ESTIMATION OF MISSING GIRLS AT BIRTH AND JUVENILE AGES IN INDIA

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Commissioned by
United Nations Population Fund (UNFPA), India

September 2007

This paper has been commissioned by United Nations Population Fund – UNFPA and reviewed by a wider group of demographers and researchers prior to its finalisation. However, the views expressed and interpretation given in the paper are those of the author and do not necessarily reflect those of UNFPA.

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1. Introduction

It has long been observed that India's population shows an unusually masculine composition. This was generally attributed to higher mortality among females than males in contrast to what has been observed in the western world. However, since the 1990s, the young ages show greater masculinity than in the past and a steep rise in the sex ratio at birth has been observed. There is evidence that sex-selective abortions are widely practiced, facilitated by easy availability of the technology of pre-natal sex-detection and access to medical termination of pregnancy, at least in some parts of the country. This paper, therefore, seeks to provide estimates of the number of sex-selective abortions in the recent years. The analysis is primarily at the national level. However, estimates for Punjab, the state in which the practice of sex-selective abortions is known to be very widely prevalent, are given in the Appendix. Some discussion on regional variations is included in a later section without detailed estimates. It must be mentioned at the outset that this work does *not* address the social, economic, and institutional causes underlying the resort to sex-selective abortions or the sex-differences in mortality. For some recent work on this issue, see Das Gupta and Bhat (1997), Agnihotri (2000, 2003), Mayer (1999), Bhat and Zavier (2007). Nor does it discuss the consequences of the imbalance caused by sex-selective abortions; these are quite well known. The focus is on estimating the magnitudes of missing girls and sex-selective abortions rather than the socio-economic determinants.

This paper follows the international convention of specifying the sex ratio (SR) as number of males per 100 females rather than the practice in India of expressing it as females per thousand males, often called female to male ratio, or FMR; clearly, FMR = 100,000/SR.

2. Prior Work on Sex Ratio of India's Population

Considerable work has been done by demographers to investigate what was considered to be the unusual sex ratio of India's population. Space does not permit a detailed review of all the work and hence only a brief review of some of the important analyses is presented here; for comprehensive reviews, the interested reader can refer to the works of Visaria (1968), Agnihotri (2000), and Bhat (2002).

While the contrast between India's sex ratio and that of the western world had been noted in various census reports, a rigorous demographic analysis emerged after the 1961 census. This was the late Prof. Pravin Visaria's doctoral research at the Princeton University that was later published by the census office as a special monograph (Visaria, 1968). Visaria investigated the sex ratio in India as well as in Pakistan (including Bangladesh at the time). A clear imbalance in favour of males was seen in the north-western region, including Punjab, Sind, Baluchistan, and the North-West Frontier Province. The masculinity was much less pronounced in the southern and north-eastern states. Visaria systematically examined the influences of a series of possible factors. The analysis established that higher female than male mortality was the principal cause of the masculinity of the population composition. Undercount of population did not seem to have played much role. The sex ratio at birth was not unusual; the reported high ratio in the north-western region was probably on account of female infanticide.

Miller (1989) examined data from the 1961 and 1971 censuses and noted spatial variations in the juvenile sex ratio (for ages 0-9 years) in rural areas using data at the district level. Evidence of female infanticide also emerged (see George *et al*., 1992). Agnihotri (2000) carried out a detailed analysis of the data from various censuses up to 1991. It was seen that sex-differentials in the infant mortality rate (IMR) are very low in India compared to the western world that shows a large disadvantage for male infants and that girls are adversely placed in child mortality. The 1991 census revealed a worsening of the population sex ratio and led to much debate on the roles of various factors, especially age and enumeration errors, sex ratio at birth and sex-selective abortions, and detailed analysis of data (Kundu and Sahu, 1991; Rajan *et al.*, 1991; Raju and Premi, 1992; Nair, 1996; Premi, 2001; Agnihotri, 2000, 2003). The most comprehensive study is that by Bhat (2002) who also critically reviews earlier work. It was noted that age misstatement had distorted sex ratios in early ages considerably giving a wrong impression of changes during 1901 to 1981. In particular, in the early censuses the ratio seemed to be very low in the 0-4 age group and high in the 10-14 age group mainly on account of sex-selective age misreporting the tendency of which had declined over the period yielding a near constancy in the ratios. However, a notable rise in the ratio in the 0-4 age group was seen after 1981. The analysis showed that while in earlier census enumerations adult women constituted the bulk of 'missing women', young ages contributed the most in the recent census enumerations. Essentially, there was clear evidence that the sex ratio at birth had altered pointing to the prevalence of sex-selective abortions. Regional variations were very conspicuous.

