1 % level) negative impacts on the ideal number and the ideal share of sons, but also a significant positive impact on the ideal number of daughters. For a 0.1 increase in the district adult sex ratio, there is a 0.3 decrease in the ideal number of sons, a 0.3 increase in the ideal number of daughters and a decrease of 7 percentage points in the ideal share of sons.

Table 3
Fixed-effects IV regressions of women's fertility preferences on instrumented district sex ratio.

	Ideal # of children	Ideal # of sons	Ideal # of daughters	Ideal share of sons
All-age male/female ratio in the district				
Fitted coefficients	−1.857	−3.340**	1.496	−0.542
Standard errors	(2.245)	(1.570)	(1.326)	(0.336)
Observations	*38,116*	*38,478*	*38,164*	*37,870*
Adult male/female ratio in the district				
Fitted coefficients	−0.273	−2.888***	2.718***	−0.764***
Standard errors	(1.145)	(0.821)	(0.690)	(0.176)
Observations	*38,116*	*38,478*	*38,164*	*37,870*

Notes: Time fixed-effects regressions with control variables: age groups, caste/religion, marital status, contraception use, years of education, newspaper exposure, employment status, number of children, logarithm of per capita income, farm household, area girl harassment risk, district deprivation index, number of immigrants in the district, share of women immigrants in the district (among all immigrants), survey years. Significance levels of fitted coefficients are: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: Indian census (2001 and 2011), IHDS (2004–05 and 2011–12), India Meteorological Department (1952–2011).

5.2. Exploring potential pathways

Following the conceptual framework illustrated in Fig. 1, Table 4 investigates the potential pathways mediating the relationship between women scarcity and fertility preferences (full regression results are reported in Table S6). These results suggest that changes in fertility preferences could be due to a redefinition of intra-household structural norms in favor of women, since higher district-level sex ratios are associated with increasing female decision-making power and autonomy (at the 1 % level), and decreasing acceptance of domestic violence in the community (at the 1 % level). However, we do not find any significant effect of sex ratios on women's mobility restriction. Moreover, the relative marriageability of women on the marriage market also matters insofar as higher sex ratios tend to decrease dowry amounts and increase the age at marriage, on average.

5.3. Robustness tests

To further examine the identified effects, we carry out robustness checks. The first test addresses the potential influence of State-level policies aiming to limit the number of authorized children. To do so, Table 5 reports the estimates on a restricted sample including only Indian States that have not applied such control birth policies. The results are very similar to those presented in Table 3, suggesting that our results are robust to a potential selection bias due to an overrepresentation of conservative districts where sex ratios would be particularly male-skewed and son preference high.

Second, in line with Eq.3., the placebo test presented in Table 6 shows that there is no significant correlation between initial population characteristics (here women's height) and district-specific demographic trajectories, indicating an absence of selection bias due to unobserved population differences across districts.

6. Discussion

Based on the combination of different datasets from the Indian census, the IHDS and temperature measures from the India Meteorological Department, this article provides an in-depth empirical exploration of the impact of district-level sex ratios on women's fertility preferences. Using individual and time fixed-effect regressions, we find that, among Indian districts where women are relatively scarce, women's ideal number of sons and ideal share of sons among her children are significantly lower, compared with districts where the sex ratio is more balanced. We also find a positive but non-significant association between district-level scarcity of women and the ideal number of daughters reported by women. From our point of view, the fact that the decline in preference for sons with increased sex ratios is not significantly compensated by an increase in preference for daughters must be linked to the context of declining fertility in India. Additional endogeneity-correction procedures based on IV, restricted samples and placebo tests largely confirm these baseline results. These findings are consistent with the empirical literature focusing on China (e.g., Dong et al., 2021; Li et al., 2016) and India (e.g., Diamond-Smith et al., 2020; Diamond-Smith & Bishai, 2015).

To better understand the mechanisms explaining how the scarcity of women can decrease the preference for sons, we investigate potential associations between district-level sex ratio and proxies of gender-related structural norms and the relative "marriageability" of women on the marriage market. As hypothesized in our conceptual framework, these investigations suggest that women have more decision-making power in the household in districts where the sex ratio is higher. In such districts, they are also less tolerant of domestic violence. In addition, the marriage market seems relatively more favorable for women when the district sex ratio is higher: the dowry paid by the wife's family is significantly lower and the age of marriage is significantly higher (which is not trivial in a country where child marriage is still a common

Table 4
Fixed-effects regressions of potential pathways on district sex ratio.

