Sex-selective abortions over the past four decades in China

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Abstract

Background China now faces multiple challenging demographic and public policy problems that have emerged from four decades of sex-selective induced abortions. The sex-selective induced abortion of female fetuses has been under-examined quantitatively in China.

Methods Using annual data on the officially registered number of births, induced abortions, and SRB data, we estimate the annual number of sex-selective abortions and then estimated two related proportions over the past decades.

Results The annual proportions and number of selective abortions rose in the 1980s with the strict family planning policy and the diffusion of sex identification technology, remained at a high level between 1990 and 2010, and then declined, totaling 30.04 million. The abortion of second-order female fetuses was the largest proportion of all sex-selective abortions but declined after 2000 partly due to the change in birth composition by order. Children's composition affected sex-selective practice. Village selective abortions accounted for the majority of all selective abortions but decreased markedly in 2010 with changes in birth composition by residence. The rural–urban comparison by order indicated that urban couples were not less likely to abort female fetuses than their rural counterparts. Sex-selective abortions still exhibit provincial differences.

Conclusions In China, the long-standing preference for sons, easy access to sex-selective technologies, and the spontaneous fertility decline have led to the continued practice of selectively aborting female fetuses, despite its prohibition. As a result, the imbalanced sex ratio may take years to normalize.

Keywords Sex-selective abortion, Sex ratio at birth, Birth order, China

Introduction

Induced abortion has been a great concern in China. According to the official statistics, the annual number of registered induced abortions increased from 5 million in the early 1970s to a peak of 14.37 million in 1983, then fluctuated between 10 and 14 million for a decade. Since 1993, the annual number has fallen below 10 million and was 8.96 million in 2020 [49]. Induced abortions fall into three categories in China, namely voluntary induced abortions, involuntary induced abortion as a submission to the family planning policy, and sex-selective induced abortions which are interwoven with the first two categories. For voluntary induced abortion, China legalized induced abortions to satisfy the demand for voluntary control over excess births as early as in the 1950s [45, 46, 71]. After 2000, small-scale surveys concerning young women indicate that young women under 25 years old and unmarried women accounted increasingly for induced abortions [70]. For involuntary induce abortion, has been mainly linked to and complicated by China's

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birth control policy over the past decades [50]. Ever since the early 1980s, forced abortions have been prevalent in the implementation of the birth control policy to help family planning cadres to achieve their quotas, and compliance with the family planning was a prominent reason for induced abortions [42, 71, 71]. In many official provincial family planning regulations, induced abortion was introduced as a remedial measure for out-of-quota pregnancies following the guidelines of the national decree [4]. However, with the currently available data, it is difficult to estimate the number of involuntary abortions.

Sex-selective induced abortion has been reported since the early 1980s with the strict implementation of the one-child-per-couple policy and the availability of sex identification technology [31, 71, 71]. The decline in fertility, either spontaneously due to socioeconomic development or involuntarily due to compliance with the family planning policy, increased the pressure for sex selection in the context of son preference [20, 27]. The introduction of ultrasound B machines and the availability of sex identification technology made the abortion of female fetuses widespread in China. Since sex-selective abortion has been prohibited, the extent to which sex-selective induced abortions are practiced is subject to debate, and the actual number of selective abortions is impossible to obtain, it can only be estimated [11, 30]. An estimate made three decades ago claims that, even if the abortion of female fetuses could explain the entire distortion in China's SRB, it would account for less than 5 percent of all abortions reported for 1986 [31]. Another survey of 820 women conducted in central rural China in 2000 found that 36 percent of reported 301 induced abortions were female sex-selective abortions [14]. Selective abortion could change with the introduction of prenatal care technology that can predict fetal sex with far greater certainty [71]. Sex-selective abortions contribute mainly to the phenomenon of missing girls, which include both prenatal and postnatal missing girls. Prenatal missing girls result mainly from the high sex ratio at birth as a result of sex-selective induced abortions, and postnatal missing girls arise from excess female infant and child mortality due to the infanticide and the abandonment of female children as well as the discriminatory treatment of girls' illnesses leading to excess [33].

To date, studies have majorly focused on a quantitative discourse on SRBs, and adopted SRB as an indicator of sex selection [24, 30, 32]. However, sex-selective abortion itself has been under-examined from a quantitative perspective, except for being recognized as one contributor to high SRBs. In this paper, we used annual data on the officially registered number of births, induced abortions, and SRB to estimate the annual number of sex-selective abortions, and then estimated two related proportions over the past decades. For certain years with data, we elucidate the difference by birth order, residence, and province. Below we first introduce the method, and then we introduce the data. After this, we present the results, and then conclusions.

Methods and data

Let N_a represent the number of induced abortions, N_{ssa} denote the number of sex-selective induced abortions, B stand for the number of births, B_m and B_f the number of male and female births. SRB_o denotes the observed SRB, and SRB_n the normal SRB without selective abortions. China's normal SRB is generally assumed to be 106 male births for every 100 female births [16, 31, 35], therefore we adopt SRB_n as 106. It is generally assumed that male fetuses are not selectively aborted and the number of male births can be taken as a benchmark [6, 9, 16]. We calculate the number of sex-selective induced abortions of female fetuses as:

$$N_{ssa} = \frac{B_m}{SRB_n} \times 100 - B_f \qquad (1)$$

If we assume that spontaneous abortions and stillbirths were naturally conceived and gender-neutral, and sex-selective abortions N_{ssa} are included in the total number of induced abortions N_a, then the proportion is

$$P_{ssa/a} = \frac{N_{ssa}}{N_a} \times 100\% \qquad (2)$$

Still, we can calculate the proportion of sex-selective induced abortions to the expected number of female births computed as the sum of female births and sex-selective induced abortions expressed in Formula (3).

$$P_{ssa/(ssa+B_f)} = \frac{N_{ssa}}{(N_{ssa} + B_f)} \times 100\% \qquad (3)$$

The annual birth numbers can be obtained from the Ministry of Public Security for household registration, the National Family Planning Commission for monitoring births in family planning implementation, and the National Bureau of Statistics (NBS) as the authoritative organization of population statistics.

Underreporting has been a concern in China's birth data quality [25]. China's NBS was aware of the issue of underreporting in censuses, intercensal 1% population sample surveys, and annual one-per-thousand sample surveys, so the NBS adjusted upward the fertility levels [25, 70]. The registered total fertility rate (TFR) in the 2000 census is 1.22, but the fertility rate internally used by the NBS is 1.40 [47], indicating an official acknowledgment of a severe under-enumeration of births in census data. The crude birth rate (CBR) derived directly

from 2000 and 2010 census data were 9.85‰ and 9.43‰ respectively, but the officially announced CBR for 2000 and 2010 were 14.03‰ and 11.90‰, respectively, as available in the official yearbooks. A new consensus argued that the NBS over-adjusted the fertility levels [25, 47, 70] . In this paper, we mainly used the official data. For annual births, the NBS published annual year-end population size and crude birth rates. With these, we calculated annual births from 1980 to 2020, which are consistent with the data published in the annual statistics communique available from 1997 to 2020.