In the 2001 census, a small improvement was observed in the overall sex ratio, to 107.2 from 107.9, but a greater imbalance noted in the young ages, 0-6 years, from 105.8 to 107.9. By then, the sex ratio at birth had emerged as a factor in the sex ratio imbalance in India. Independent investigations showed the existence of the practice of sex-selective abortions on a non-negligible scale (Ganatra *et al*., 2001; Arnold *et al*., 2002; Jha *et al*., 2006; Visaria, 2007). Evidence has also emerged of a rise in the sex ratio of births to India-born mothers in England and Wales (Dubuc and Coleman, 2007).

To sum up, most of the early work on India's sex ratio at young ages identified mortality differentials and sex selective age mis-statement and underenumeration as the prime factors. Whereas in the western world, female mortality was substantially lower than male mortality, in India, either female mortality was higher than male mortality or was not as lower as in the western world. Specifically, female life expectancy was either lower than male life expectancy in India or if higher, not as high as that observed in the western populations. Besides, sex selective underenumeration and age mis-statement also contributed. However, with the emergence of techniques of pre-natal sex detection, first with amniocentesis and later with the help of sonographic scans, selection of sex became an easy task in the last two decades. Recent research has, therefore, looked at sex-selective abortions as a major factor causing imbalance in India's sex ratio especially at young ages. This calls for an assessment of the numbers of 'missing girls' and sex-selective abortions. The basic approach is described in the next section.

3. Notation and Basic Relationships

The term 'number of missing females (or women or girls)' has been commonly used. This is the number of females, relative to the number of men, which should have been in the population but were not. If migration as a factor is ruled out, females can be 'missing' on account of higher than expected mortality (compared to males) and higher than normal sex ratio at birth. Besides, sex-selective reporting errors can distort the observed sex ratio in a population, that is, some may not be 'truly missing' but only 'reportedly missing'. If expected sex ratio is available, estimation of the number of missing females is fairly straight forward. This is often done by age (or age group).

If ESR_i is the expected (or standard) sex ratio for age group i, and MP_i and FP_i are the male and female populations respectively in the age group, then expected female population EFP_i is given by

$$EFP_i = MP_i * 100/ESR_i , \quad (1)$$

and the number of missing women in the age group as

$$EFP_i - FP_i = MP_i * 100/ ESR_i - FP_i. \quad (2)$$

The expected sex ratios, that is, the ESR values, can be taken from a 'standard' age-sex distribution; this could be an earlier census distribution. But since even in earlier censuses

(or standard distributions) some females might have been missing and it is the departure from this that is being estimated, the number missing obtained this way is actually the number 'additionally missing' compared to the earlier distribution[1]. But this does not, by itself, convey the magnitude of the problem at the present time. Hence, the method of 'demographic analysis', that derives the expected sex ratio from normal sex ratio at birth and female and male survival, is employed here[2]. Essentially, one can begin with the sex ratio at birth and project the female and male populations under certain assumptions of mortality (this really amounts to projecting the male and female populations using standard component projection methodology, allowing for mortality to vary over time, and then obtaining the expected ratio of male to female population). If the influences of age mis-statement and underenumeration can be minimised, the gap between expected and actual female population is due to the combined effect of departure from normal sex ratio at birth and sex differentials in mortality. Note that since both sex ratio at birth and mortality are not balanced, with the ratio at birth being favourable to males and in survival favourable to females, it is possible to attribute portions of the deficit to departures from the normal sex ratio at birth (NSRB) and normal sex-differential in mortality.[3]

The departure of the actual number of females in a given age group from the expected number allows a computation of the actual sex ratio at birth for the corresponding cohort. This we call 'implied sex ratio at birth'; this is computed as

$$\text{Implied SRB} = \text{NSRB} * (EFP_i / FP_i) = \text{NSRB}*(SR_i / ESR_i) \quad (3)$$

where SR_i is the actual sex ratio for age group i. The same result is reached by reverse surviving male and female populations to birth and then computing the sex ratio at birth[4].