	Gender structural norms in the household			Marriageability	
	Decision-making power (5-point score)	Mobility restriction (5-point score)	Domestic violence acceptance	Dowry price (in roupies)	Age of marriage (in years)
All age male/female ratio in the district					
Fitted coefficients	1.250***	0.160	−2.071***	−142,129	1.309**
Standard errors	(0.343)	(0.344)	(0.503)	(−39,616)	(0.646)
Observations	*44,792*	*44,809*	*44,626*	*44,173*	*44,835*
R-square	*0.636*	*0.586*	*0.604*	*0.771*	*0.852*
Adult male/female ratio in the district					
Fitted coefficients	0.591***	0.081	−0.854***	−68,074***	1.096***
Standard errors	(0.202)	(0.202)	(0.296)	(–23,313)	(0.380)
Observations	*44,792*	*44,809*	*44,626*	*44,173*	*44,835*
R-square	*0.635*	*0.586*	*0.604*	*0.771*	*0.852*

Notes: Time fixed-effects regressions with control variables: age groups, caste/religion, marital status, contraception use, years of education, newspaper exposure, employment status, number of children, logarithm of per capita income, farm household, area girl harassment risk, district deprivation index, number of immigrants in the district, share of women immigrants in the district (among all immigrants), survey years. Significance levels of fitted coefficients are: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: Indian census (2001 and 2011), IHDS (2004–05 and 2011–12).

Table 5
Fixed-effects estimates based on the restricted sample excluding Indian States that have applied a birth control policy.

	All women (15–49)			
	Ideal # of children	Ideal # of sons	Ideal # of daughters	Ideal share of sons
All age male/female ratio in the district				
Fitted coefficients	−0.323	−0.585**	0.032	−0.098*
Standard errors	(0.351)	(0.258)	(0.217)	(0.056)
Observations	*19,949*	*17,694*	*17,543*	*17,314*
R-square	*0.715*	*0.751*	*0.731*	*0.684*
Adult male/female ratio in the district				
Fitted coefficients	−0.108	−0.270*	0.098	−0.061*
Standard errors	(0.205)	(0.150)	(0.126)	(0.032)
Observations	*19,949*	*17,694*	*17,543*	*17,314*
R-square	*0.715*	*0.751*	*0.731*	*0.684*

Notes: Excluded States are Rajasthan, Odisha, Andhra Pradesh, Haryana, Himachal Pradesh, Madhya Pradesh, Chhattisgarh, Uttarakhand, Maharashtra, Gujarat and Bihar in restriction 2. Time fixed-effects regressions with control variables: age groups, caste/religion, marital status, contraception use, years of education, newspaper exposure, employment status, number of children, logarithm of per capita income, farm household, area girl harassment risk, district deprivation index, number of immigrants in the district, share of women immigrants in the district (among all immigrants), survey years. Significance levels of fitted coefficients are: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: Indian census (2001 and 2011), IHDS (2004–05 and 2011).

Table 6
Placebo tests regressing current height on change in district-level sex ratio.

	Female height in 2011–2
Delta of all age male/female ratio in the district (2011–2001)	
Fitted coefficients	0.019
Standard errors	(0.020)
Observations	*22,070*
R-square	*0.085*
Delta of adult male/female ratio in the district (2011–2001)	
Fitted coefficients	0.001
Standard errors	(0.012)
Observations	*22,070*
R-square	*0.085*

Notes: Excluded States are Rajasthan, Odisha, Andhra Pradesh, Haryana, Himachal Pradesh, Madhya Pradesh, Chhattisgarh, Uttarakhand, Maharashtra, Gujarat and Bihar in restriction 2. Time fixed-effects regressions with control variables: age groups, caste/religion, marital status, contraception use, years of education, newspaper exposure, employment status, number of children, logarithm of per capita income, farm household, area girl harassment risk, district deprivation index, number of immigrants in the district, share of women immigrants in the district (among all immigrants), survey years, urbanicity of living area, Indian States fixed-effects. Significance levels of fitted coefficients are: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.
Source: Indian census (2001 and 2011), IHDS (2004–05 and 2011–12).

practice). Broadly speaking, these results regarding pathways are consistent with the literature examining the case of India (e.g., Francis, 2011; Robitaille, 2020).