In addition to underreporting in births, there is a sex-selective underreporting of female births and a controversial level of SRB. Sex-selective underreporting of female births is regarded as a determinant in China's distortion in SRB [13, 14, 25, 31, 71]. While most studies argue that female births have been predominantly under-enumerated and that the actual SRB should be lower than observed, some others believe that it is male births that are rather underreported. There are also claims that female under-reporting accounts for a very small portion of China's higher SRB, and the majority of SRB distortion is attributed to sex-selective abortion of female fetuses [16, 71]. For SRB data, in census years or intercensal 1% population sample survey years. For other years after 1986, the SRB was calculated based on the annual one-per-thousand sample survey. For years before 1986, the SRB data were cited from the tabulated results from China's 1988 National Fertility Survey (the two per thousand survey), a representative survey with an emphasis on the birth history of 459,000 married women of 15–57 years old in 1988 [44] One concern is the comparability and consistency of SRB over time due to the marked variation in sample size from over 10 or 20 million in census years to just more than 10 thousand births in one-per-thousand sample surveys. In most years, the SRB was calculated based on a one-per-thousand sample, and the smallest sample size exceeds 10 thousand births, which attenuated the concern of comparability. The accuracy of the number of induced abortions is also a subject of debate. China registers induced abortions (NHFPC, 2021), and some demographers argue that the official figures are a reasonably accurate representation of total induced abortions [71]. However, there were portions of induced abortions not registered in the official system [71], partly due to the social unacceptability of extramarital pregnancies in China [3] and the illegalization and prohibition of non-medical sex-selective abortions [11, 71]. Recently young and unmarried women accounted for an increasing portion of abortions [70]. While small-scale surveys indicated under-enumeration in abortions and sex-selective abortion numbers [14, 51], the extent of under-reporting was not officially or reliably provided.

For induced abortion data, we adopted annual induced abortion numbers from the yearbooks published by China's Ministry of Health (renamed Public Health and Family Planning Commission in 2013 and Health Commission in 2018). This organization registered family planning surgical operations including induced abortions that could be tracked in hospitals, clinics, and family planning service stations. But whether induced abortions without official registration were estimated and included in the official figures or not was clear.

In this paper, we used annual data on the officially registered number of births, induced abortions, and SRB data to estimate the number of sex-selective abortions and two related proportions. However, there is an obvious underreporting phenomenon in China's birth data, particularly the serious underreporting of female infants, leading to a skewed sex ratio and an overestimation of the proportion of sex-selective abortions. We employed survival analysis to test the accuracy of the birth number in China. Given that the calculated births number an entire year while census time points vary, we utilized the linear difference method [7] to compute the adjusted survival rate, as illustrated in Fig. 1. The results indicate that the number of births is not significantly overestimated or underestimated, and the calculated number and proportion of sex-selective abortions using official data closely reflect the actual trend.

Results
SRB trend
Figure 2 depicts China's overall SRB from 1980 to 2020 and SRBs by birth order in 1982, 1987, 1990, 2000, 2005, 2010, 2015, and 2020. Figure 3 presents SRBs by residence in 1987, 1990, 2000, 2005, 2010, 2015, and 2020. The trend of China's SRB and the difference in SRB by birth order and residence have been well documented, so we do not reiterate here.

Induced abortions
Table 1 shows the number of births, SRB, as well as the number and proportion of induced abortions from 1980 to 2020. In the 1980s, the number of induced abortions was already large, 9.53 million for 1980. This figure increased rapidly, peaking at 14.37 million in 1983, and then sharply declined in 1984. Induced abortion has been officially advocated as a "remedial" measurement for out-of-quota pregnancies. By combined measures of reward, persuasion, and coercion, China's mass sterilization campaign in 1983 numbered 14.37 abortions [45, 71]. However, the enforced measures and campaigns caused an uproar and ignited strong resistance, so the enforcement
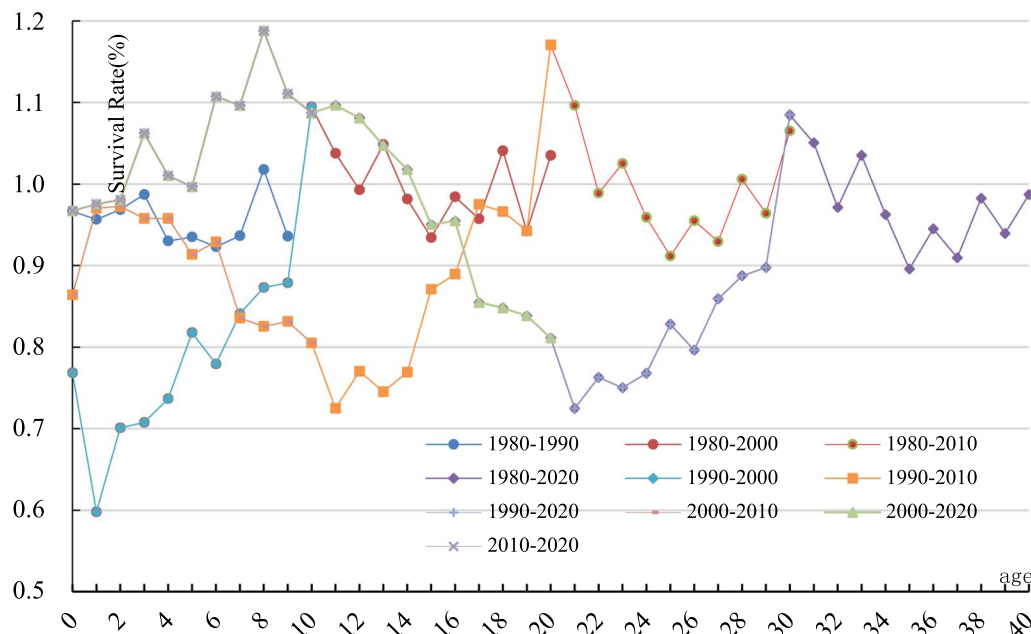
Fig. 1 Survival rate of birth population at different census time points(%)
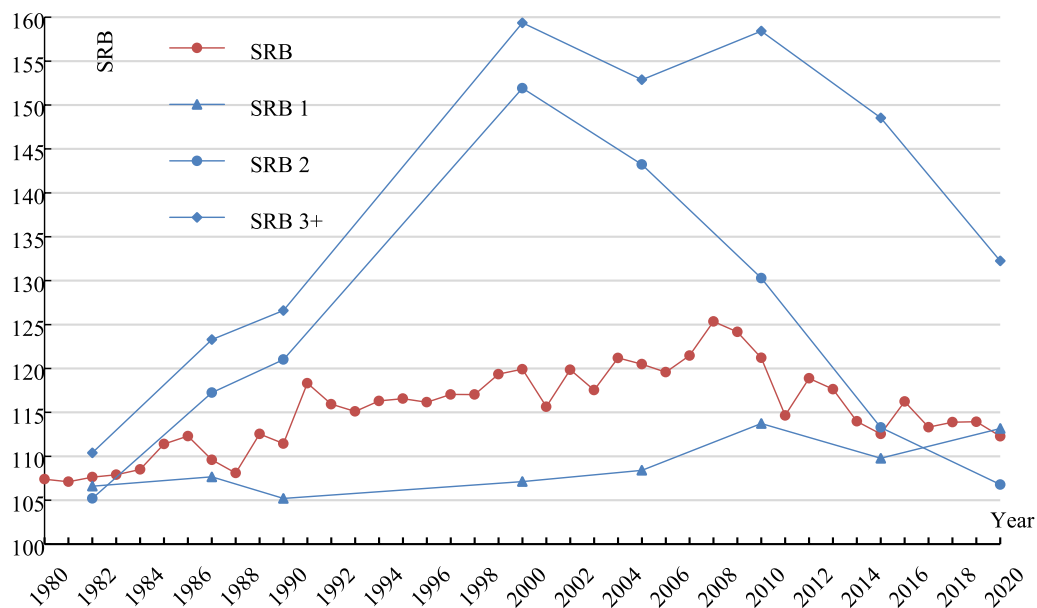
Fig. 2 SRB by birth order

was relaxed, and the number of induced abortions declined [10, 45].