The estimation of the number of sex-selective abortions is a simple task given the sex ratio at birth, the normal sex ratio at birth, and the total number of births. Let FB, MB, and LB be the actual number of female, male, and total live births respectively, and SRB the sex ratio at birth, given by SRB = 100*(MB/FB). Further, let SSA be the number of sex-selective abortions in a given population within a specified period. Let EFB, EMB, and ELB be the expected numbers of female, male, and total live births respectively in the absence of sex-selective abortions. The normal sex ratio at birth (in the absence of sex-selective abortions), NSRB, equals 100*(EMB/EFB). Further, if there are no male sex-selective abortions, then EMB = MB, and hence the expected number of female births (EFB) is given by applying the normal sex ratio at birth (NSRB) to the number of male births (MB) to yield

$$EFB = MB* [100 / NSRB]. \quad (4)$$

The number of sex-selective abortions, SSA, is given as

$$SSA = EFB - FB = MB* [100 / NSRB] - FB; \quad (5)$$

and it can be shown algebraically that

$$SSA = LB*[100*(SRB - NSRB)] / [NSRB*(SRB+100)]. \quad (6)$$

Thus, the estimate depends heavily on (and is thus sensitive to) the term (SRB – NSRB), the gap between the observed and the normal sex ratios at birth, scaled by the number of births. It is, therefore, necessary to have good estimates of SRB and NSRB.

4. Data Required for the Estimation

As seen above, the estimation of missing girls and sex-selective abortions is a simple task if the requisite data are available. These are: sex distribution of population, especially by age since the number missing could vary by age, the sex ratio at birth, the normal sex ratio, and mortality by sex (life tables or at least survival probabilities or ratios). We examine these below.

4.1 Sex ratio by age

Conventional age groups

The Indian census provides tabulations by age and sex allowing computation of sex ratios by age. The sex ratios in individual age groups need to be viewed carefully since age mis-statement, known to be common in India, distorts sex ratios if such errors are sex-selective. A detailed analysis of data from 1901 to 1991 by Bhat (2002) showed that in the past while the 0-4 age group showed a deficit of males, the 10-14 age group shows a huge surplus. But for the broad 0-14 age group, the distortion is not so pronounced. Male deficit in the 0-4 age group is inexplicable given that sex ratio at birth is masculine and survival in India does not favour girls, in any case not to a large extent. The distortion occurs presumably on account of over-reporting the ages of boys effectively shifting them selectively to higher ages, creating a deficit of boys in very young ages and consequently a surplus in older ages. Over time, this tendency seems to have declined indicating an improvement in age reporting (see Fig. 1 and Appendix Table 1 for the trends). Encouraged by this improvement in age reporting, we use the age-wise sex ratios of the 2001 census for the conventional groups to estimate the numbers of missing girls. However, sex ratios from earlier censuses can not be used as 'standard' to estimate the number of missing females in individual age groups.

Single-year ages

In principle, sex ratios by single year of age allow an assessment of numbers of missing girls by single year and consequently of detailed trends in sex selective abortions. The Indian census has been providing such data since 1961 and trends from these are presented in Fig.2 (also see Appendix Table 2). A peculiar pattern is seen. The sex ratio is very high (excess males) at age 12, and quite high at some other ages, notably 14, 10, and 5 and low (less than 105) at age 3 as well as 0, 1, 7, and 9. Over the years, especially in 1991 and 2001, the sex ratio has shown a rise in most ages except the teen ages (12-14). The latter seems to be on account of a better age reporting; the ratio in the 10-14 group is not as large as in the past. However, the single-year data even in 2001 census do not appear satisfactory enough to draw inferences. This is best seen from the case of age

3. The sex ratio at this age is consistently low in all the censuses; there is no reason to believe that a deficit of male births occurred at three years before all the censuses. Therefore, we prefer not to use sex ratios based on single-year age data in the estimation.