This study provides an important contribution to understanding the relationship between sex ratios and preference for sons, opening up potential research avenues. First, one of the important contributions of this study is that the framework underlying the analysis puts women's voice and agency at the forefront, addressing some of the limitations previously directed towards the sexual selection theory. However, using women's stated preferences in the empirical analysis is limited by a lack of data on husband's preferences and on how spouses' son preference influence one another in our study. It would be possible that either women do not state their true preferences or that their preference does not matter in terms of decision-making (Robitaille & Chatterjee, 2020). Investigating the influence of imbalanced sex ratios on male fertility preferences is an interesting research avenue to expand on our findings. The literature on this topic, which is still limited due to a lack of data on male preferences, tends to show a woman's preference is relatively more important than her husband's preference for abortion decisions in Madhya Pradesh (India) and for the decision to have a third child in Nepal (Jennings & Pierotti, 2016; MacQuarrie & Edmeades, 2015).

Second, this article focuses on the influence of adult sex ratios on fertility preferences. Further research can provide insights into the influence of sex ratios at birth, or child sex ratios, on fertility preferences. This would allow investigation of whether women shape their fertility preferences based on their own experience in the marriage market or by anticipating future marital prospects of their children based on the composition of their age cohorts.

Third, to account for the potential influence of migration on the relationship between sex ratios and fertility preferences, our regressions control for district-level migration levels. However, the data lack information at the individual level on marriage-related migration, which would strengthen the econometric models and provide more robust results. While a large proportion of women in India migrate for marriage,

these movements often occur within the same *jatis* (i.e., sub-caste endogamy) which are regionally bounded. Facing the local shortage of brides, cross-regional marriages are, however, increasing, as documented by Mishra (2013) in Haryana and Chaudhry (2019) in Uttar Pradesh. Rao & Finnoff (2015) show that in 2007–2008, 68 % of women's migration for marriages took place within the same district, followed by 26 % in the same State but different districts, and 6 % in different States. Given the large share of intra-district migration for marriage, we argue that it is unlikely to significantly bias our results. Nevertheless, richer data on both fertility preferences and migration trajectories would allow to explore whether inter-district marriages influence the mechanisms uncovered in this study.

To conclude, in accordance with the previous literature analyzing the case of India (e.g., Diamond-Smith et al., 2020; Diamond-Smith & Bishai, 2015), the present study indicates that self-corrective forces in society may contribute to balance sex ratios over time, alternating periods of growth and periods of decline. Indeed, our results show that an increase of the male/female ratio tends to change gender norms, not only in the household but also in the community – namely through the marriage market – contributing to improving women's conditions and changing women's fertility preferences (i.e., decreasing son preference and increasing daughter preference).

It is nevertheless important to interpret the findings on the existence of this self-corrective phenomenon with nuance. Experiences from other Asian countries show that son preference can persist, even when it has decreased to a great extent and sex ratios have become less skewed. Yoo et al. (2017) provide such evidence in the context of South Korea, where they find that son preference is a persistent behavior that lingers despite having substantially decreased between 1991 and 2012, concomitantly to the normalization of sex ratios at birth. Tang & Hou (2024) document the same entrenched preference in China, especially in some Southeastern provinces. Son preference is an integral component of a patriarchal gender norms system which is potentially why the effects shown in our study are relatively small despite being significant. In many Asian contexts, patrilineal preferences and practices, marriage practices (e.g., dowry payment, arranged marriages, etc.), gender-based inheritance systems, considering sons as financial providers for the family and/or gender stereotypes, are persisting structural gender norms (Brunson, 2010; Robitaille, 2020; Tang & Hou, 2024). These phenomena are particularly prominent in India and explain why son preference is a persisting norm, especially in the Northeastern States where the Brahmanical tradition emphasizing the role of sons prevails (Kumar & Rohtak, 2018; Lawrence & Hensly, 2023).

Given the potential rebalancing nature of sex ratios that our findings suggest, in light of the albeit limited shift of son preference, this study calls for ambitious and tailored gender-based policies to accelerate the decline in skewed sex ratios and son preference. Although evidence regarding the effectiveness of legislative bans on sex-selective abortions and conditional cash transfers aimed at offsetting the 'cost of daughters' compared to sons is mixed, indirect legislative reforms in areas such as family law, social security, labor markets, education, and political representation, along with mass media campaigns, present promising strategies for transforming gender norms and reducing son preference (Kumar & Sinha, 2020).

CRediT authorship contribution statement

Matthieu Clément: Writing – review & editing, Writing – original draft, Validation, Investigation. **Pierre Levasseur:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Suneha Seetahul:** Writing – review & editing, Writing – original draft, Visualization, Validation, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.worlddev.2025.107046.

Data availability

Data will be made available on request.

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