In the late 1980s and early 1990s, the number rebounded when the government imposed measures to minimize the unfavorable demographic impact of the relaxed policy introduced in 1984, and again strengthened its mandatory program on induced abortion and sterilization [29, 71]. Afterward, the number of induced

abortions began to decline. Since the middle 1990s, the number of induced abortions has been quite stable, but recently it resurged. For some empirical research on induced abortions, China's family planning policy was regarded as a dominant predicator for abortion [71]. From 2009 to 2020, while the total number of family planning operations decreased from 22.77 million to 14.69 million, the percentage of induced abortions increased

Fig. 3 SRB by residence

from 6.11 million and 26.8 percent to 8.96 million and 61.02 percent. On one hand, the conception rate of married childbearing w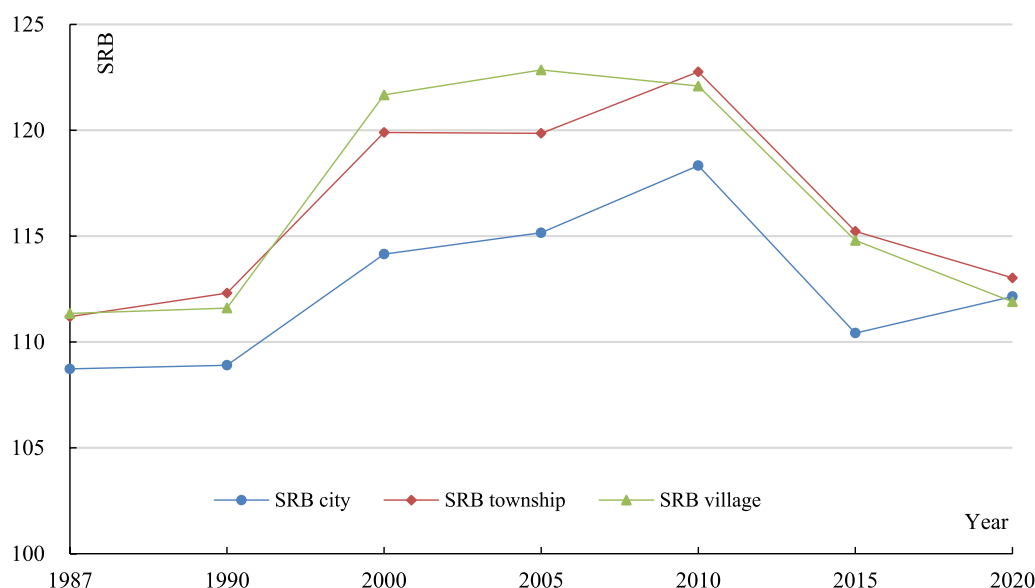omen dropped from around 89.0 percent in 2009 to 80.6 percent in 2018 [49], increasing the risk of unwanted pregnancies and abortions. Meanwhile, induced abortions are becoming more common among unmarried young women, especially rural–urban migrant females [70]. Globally 27 percent of induced abortions were obtained by unmarried women in 2010–2014 [71], women in the 20–24 age group tend to have the highest abortion rate, and the bulk of abortions are accounted for by women in their twenties [71]. China has been more and more tolerant of extramarital pregnancy and induced abortions, coinciding with the global trend. Worldwide, an estimated 50.4 million induced abortions occurred annually in 1990–94, and 56.3 million in 2010–2014 [71]. China accounted for a marked proportion of the world total.

Number and proportion of sex-selective induced abortions
Table 1 and Fig. 4 present the number and proportions of sex-selective induced abortions. The number and proportions of sex-selective induced abortions to total abortions and expected births began to rise in the 1980s, remained at a high level in 1990 through 2010, and then declined. There has been a total of 30.04 million sex-selective aborted female fetuses from 1980 to 2020.

The number and proportion of sex-selective induced abortions changed over time. In the early 1980s, the number and proportion of sex-selective abortions began to rise. The number and proportions were relatively

high after 1984. In 1985, the number jumped to half a million and the two proportions rose to almost 5 percent. As ultrasound technology was first introduced in the early 1980s, some western scholars doubted the availability of this technology and its wide access in the 1980s in China and thought sex-selective abortions were trivial if not nonexistent [1, 38]. Most scholars believed that ultrasound technology was applied to sex selection, especially in the middle 1980s and later [16, 31, 71]. Due to the uncertainty in the extent of the availability of the technology, and the government's concerns over its illegal application for sex selection, it was difficult to gauge the prevalence of sex-selective abortions [31]. Zeng et al. [71] argued that the illegal use of this technology for sex identification was not rare. Our estimates showed that in 1980 through 1984 sex-selective induced abortions were just incipiently spreading. With this relaxation, rural couples in some provinces were permitted a second child and had the chance for repeated pregnancies and sex-selective induced abortions. Medical records of over 1.24 million pregnancies, presumably free of sex-selective underreporting, indicated that the SRB from 1988 through 1991 was 108.0, 108.3, 109.1, and 109.7. This evidence meant that some of those women had undergone sex-selective abortion before this pregnancy, and also proved the increasing prevalence of ultrasound B technology and sex-selective induced abortions in the late 1980s [16, 71]. Hull [31] estimated that the number of sex-selective induced abortions would represent less than 5 percent of all induced abortions reported for 1986. Our estimate shows that in the middle and late 1980s the

Table 1 Number and proportion of sex-selective abortions

Year	SRB	No. of Birth(million)	Na(million)	Nssa(thousand)	Pssa/a(%)	Pssa/(bf + ssa) (%)
1980	107.40	17.87	9.53	113.80	1.19	1.30
1981	107.10	20.78	8.70	104.12	1.20	1.03
1982	107.63	22.47	12.42	166.42	1.34	1.51
1983	107.90	20.66	14.37	178.12	1.24	1.76
1984	108.50	20.63	8.89	233.36	2.62	2.30
1985	111.40	22.11	10.93	532.81	4.87	4.85
1986	112.30	23.96	11.58	670.77	5.79	5.61
1987	109.60	25.29	10.49	409.78	3.91	3.28
1988	108.10	24.64	12.68	234.58	1.85	1.94
1989	112.54	24.14	10.38	700.76	6.75	5.81
1990	111.45	23.91	13.49	581.16	4.31	4.89
1991	118.33	22.65	14.09	1206.36	8.56	10.42
1992	115.94	21.25	10.42	922.65	8.86	8.57
1993	115.11	21.32	9.50	851.98	8.97	7.92
1994	116.30	21.10	9.47	948.21	10.02	8.86
1995	116.57	20.63	7.48	949.94	12.71	9.07
1996	116.16	20.67	8.83	916.69	10.38	8.75
1997	117.04	20.38	6.59	978.36	14.85	9.44
1998	117.03	19.91	7.38	954.45	12.93	9.42
1999	119.35	19.09	6.76	1096.09	16.20	11.19
2000	119.92	17.71	6.66	1057.57	15.88	11.61
2001	115.65	17.02	6.28	718.28	11.43	8.34
2002	119.86	16.47	6.81	979.24	14.37	11.56
2003	117.54	15.99	7.22	799.90	11.09	9.81
2004	121.20	15.93	7.14	1032.72	14.46	12.54
2005	120.49	16.17	7.11	1002.81	14.11	12.03
2006	119.58	15.84	7.31	924.20	12.65	11.36
2007	121.48	15.94	7.63	1050.74	13.77	12.74
2008	125.35	16.08	9.17	1302.58	14.20	15.44
2009	124.16	16.15	6.11	1234.33	20.20	14.63
2010	121.21	15.92	6.36	1032.42	16.23	12.55
2011	114.66	16.04	6.63	610.26	9.20	7.55
2012	118.88	16.35	6.69	907.66	13.57	10.83
2013	117.64	16.40	6.24	827.72	13.27	9.90
2014	113.98	16.87	9.62	593.73	6.17	7.00
2015	112.55	16.55	9.85	480.96	4.88	5.82
2016	116.23	17.86	9.64	797.26	8.27	8.80
2017	113.31	17.23	9.63	557.34	5.79	6.45
2018	113.88	15.23	9.74	529.66	5.44	6.92
2019	113.93	14.65	9.76	512.31	5.25	6.96
2020	112.28	11.99	8.96	334.58	3.73	5.59

N_a represent the number of induced abortions, N_{ssa} denote the number of sex-selective induced abortions, $P_{ssa/a}$ represent the proportion of sex-selective induced abortions to the total induced abortions, $P_{ssa/(ssa+B_f)}$ represent the proportion of sex-selective induced abortions to the expected number of female births

number of sex-selective abortions fluctuated around half a million and the proportions to total abortions and the expected births around 5 percent.