The sex ratio at age 0 was 101, 101, and 103 respectively in the 1961, 1971, and 1981 census distributions; this is obviously an artifact of sex-selective age-misreporting as otherwise the ratio should have been close to 105 or higher (infant mortality was not higher for males than females at the time). The 1991 and 2001 censuses show ratios of 106 and 109 respectively, which are above 105, partly due to improvements in age reporting as noted above, but also possibly due to a true rise on account of sex-selective abortions. But decomposing the departure into the two components is not possible since the sex ratios from the earlier censuses are not usable as 'standard'.

It is appropriate to note here that analysis of the Chinese age-sex data permits assessment of trends in missing girls (or births) based on single year data (Cai and Lavely, 2003). Unlike India, age reporting in China is quite accurate on account of the system of animal years that makes it easy to locate births in correct calendar years.

4.2 Levels and Trends in Sex Ratio at Birth

In the past, the sex ratio at birth (SRB) of India's population was not known to be much different from the world standard of 105 (Visaria, 1968). However, the ratio has risen considerably in the recent past, especially since the 1980s. Since 2000, the Sample Registration System (SRS) has been giving data on the SRB, as three-year averages. Besides, for the periods 1982-84 to 1996-98, the estimates are given in a graph in a census report (India, Registrar General, 2001). From these, a series is obtained and presented in Table 1. It can be seen that the SRS estimates of SRB in the 1980s are generally close to 110. Though there are minor fluctuations even in the three-year averages, a small rise in the SRB is seen since the early 1980s, from about 110 to 113, the ratio seems to have become more masculine in the early 1990s, declined somewhat, and risen again after 2000. The Pre-Natal Diagnostic Techniques (Regulation and Prevention of Misuse) Act (PNDT Act) was passed in 1994. Whether this had any sobering influence on the practice of sex-selective abortions can not be said conclusively. Another explanation is that the SRS changed the sample units in 1994 and this could have brought about a break from the early 1990s to the late 1990s (Pandey, 2007).

However, the SRS estimates are not corroborated by other data. Census tables on children ever born by sex allow computation of the SRB. Children ever born for relatively young women, say in the age group 20-29, would be recent births and the ratio based on these would give a reasonable picture of the recent SRB. Table 1 gives estimates from the 1981, 1991, 2001 censuses based on the sex composition of children ever born to women of age 20-29. These values are close to 107, higher than the standard 105 but lower than the direct estimates from the SRS. The 2001 census also gives the sex distribution of births in the year before the census (called 'births last year'). This shows the sex ratio at birth as 110.4, close to the SRS values. However, the counting of births last year as reported in the census is quite incomplete, only about 75 percent of births are covered

possibly due to reference period errors (the number of births last year is given as 19.9 million whereas the expected number of births computed by applying the SRS estimate of crude birth rate to the population is over 26 million). Therefore, not much confidence can be placed in this sex ratio.

India's two National Family Health Surveys (NFHS-1 and 2) and the Special Fertility and Mortality Survey (SFMS) also give estimates of SRB. The NFHS-1 and the NFHS-2 estimates refer to births in the five-year period preceding the surveys, that is for the periods 1988-92, and 1994-98 respectively, and the SFMS estimate refers to births during 1997. The NFHS-1 estimate is 105.2, showing no departure from the norm. The NFHS-2 estimate shows a higher value, 107.0, yet it is not as high as the SRS estimates for the corresponding period. Only the SFMS shows a SRB as high as in the SRS, close to 111 for 1997, in fact, equal to the 1996-98 SRS estimate. But it must be noted here that the SFMS was also conducted by the SRS organisation whereas the NFHS-1 and 2 were carried out independently of the SRS.