For the two decades from 1990 to 2010, both the number and the proportions fluctuated at a very high level, oscillating around 1 million and stabilizing above 10 percent for most years. This high level could be
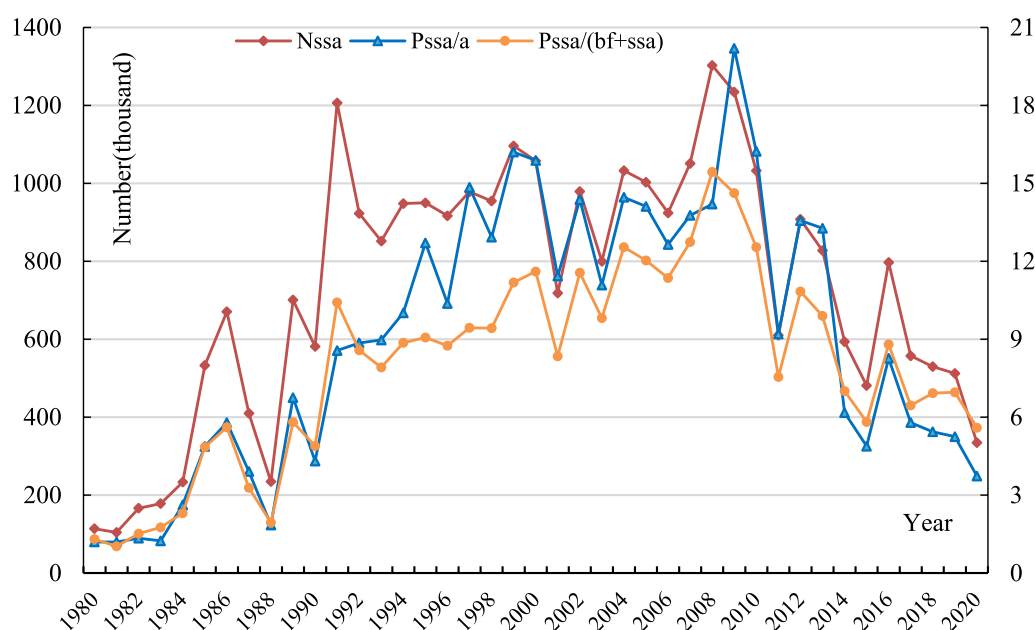
Fig. 4 Number and proportion of sex-selective abortions. *Note* N_{ssa} denote the number of sex-selective induced abortions, $P_{ssa/a}$ represent the proportion of sex-selective induced abortions to the total induced abortions, $P_{ssa/(ssa+B_f)}$ represent the proportion of sex-selective induced abortions to the expected number of female births

ascribed to several factors. The first factor is further diffusion of sex-selection technology and readily accessible equipment. The second factor is the birth control implementation characterized by a predominant 1.5-child policy in most rural regions. By 1990, almost 20 provinces implemented the 1.5 child policy in rural areas [26, 45, 71, 70]. This policy devalued daughters, and implicitly stimulated couples to abort female fetuses [48, 70]. The third reason is the fertility squeeze effect, namely the role of the declining fertility in exerting pressure on couples to resort to sex-selective abortion [5, 20, 27, 39]. According to a survey in central rural China conducted in 2000, among 427 male and 279 female fetuses, 25.4 percent of the female fetuses were aborted, compared to just 1.6 percent of the male fetuses [14]. An estimate of 19.1 percent of couples in 1.5-child policy areas underwent sex-selective abortions, compared to only 4.6 percent in two-child policy areas [70]. In 2007, the National Population and Family Planning Commission conducted a survey of aborted fetuses in some provinces over seven years from 2000 to 2006. The survey was carried out by provincial and local family planning organizations. The number of fetuses identifiable by sex in 2000 to 2006 was 12,677, 10,922, 12,301, 13,742, 14,937, 15,541, 18,549 respectively, and the ratio of males for every 100 aborted female fetuses was 74.02, 70.47, 73.45, 72.51, 71.79, 71.31, 64.89 respectively. About a third of the aborted female fetuses were selectively aborted [8].

Ever since 2010, the number dropped below 1 million and proportions below 10 percent. The prenatal sex identification technology has been easily available and affordable, and fertility remained at a very low level spontaneously, both of which contributed to sex-selective induced abortions. There are still other factors pushing the sex-selective abortion phenomenon down. China continuously advocates gender equality and the social status of women has improved markedly, while China combats "two illegals" [40, 48]. Surveys in rural China did indicate a markedly improved bargaining power of women over marriage and intrahousehold power structure, as well as a radical change in attitude towards sons and daughters [43]. China may optimistically follow the SRB transition trajectory of South Korea and return to normal [18, 27], which means that there would be no more sex-selective induced abortions. As gender equality has gained widespread acceptance, with the advancement of women's education leading to higher social standing, the desire for male offspring is noticeably diminishing [37]. With the introduction of the universal two-child policy in 2016, there was a substantial decrease in sex-selective abortions, as evidenced by the reduction in China's SRB from 116.23 in 2016 to 112.28 in 2020. This shift reflects a positive trend towards gender equality and the appreciation of girls within Chinese society [23, 71].

Table 2 Number and proportion of sex-selective abortions by birth order

Year	Nssa 1	Nssa 2	Nssa 3+	Pssa/(bf+ssa) 1	Pssa/(bf+ssa) 2	Pssa/(bf+ssa) 3+
1982	29.09	−21.16	133.74	0.56	−0.76	3.99
1987	99.47	375.02	323.18	1.54	9.59	14.02
1990	−43.28	479.59	395.35	−0.76	12.41	16.27
2000	61.47	794.15	202.11	1.05	30.23	33.49
2005	111.02	739.22	152.59	2.22	25.99	30.66
2010	337.70	495.57	199.40	6.80	18.64	33.09
2015	149.48	211.86	190.11	3.44	6.43	28.64
2020	174.15	18.38	142.31	6.34	0.73	19.85

$N_{ssa}1$, $N_{ssa}2$, and $N_{ssa}3+$ denote the number of sex-selective induced abortions for first, second, third and above births, $P_{ssa/(ssa+B_f)}1$, $P_{ssa/(ssa+B_f)}2$, and $P_{ssa/(ssa+B_f)}3+$ represent the proportion of sex-selective induced abortions for first, second, third and above births to the expected number of female births

Number and proportion by birth order

We still examined the number and proportion of sex-selective induced abortions by birth order, as presented in Table 2.[1] Whether the female fetus will be aborted or born after an ultrasound B-scan is related to the order of the pregnancy and children composition. The higher the pregnancy order, the more likely the female fetus is to be aborted [14].

For first births, the number and proportion were negligible before 2010 but rose in 2010. Since the late 2000s, as fertility spontaneously declined further, people turned to sex-selective abortion for first births. The survey data collected in 2013 in western China indicate that couples with son preference would turn to sex-selective induced abortions to ensure a son at first birth, and then subdue their intention to produce a second child [34].

For second, third and above births, the number and proportion rose from 1982 to 2000, remained at a high level during most of the period. However, the number and proportion of sex selective abortions for second births started to decline after 2000. In 2020, the number and proportion were 18.38 thousand and 0.73 percent, respectively.

Scholars have discerned the sex-selective induced abortion contribution to the distortion in China's sex ratio at the second birth order in the 1980s [16]. In 2005, the intercensal 1% population sample survey indicates that the sex ratio rose steeply for second-order births while for first-order births it's normal [71]. According to our estimate, the abortion of second-order female fetuses contributed most to the total of sex-selective induced abortions, followed by third-order induced abortions. In 2000, the sex-selective induced abortions at second-order births accounted for 75.08 percent of all sex-selective induced abortions, whereas the sex-selective induced abortions at first-order births accounted for about 5.8 percent. In 2020, the percentage of first-order selective abortions rose to 52.01 percent due to the increase in the selective induced abortions at first birth as a result of fertility decline and to the change in birth order composition. Besides birth order, the heightened tendency of being aborted for female fetuses is correlated with the children's composition. Couples with only daughters are more likely to sex-select their next fetus to ensure a son. The 1990 census data indicate that the sex ratio of second births for women who had a daughter was 149.44, and 224.88 for women with only two daughters [17, 41]. In 2000, the survey conducted in central rural China with a 1.5 child policy as mentioned above showed that 92 percent of the female fetuses in the second pregnancy were aborted if the first child was a girl, versus 5 percent if the first child was a boy [14]. In the official survey implemented in 2007 in Cai [8], among the aborted fetuses identifiable with gender, families with only one daughter recorded the lowest sex ratio of 50.18, and 70.06 for families with only two daughters [8].

We calculate the proportion of sex-selective induced abortions by children composition in 1990 and 2000. The data for the 1990 calculation is 1 percent of the total population from the Integrated Public Use Microdata Series (https://ipums.org/), including 3.21 million 15–49-year-old women with birth information. For 2000, we had no micro-data and adopted the SRB data from Sun [71]. The proportion of sex-selective induced abortions to the expected births by birth composition is listed in Table 3. In the composition of children, the birth sex ratio of boys is low, and the proportion of sex-selective abortion is also low. In 1990, the sex ratio at birth was low at 106 among families with boys, resulting in a negative proportion of sex-selective abortions,

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[1] In 1990, the sex ratio of first births was 105.20, lower than normal SRB of 106 adopted in this paper. Consequently, the proportion of sex-selective abortions is negative, as calculated with formulas (1) and (3) presented.

Table 3 Proportion of sex-selective induced abortions by children composition

Children composition		SRB		Proportion % (No. of female births)	
Boys	Girls	1990	2000	1990	2000
0	0	105.85	105.50	−0.14(59,338)	−0.47
1	0	100.66	107.30	−5.31(17,377)	1.21
0	1	144.28	190.00	26.53(15,096)	44.21
2	0	76.76	76.50	−38.10(3,218)	−38.56
1	1	114.80	122.10	7.67(5,513)	13.19
0	2	206.40	380.60	48.64(3,360)	72.15
3	0	69.85		−51.76(461)	
2	1	90.12		−17.62(1,063)	
1	2	142.36		25.54(1,480)	
0	3	206.64		48.70(903)	

Data source: Data for 1990[3] was calculated by author with data from the IPUMS. Data for 2000 was calculated with SRB from Sun [71]

which indicates that the decision to abort female fetuses was closely related to the gender composition of the children. There is a strong gender preference in China, and the preference for boys drives couples with only girls or more girls to continue to have children, prompting the proportion of selective abortion to increase. The results reveal that the heightened tendency of being selectively aborted for female fetuses is closely related to the sex composition.

Number and proportion by residence

Figure 5 presents the number and proportion for city, township and village populations. In 1987 and 1990 the proportion of selective induced abortions to the expected births was very low but rose steeply in 2000. Village and township proportions were higher than that of the city. In the countryside, sons could provide labors in the agricultural production, continue the family lineage, and provide old-age support for parents, therefore sons were much valued among the rural population. Rural couples in the 1.5 child policy areas preferred to have one daughter first so they could have a second birth for a son to achieve "having both a son and a daughter" in compliance with the policy, but that also meant much pressure to ensure a son and higher likelihood of resorting to sex-selective induced abortions at second birth.

The majority of sex-selective induced abortions of female fetuses took place among rural couples. In 2000, the number of sex-selective induced abortions for the city, township, and village populations was 125 thousand, 138 thousand, and 795 thousand, accounting respectively for 11.79 percent, 13.08 percent, and 75.14 percent of all sex-selective induced abortions. The number for village population declined to 102 thousand, and the proportion declined to 30.43 percent in 2020. In contrast, city and township selective induced abortions increased rapidly to 42.02 percent and 27.55 percent of total selective induced abortions respectively due partly to the rapid urbanization process from 36.92 percent in 2000 to 63.89 in 2020.
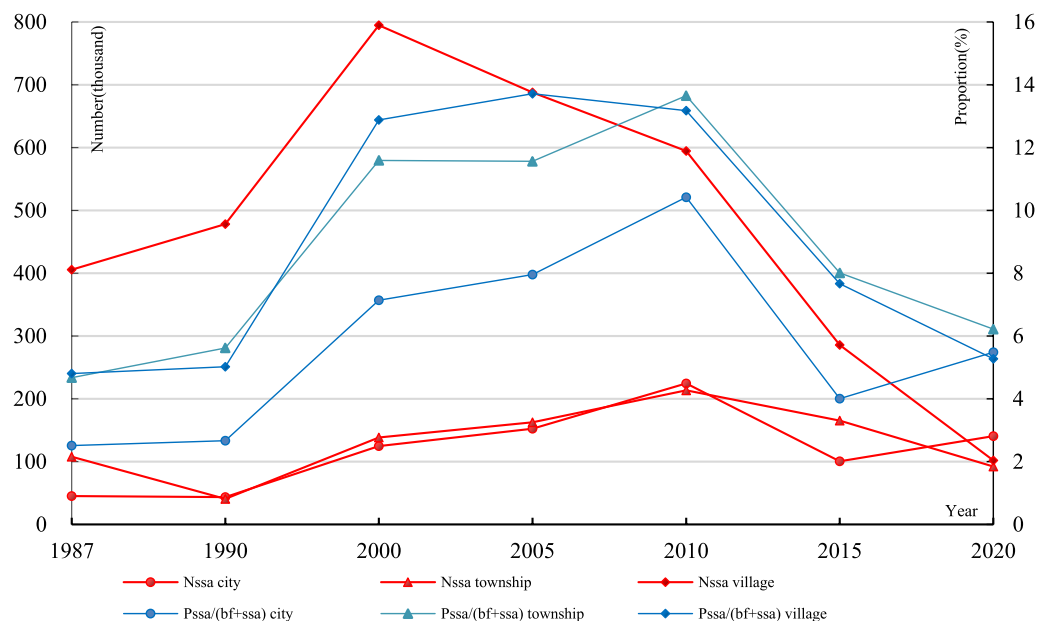

Fig. 5 Number and proportion of sex-selective abortions by residence. *Note* N_{ssa} city, N_{ssa} township, and N_{ssa} village denote the number of sex-selective induced abortions for city, township, village births, $P_{ssa/(ssa+B_f)}$ *city*, $P_{ssa/(ssa+B_f)}$ *township*, and $P_{ssa/(ssa+B_f)}$ *village* represent the proportion of sex-selective induced abortions or city, township, village births to the expected number of female births

Table 4 Proportion of selective abortion by birth order and residence (%)