Clearly, there is no agreement between the SRS estimates and the census and the NFHS estimates; the former are higher than the latter sets by about 4 points. Hence, while in the recent years India's SRB has undoubtedly risen above 105, one can not be so sure about its being as high as 111. Therefore, we use both the given SRB values from the SRS as well as the implied SRB obtained from the census sex distribution (using eq. 3 above).

What is the value of NSRB, the normal sex ratio? Universally, the ratio is between 103 and 107, generally close to 105, in the absence of any intervention. Visaria(1968), after a careful evaluation of evidence up to 1961, concluded that "…there is no factual basis for the hypothesis that the population of the Indian sub-continent has a higher sex ratio at birth than the western populations" (p. 37). Recent evidence on India-born mothers in England and Wales shows that prior to 1980s, the sex ratio at birth was close to 105, but for more recent births, it was higher (Dubuc and Coleman, 2007). Since these births occurred in England and Wales, where the registration of births is known to be complete and hence the SRB is accepted as accurate, there is no reason to dispute that the sex ratio for Indian couples was close to the standard 105 prior to the 1980s. Some analysts use 105.5 or 106 as the normal sex ratio. We use 105 as the NSRB in this paper but also give alternate estimates for an NSRB of 106.

4.3 Levels and Trends in Mortality

In the absence of a reliable civil registration system in India, mortality has in the past been estimated indirectly. The census organisation itself estimated life expectancies for intercensal periods. Since 1971, the Sample Registration System has been constructing life tables for five-year periods. Estimates from the census and the SRS are presented in Appendix Table 3. Of interest are the sex differences in mortality as seen from the life expectancies. In the western populations, female mortality is considerably lower than male mortality and hence female life expectancies higher. The picture in India is somewhat different. Female life expectancy has been close to male expectancy throughout the century; it was marginally higher than male expectancy during 1901-21,

very close to male expectancy for the next three decades, marginally lower up to 1980, again very close in the 1980s and a shade higher since 1990.

The pattern observed in the western countries is that women have a substantial advantage in survival over men. Clearly, women in India did not enjoy this. In order to see how poorly placed Indian women are in relative terms, one can compare the mortality level to that of western women at the same level of male mortality. The Regional Model Life Tables developed by Coale and Demeny (1966) give pairs of male and female life tables at different levels (the new United Nations Model Life Tables for Developing Countries give male and female series of tables separately but not in pairs). From these sets, female life expectancies corresponding to the given male expectancies have been computed from the Model West of the Coale and Demeny life tables for each period; these are given in the last column of Appendix Table 3. The expected female life expectancies are considerably higher than the Indian female life expectancies for the respective periods. Thus, in relative terms, the Indian women face higher mortality risk compared to western women at the same level of male mortality. For example, for the period 2001-05, the female expectancy was 63.7 years and the male expectancy 62.1 years. At this male expectancy, the female expectancy would be 65.9 years in the West Model, well above the actual value of 63.7. The disadvantage was high, of the order of 3-5 years in the middle of the last century, and about 2 years at the earlier periods and towards the end. Consequently, the number of surviving women relative to males is lower in India than in the western countries and thus the sex ratios unfavourable to women.

For the young ages, one needs to look at mortality differences only in early childhood. The SRS estimates of infant mortality rate (IMR) by sex given in Appendix Table 4 show very small differences by sex. Thus, Indian girls do not have higher survival probabilities than boys. Moreover, survey estimates of under-five mortality rate (U5MR) show higher mortality for girls than boys. Clearly, girls in India are at a disadvantage compared to boys in survival.

5. Estimation of the Number of Missing Females

We now estimate the numbers of missing girls and decompose the deficit into contributions of excess female mortality and departure from the normal sex ratio at birth. This has been done for ages 0-14 since the practice of sex-selective abortions being relatively recent, could only have affected young ages. We first estimate the expected sex ratios (ESR_i) for each of the young age groups, 0, 1-4, 5-9, and 10-14 for the year 2001 on the basis the male and female survival from birth to the various age groups at specified levels of male and female mortality and the normal sex ratio at birth[5]. The normal sex ratio at birth is taken here as 105. Further, it is assumed that there is no sex selective migration in these ages, a fairly reasonable assumption. The ESR_i values are then applied to the male population in the age group to estimate expected female population from eq.(1) and the number of missing girls from eq.(2).