Birth Order	2000			2010			2020		
	City	Township	Village	City	Township	Village	City	Township	Village
1	2.64(94,324)	3.95(56,390)	−0.33(237,653)	6.56(112,956)	7.41(64,641)	6.71(168,579)	5.39(127,127)	7.36(59,884)	7.09(73,362)
2	28.19(12,456)	31.43(12,042)	30.33(97,865)	19.81(28,618)	20.21(31,639)	17.80(101,409)	2.14(105,184)	0.64(66,008)	−1.08(81,394)[a]
3 +	37.33(1458)	41.23(1985)	32.47(23,355)	39.55(2722)	37.27(4660)	31.27(22,763)	26.54(12,942)	21.90(14,788)	15.49(30,394)
Total	7.14(108,238)	11.59(70,417)	12.88(358,874)	10.42(144,296)	13.65(100,940)	13.18(292,751)	5.48(245,253)	6.22(140,680)	5.27(185,150)

Number in the parenthesis is the number of female births

[a] In 2020, the SRB for the second birth in the Village was 104.87, which is lower than the normal SRB of 106. Therefore, the proportion of sex-selective abortion is negative

It was generally argued that rural parents were more likely to sex select children. Sex selection mostly occurred among the rural population. However, when we broke down the proportion of selective abortions to the expected births by birth order for city, township, and village populations, as shown in Table 4, we found that the proportion for city and township populations were not significantly lower than the corresponding proportion for village population, indicating that urban people were not less likely to sex select their children than their rural counterparts for the same birth order. But as first births with a much lower percentage of selective abortions accounted for 87.14 percent and 80.08 percent of all city births and township births respectively in 2000, 78.28 percent and 64.04 percent in 2010, and 51.81 percent and 42.85 percent in 2020, much higher than the 66.22 percent in 2000, 57.58 percent in 2010, and 40.03 percent in 2020 for village population, the overall percentage of selective abortions to expected births ranked highest among village population than the urban population. In recent years, the preference for boys in fertility has decreased while the preference for girls has increased. Since 2017, this preference has significantly favored girls [71], and the sex ratio at birth has gradually normalized. In 2020, the SRB for second birth in rural areas was 104.87, which was below the normal SRB of 106, suggesting a decline in sex-selective abortions.

Number and proportion by province

Table 5, Figs. 6 and 7 present the number and proportion of sex-selective induced abortions by province. Table 4 presents the temporal trend of each province and the comparison among provinces in terms of the proportion of sex-selective induced abortions to the expected births. Generally, the proportion rose from 1990 to 2000 and 2010, then declined in 2015, the proportion of sex-selective abortion was notably lower in the western and northeastern areas compared to the central and eastern regions of China. These results highlight the provincial disparity in the proportion of sex-selective abortion. Figures 6 and

7 illustrate the spatial discrepancies with maps. The central and eastern provinces have a higher proportion and larger numbers due to their larger population and the fertility squeeze.

China is characterized by a vast provincial difference in population indicators like population size, number, and order composition of births. According to the 2000, 2010, and 2020 censuses, nine, ten, and eleven provinces had a population of over 50 million, while five, four, and three provinces had a population of less than 10 million in those respective year [52, 71, 71]. Along with the marked difference in population indicators was China's provincially localized family planning policy [26, 45, 71, 70]. Around 2000, six provinces implemented one-child policy, including Beijing, Tianjin, Shanghai, Chongqing, Jiangsu, and Sichuan, five provinces implemented two-child policy, including Hainan, Ningxia, Qinghai, Yunnan, and Xinjiang; and the other 19 provinces implemented 1.5-child policy [26]. Each province has its policy fertility circa 2000 and 2010 [26, 71]. In provinces granting a quota of 1.5 or two births per couple, couples relied heavily on selective induced abortion for the second pregnancy if their first-born was a daughter [21]. Since 2013, China has gradually introduced the "selective two-child policy", "universal two-child policy", and "three-child policy", thereby expanding the options for women of childbearing age. Meanwhile, people have lowered the importance of having a boy, leading to a decrease in the desire for sons. In 2020, sex-selective abortions significantly declined in every province, indicating that the policy has positively impacted the reduction of these practices. In 2020, the SRB in seven provinces–Shanxi, Inner Mongolia, Jilin, Heilongjiang, Tibet, Ningxia, and Xinjiang–fell below 106, returned to normal levels, resulting in a decline in the proportion of sex-selective abortions, or even negative values, indicating a weakening preference for boys in some provinces in China.

The difference in selective abortions by province is a combined result of socioeconomic development, cultural environment, population base, family planning policy as

Table 5 Proportion of selective abortions ($P_{ssa/(Bf+ssa)}$) over time by province

Region	Province	1990	2000	2010	2015	2020
Eastern	Beijing	1.20	7.49	5.48	3.82	3.69
	Tianjin	3.75	6.17	7.50	2.92	2.18
	Hebei	5.13	10.52	10.71	6.89	2.39
	Shandong	7.42	6.60	14.71	2.91	5.79
	Shanghai	−1.32	8.23	4.92	3.58	2.86
	Jiangsu	7.34	11.81	12.67	7.54	4.27
	Zhejiang	9.51	6.29	10.44	−0.11	4.35
	Fujian	3.16	11.86	15.68	5.89	11.74
	Guangdong	5.02	23.05	18.14	11.27	9.81
	Hainan	7.66	21.50	18.10	7.30	12.07
Central	Shanxi	3.14	5.99	6.25	3.46	−2.98
	Henan	8.30	18.65	16.95	8.71	4.54
	Anhui	4.57	18.94	19.13	2.88	7.46
	Hubei	3.07	17.20	14.47	3.46	8.05
	Jiangxi	4.08	23.19	17.36	8.66	13.63
	Hunan	3.77	16.48	15.73	13.34	9.33
Western	Chongqing		8.46	6.85	5.95	1.40
	Sichuan	5.80	8.91	6.18	6.67	4.89
	Shaanxi	4.24	15.30	8.70	8.46	2.32
	Guizhou	−3.18	−0.60	16.01	1.60	6.68
	Yunnan	1.47	4.13	6.70	6.53	1.16
	Guangxi	8.87	17.70	13.11	11.76	8.60
	Tibet	−2.44	−8.80	−5.92	16.69	−4.80
	Gansu	3.26	11.19	15.06	9.92	2.23
	Qinghai	−1.81	−2.40	5.94	3.56	4.18
	Ningxia	0.76	1.84	7.31	8.08	−0.31
	Xinjiang	−1.34	0.61	−0.42	3.93	−0.11
	Inner Mongolia	2.29	2.29	2.64	2.31	−0.38
Northest	Liaoning	3.73	5.50	6.12	4.85	1.07
	Jilin	2.26	3.52	8.36	6.19	−1.87
	Heilongjiang	1.37	1.41	7.91	5.15	−0.46

$P_{ssa/(ssa+B_f)}$ represent the proportion of sex-selective induced abortions to the expected number of female births computed as the sum of female births and sex-selective induced abortions by province

well as many other factors. Due to space limitations, we do not investigate further into provincial differences.

Conclusion

Sex-selective induced abortion of female fetuses has been practiced since the early 1980s in China, and will still be performed widely in the future. The spread of sex-selective induced abortion has been facilitated by China's family planning program that adopted abortion as one remedial measure for out-of-quota pregnancies. This phenomenon, first as a countermeasure by farmers against the birth constraints, is now an active measure by couples with son preference in the fertility squeeze context. Due to legal, ethical, and moral considerations, the data on sex-selective induced abortions is unavailable.

In this paper, with official data we estimated the number and proportions of sex-selective induced abortions of female fetuses, the findings are as follows.

The annual proportions and number of sex-selective induced abortions of female fetuses began to rise in the 1980s, remained at a high level in 1990 through 2010, then declined. This practice of selective abortion was made instrumentally possible by the large-scale introduction of ultrasound B machines in the early 1980s but was driven mainly by the conflict between the birth constraint of the nationwide family planning and the pursuit of sons by the peasants [16, 24, 71]. At the beginning stage, the proportions and number were low, but with the diffusion of this technology and the stringent implementation of family planning policy, the proportions and number
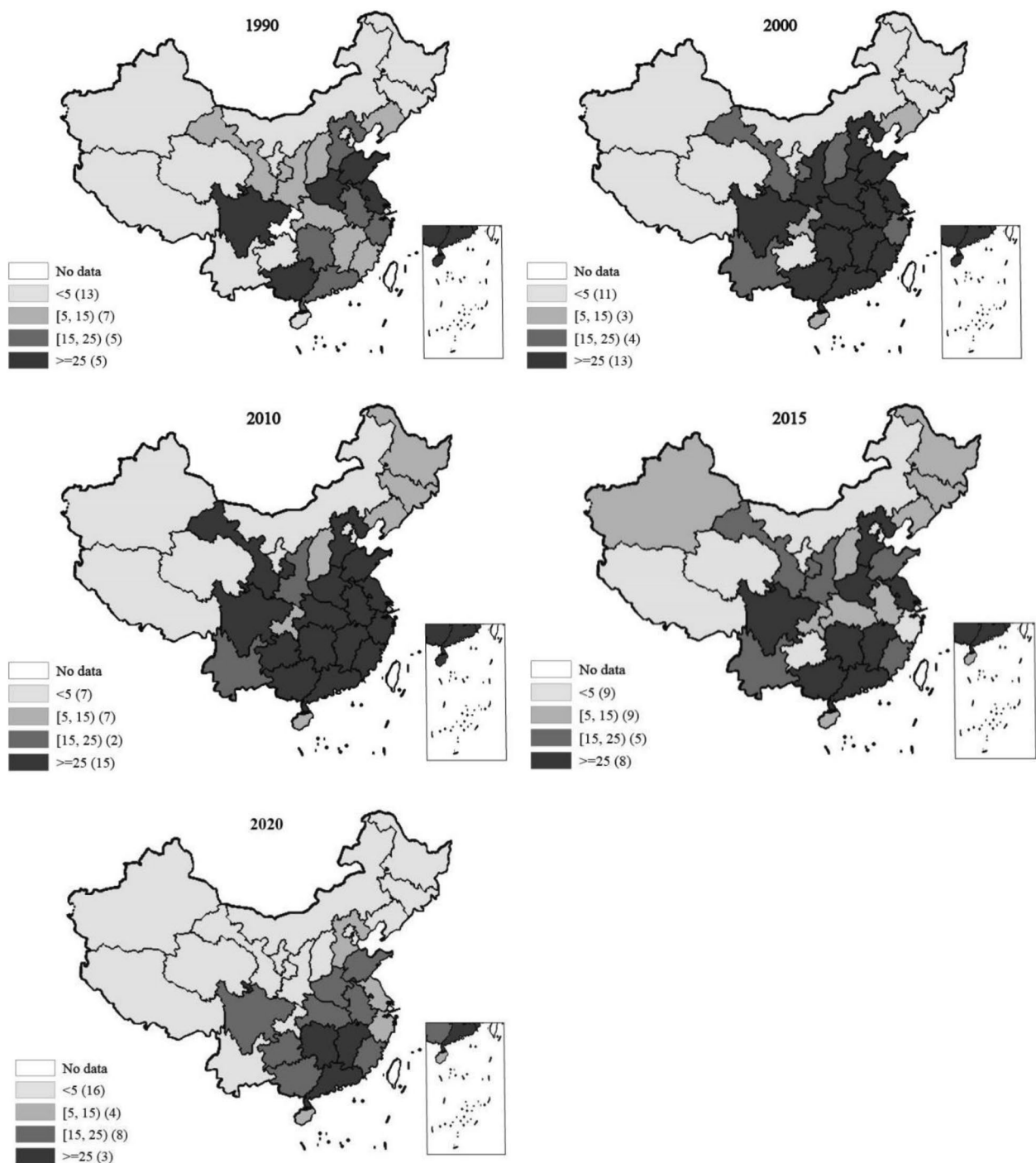
Fig. 6 Number of sex-selective abortions over time by province (thousands)

remained at a high level for two decades and declined in the 2010s due to the mainstreaming of gender equality and improved status of women. Worldwide sex-selective abortions represented around 3 percent of all induced abortions [5], China was much higher than that. More recently, with the relaxation of family planning and the spontaneous fertility, people mostly intended to have only one child or two children, selective abortion is still being practiced. China had a large scale of sex-selective abortion phenomenon, leading to a serious gender imbalance
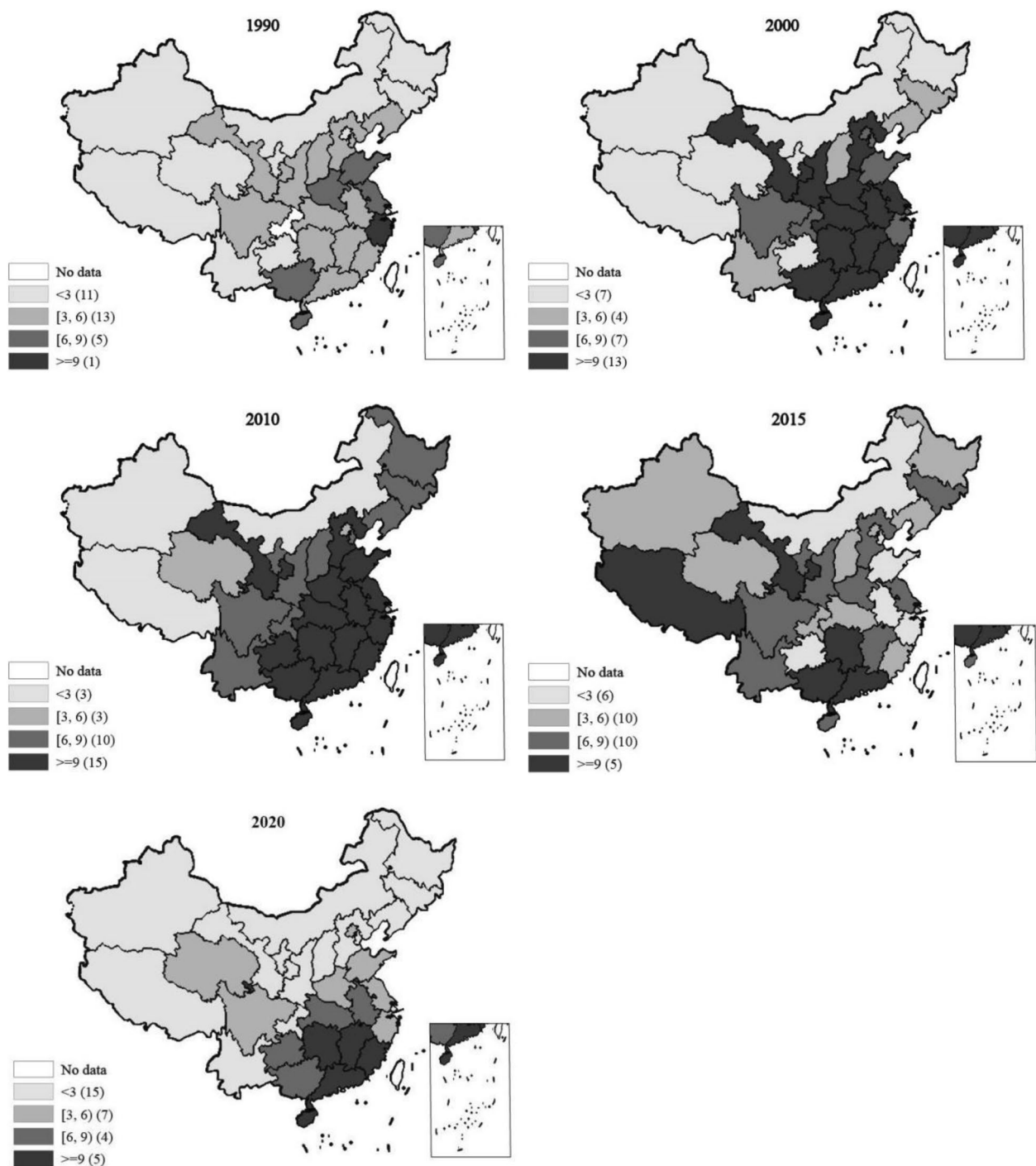
Fig. 7 Proportion of sex-selective abortions over time by province (%)