First, the SRS estimate of male life expectancy is accepted and the female life expectancy is calibrated corresponding to this male expectancy in the West Model of the Coale-

Demeny Regional Model Life tables (given in the last column of Appendix Table 3). The male and female survival ratios are obtained using the U.N. South Asian Model life tables (U.N., 1982) and the ESR_i values for the age groups 0, 1-4, 5-9, and 10-14 computed for 2001; these are denoted as ESR^W_i to signify that these are based on the West Model sex differential[6]. The corresponding expected female populations are denoted as EFP^W_i . The difference between the expected (EFP^W_i) and actual (FP_i) female populations is the number of missing girls in the respective age groups had India followed the Model West pattern of sex differential in mortality.

Second, the process is repeated using actual female life expectancies; the expected sex ratio is ESR_i and the expected female population EFP_i . The difference between the two expected values of female population, using western sex differential in mortality and actual morality by sex, is the contribution of 'excess female mortality', that is excess over the western pattern. The number of missing girls computed after applying the actual male and female mortality levels (EFP_i - FP_i) is due to departure of sex ratio at birth from 105 and age mis-statement and enumeration errors (migration is ignored as these are young ages).

The results are shown in Table 2. It is seen that with NSRB of 105 and under western mortality differential, there should have been 8.292 million girls of age 0 (the table gives figures in thousands), but the actual number is 7.913 million, a deficit of 0.379 million girls. Similarly, the deficit is 1.461 million, 3.242 million and 4.770 million in the 1-4, 5-9 and 10-14 age groups respectively. The total deficit for 0-14 ages is 9.852 million or nearly 10 million.

However, given the Indian mortality differences, the deficits are considerably smaller, 0.345, 0.820, 1.955, and 2.953 million respectively for the four age groups and a total deficit of 6.071 million instead of 9.852 million. The difference of 3.780 million is the contribution of excess female mortality in India compared to the west for missing female in the ages 0-14. Overall, 38 percent (100*3.780/ 9.850) of the female deficit is attributable to excess female mortality and the rest to higher than normal sex ratio at birth and other errors.

The numbers of missing females in individual age groups need to be viewed with caution since these are distorted by net transfers due to age mis-statement. If for the broad 0-14 age group net enumeration and age reporting errors are negligible, as some analysts have noted, the shortfall of 6.071 million is primarily due to higher than normal sex ratio at birth. This works out to 3.5 percent of female population in this age group.

On the basis of the numbers of expected and actual females in various age groups, the values of the implied SRB[7] computed using eq (3) are given towards the end of Table 2; the SRB values of 109.6, 106.9, 108.3, and 110.2 corresponding to age groups 0, 1-4, 5-9, and 10-14 refer to the periods 2000, 1996-1999, 1991-95, and 1986-1990 respectively as the survivors in these age groups are out of births in the periods shown (ignoring a shift of two months as the 2001 census refers to 1st March rather than 1st January). For the age 0, the sex ratio in the 2001 census was 109.3 whereas a normal sex ratio at birth of 105

would have given a ratio of 104.7 for the survivors of this age under the specified mortality conditions. Thus, the SRB for 2000-01 should have been 109.6, given by 105*(109.3/104.7). But this needs to be accepted with caution[8]. Note that the implied SRB for the period 1986-90 is higher (110.2) than for the later periods, 108.3, 106.9, and 109.6. However, it would be wrong to conclude that the SRB was actually higher in the late 1980s that in the 1990s. It is known that the sex ratio at 10-14 is generally high due to age mis-statement (net transfer of females out of this age group) and the high value obtained, 110.2, might be a result of this factor rather than of a truly high SRB for this period. Therefore, we refrain from using the implied SRB values to assess trends directly.

Based on the broad age group 0-14, the implied average sex ratio corresponding to the period 1986-2001 (15-year period before the 2001 census) is 108.7. The reported SRB from the SRS for the 15-year period (1986-2000) is higher than this, approximately 111.3 (since annual estimates are not available, this value has been inferred from the three-year averages and hence is only approximate). On the other hand, the implied SRB is higher than the NFHS and census based estimates. Overall, the SRS series of SRB appear to be overestimates. We can now get a correction factor for the estimates of the SRB from the SRS on the assumption that *for the broad age group 0-14*, net errors of enumeration, age mis-statement, and migration do not affect the sex ratio. The correction factor is given by the ratio of the implied sex ratio to the SRS estimate as ***108.7/111.3 = 0.9766***.

6. Estimation of the Number of Sex-Selective Abortions

Sex-selective abortions alter the sex ratio at birth and hence the departure of the sex ratio at birth (SRB) from the normal sex ratio at birth (NSRB) among a given number of live births gives the number of sex selective abortions. The basic formulation for estimating the number of sex-selective abortions (SSA) has been given in eq.(5) on the assumption that there are no male sex selective abortions. This is applied to estimate the numbers of sex-selective abortions during the five time periods: 1981-85, 1986-90, 1991-95, 1996-2000, and 2001-05. We have SRB estimates from the SRS for three-year segments (as moving averages) beginning 1982-84. The 1982-84 value was assumed to be valid for the 1981-85 period and for the later periods, averages were obtained from the set. However, since the analysis of missing girls in the previous section indicated that the SRBs from the SRS are probably over-estimates, adjusted SRBs were obtained by applying the correction factor (0.9766) to the SRS estimates of SRBs[9]. The normal sex ratio at birth (NSRB) has been taken to be 105.

The actual number of live births (LB) required for computing the SSA is obtained by first obtaining the mid-period population from 1981, 1991 and 2001 census figures by interpolation for the periods up to 2001 and by extrapolation for 2001-05. The crude birth rate (CBR) for each of the periods is taken from the SRS series (India, Registrar General, 1999, 2003, 2004a, 2004b, 2005b, 2006a, 2006b).

One can compute the number of sex-selective abortions (SSA) directly from eq. (6) given LB, SRB, and NSRB. However, for the sake of clarity, the step-by-step computations of male births (MB), female births (FB), and expected female births (EFB) leading to the

SSA are shown in Table 3. During the five-year period 1981-85 there were over a million (1.110 million) sex-selective abortions. This remained at about the same level (1.269 million) during 1986-90. But there was a huge increase in the next quinquennium, 1991-95, to over 3 million (3.129 million), a fall to 2 million in the subsequent period, and again a rise to over 3 million (3.412 million) in the first five years of the present century. Essentially, the number of sex-selective abortions has been quite high since the 1990s.

In order to have a clear idea of the magnitude, the table also gives annual number of sex selective abortions, and further, the number of sex selective abortions as percent of female births in the respective periods. The annual number of sex-selective abortions rose from over two hundred thousand to over six hundred thousand during 1991-95 and again during 2001-05. This amounted to about two percent of female births initially climbing to well over five percent. During the 25 years since 1981, broadly corresponding to the beginning of easy availability of sex detection tests, nearly 11 million sex-selective abortions were performed. These amounted to 3.6 percent of female births or 1.7 percent of live births.

If the SRS estimates of SRBs are accepted rather than the adjusted ratios which are lower, the number of sex-selective abortions would be much higher, more than 18 million over the period 1981-2005 (computations not shown), nearly three percent of all live births and six percent of female births. On the other hand, if the normal SRB (NSRB) is taken to be higher than 105, say 106 as some analysts assume, the number of sex-selective abortions would be smaller; about 8 million over 1981-2005 using adjusted sex ratios at birth. Alternate estimates can be easily obtained by substituting appropriate values in eq.(6); see Table 4. Regardless of which estimate one accepts as the most likely to be correct, the number of sex-selective abortions in India has been quite high.