in the society. there has been a total of up to 30.04 million of sex-selective induced abortions of female fetuses between 1980 and 2020 according to this estimate. This total number is higher than that of 11.9 million (with interval confidence 8.5–15.8 million) missing female, and higher than 10.60 million (with interval confidence 8.0–13.6 million) missing female in India for the period between 1970 and 2017obtained by Chao et al. [9], but is lower than the general claim that China is short of 30 to 40 million missing females [51], and lower than 45.81

million missing females that comprise both sex-selective abortion and excess female child mortality [6]. The problem of missing girls is growing faster in China than India [9, 19]. This suggests that China's gender imbalance is even worse than India's, with far-reaching consequences for society. But this number should be interpreted with caution, as it was affected by some factors. If we took the lower bounds or upper bounds of all SRBs, the total number of selective abortions of female fetuses would be reduced to 20.41 million or increased to 36.88 million.[2] Still, due to underreporting in total induced abortions, the proportion of selective induced to total induced births should be downward adjusted accordingly.

The proportions and number of selective abortions varied with birth order and children composition. For first births, the proportions and number were negligible before 2010, but rose in 2010, as couples with son preference tended to abort the female fetus at first order recently to have a son with just one birth. The proportions and number for second, third and higher-order births rose in the 1980s, and remained at a very high level during most of the period, then declined after 2010. With the availability of sex identification technology, a county could increase the probability of a male birth by 1.3 and 2.4 percentage points for second-order and third- or higher-order births, or even by 4.8 percentage points for second-order births and 6.8 percentage points for third-order births for couples with no sons [12]. China's localized family planning policy, especially the 1.5 child policy in rural areas, stimulated couples to abort female fetuses [25, 70]. Sex-selective abortions are most likely to occur when couples had only daughters, the more daughters there are, the more likely for the next female birth to be aborted. The higher the order, the more likely it is for women to visit private clinics for the gender information of the fetus even at a higher cost [14]. However, with the spontaneous fertility decline, birth order composition change and the intention of aborting first-order female fetuses, the proportion of abortion of first-order fetuses to total selective abortions rose markedly, from 5.8 percent in 2000 to 32.70 percent in 2010. The increasing costs of raising children have forced parents to realize their desire for a son within the confines of fewer births [48], the fertility decline increased the pressure for sex selection, and people with a strong son preference tend to selectively abort female first-order fetuses [34].

City, township, and village populations showed a difference in proportion and number in census or intercensal 1% population survey years. The proportion of selective induced abortions to the expected births rose steeply in 2000 from a past low level, village and township proportions were much higher than that of the city. Sex-selective induced abortions majorly took place among the rural population, but the proportion of urban selective abortions rose markedly due partly to the urban–rural composition change in births as a result of the rapid urbanization process after 2000. When comparing by birth order, city and township proportion was higher than that corresponding proportion of village population, urban people were not less likely to sex select their children than their rural counterparts. Just as the research by birth order in SRB [25, 32], when we discuss the selective abortion difference between urban and rural populations, it is more enlightening to provide comparison by birth order after eliminating the effect of birth order composition.

For provincial comparison, the proportion generally rose from 1990 to 2000 and 2010, then declined in 2015. Central and eastern provinces had a higher proportion and larger numbers. With the liberalization of the three-child policy, several provinces are seeing a return to a normal sex ratio at birth. This shift helps reduce discrimination against girls and women and promotes gender equality, fostering a more balanced society where all genders are valued.

Discussion

After four decades of selectively aborting female fetuses, China is now confronted with numerous challenging demographic and public policy questions that have arisen from sex-selective induced abortions and the subsequent phenomenon of missing girls [6, 51], which has led to an imbalanced population sex structure and a male marriage squeeze [28], and affected China's population trajectory in the long term [2]. Accordingly, people have adjusted their economic behavior in a context of a shortage of marriageable women, for example accumulating wealth for marriage [70] and raising the bride price and marriage expenditure to compete in the marriage market [36]. The long-term practice of selective induced abortions of female fetuses has affected and will continue to affect many aspects of Chinese society, the implications of which should now be handled with caution in China.

China's birth control policy and its enforcement of induced abortions as a birth control measure have been widely criticized [71], and the imbalanced sex structure and excess males due to sex-selective induced abortions and their potential threat to society have been widely discussed. Besides, there are some direct and indirect costs of this sex-selective practice, such as the immediate costs of sex-selective induced abortion related operations and complications, the costs of medical care

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[2] Due to the lack of birth numbers for 1988 in Liang and Chen [44], the lower and upper bounds of sex selective induced abortions in 1988 was replaced by the estimated number in Table 1.

for longer-term health consequences. Sex-selective induced abortion is generally stigmatized. Mothers who underwent sex-selective abortions suffer psychological pressure and health risks. More broadly, selective abortion deprives the aborted fetus of the right to life and tramples on the birth right of women.

The academic consensus in China aligns with the official stance that non-medical sex-selective abortion, as well as non-medical prenatal sex diagnosis, are morally unacceptable and should be prohibited by law [51]. China continuously advocates gender equality and the social status of women has improved markedly, while China combats "two illegals" [40, 48]. In 2014, Hubei province alone rewarded more than 540 people who reported "two illegals" cases, broke 4193 "two illegals" cases, and punished 422 doctors who practiced "two illegals" [36]. However, China's prohibitive laws and polices have never been rigorously implemented and that the penalties for violation of these codes are not made explicit and are often very lenient in practice. Women's reproductive health can be improved by reducing unintended pregnancies and induced abortions, as well as by enhancing sexual health education, elevating sexual morality, decreasing premarital sex, increasing awareness of contraception, fostering a positive and healthy conception of fertility. A relaxation in the one-child policy could allow more parents to have a son without resorting to sex selection [22]. The implementation of the three-child policy will enhance fertility support, improve women's education, promote gender equality, reduce discrimination against girls and women, and shift gender preference towards "no preference." Additionally, we will continue to combat the "two illegals", monitor new technologies in gender identification, and remain vigilant against gender selection in assisted reproductive technology. With high levels of development, modernization, and urbanization, son preference will decline, and the value of sons and daughters tends to equalize [5, 15]. In China, the deeply entrenched son preference is currently waning due to low fertility intention, the pressure from the tight male marriage market, the heavy burden of marriage, and the improved status of women. We hope all this will reduce sex-selective abortion and improve gender equality in China.

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Author contributions
QJ conceived the idea, LMperformed material preparation, data collection, QJ and LM drafted the original manuscript. All authors revised the manuscript, interpreted the results, and drew conclusions. All authors read and approved the final manuscript.

Availability of data and materials
The datasets used for analysis and reaching the conclusions of this study are available online at the National Bureau of Statistics (https://data.cnki.net/yearbook/Single/N2021020056) and China's Ministry of Health (https://data.cnki.net/yearbook/Single/N2021020144), which offer a public, open-access database.

Declarations

Ethics approval and consent to participate
This study used secondary data from the public domain and information that can identify specific individuals was not included. Ethics approval and consent to participate are not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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