7. Comparison with Earlier Estimates of Sex-Selective Abortions

Earlier research has given estimates of sex-selective abortions. The most widely cited estimates are by Jha *et al* (2006). These are based on the data from a special survey, called Special Fertility and Mortality Survey (SFMS), 1998, conducted by the Sample Registration System of the Office of the Registrar General, India. This covered 1.05 million households in a nationwide sample, a size much larger (about ten times) than the NFHS-2 sample. The survey found a sex ratio at birth of 111.2 males per 100 females (an adjusted sex ratio of 899 females per 1000 males). The ratio varied substantially by sex composition of previous children (lower ratio in case of more female children than male) clearly indicating the prevalence of sex selective abortions. The paper also gives two estimates of the annual number of sex selective abortions (see Table 4 of that paper), 0.59 million and 0.74 million, corresponding to female male ratios at birth of 950 and 975 (equivalent to NSRB of 105.3 and 102.6) respectively. This has been obtained assuming that the number of live births (LB) is 28.0 million, with 13.1 million female births (FB) and 14.9 million male births (MB). But this estimate is incorrect as it uses a wrong formulation, of redistributing the actual number of births (LB) into female and male births according to the NSRB, rather than redistributing expected births (ELB).[10]

The correct estimates of expected number of female births, applying eq.(5) are:

for NSRB = 105.3, EFB = MB *100/(NSRB) = 14.9 *100/ (105.3) = 14.15 million, and since actual number of female births is 13.1 million, a deficit of 1.05 million.

and for NSRB of 102.6, EFB = MB* 100/ (NSRB) = 14.9 * 100/ (102.6) = 14.52 million, and since actual number of female births is 13.1 million, a deficit of 1.42 million.

Thus, the actual estimates are much larger (almost double) than those given in the paper.

The paper also gives a quick estimate of sex-selective abortions as 10 million over two decades assuming that the number of sex selective abortions per year has remained constant (0.5 million) since the access to ultra sound technology became widely available. Here, first, the annual estimate needs to be corrected and further it must be seen if the sex ratio at birth was about 111 since the early 1980s (see also the comment by Bhat, 2006).

Earlier, Arnold *et al*. (2002) had provided estimates of sex-selective abortions on the basis of detailed analysis of data from the National Family Health Survey (NFHS)- 2, conducted during 1998-99 in a nationwide sample in India. The NFHS -2 had obtained information on whether a sex determination test was carried out during pregnancy for births that occurred during the three-year period preceding the survey. Those women who had such a test had a sex ratio at birth of 111.2 (or 891 females per 1000 males) whereas the expected ratio is 105. From this, it was estimated that 106,107 sex-selective abortions were performed per year during the period (assuming all sex-selective abortions are of female foetuses). Another estimate of sex selective abortions obtained in the paper from the differences in actual and expected sex ratios (106.9 and 105 respectively) is 'less than 117,000' (p.780) with the remark that this is similar to that obtained earlier. However, this estimate does not appear to be correct.[11] The correct estimate of sex selective abortions based on the given assumption (that all the difference between the sex ratio of 106.9 and 105 is due to sex-selective abortions) is 226,750[12]. This estimate (226,750) is about twice that (117,000) mentioned in the paper. The correct estimate is also larger than the estimate obtained earlier, 106,107. That the estimate of SSA obtained using sex ratios at birth (226,750) is much higher than the estimate using actual reporting of abortions of female foetuses (106,107) indicates that a large proportion of abortions or sex detection tests are not reported in the survey.

Bhat and Zavier (2007) estimated, using the NFHS-2 data on use of PNDT and sex ratio at birth, that at a normal sex ratio at birth of 105, 13.9 percent of female births were subjected to PNDT and of these 16.9 percent were aborted (given in Table 4 in that paper). From this, it can be inferred that 2.3 (= 13.9* (16.9/100)) percent of female births were aborted. Estimates for other values of normal sex ratio at birth are also provided. A comparative view of various estimates is presented in Table 5.

Cai and Lavely (2003) provide numerical estimates of missing girls in China for births cohorts of 1980-2000. For the period as whole, 4.1 percent of girls were missing and in the late 1990s, the percentage rose to over 8 percent of girls, much higher than seen in

India. This is to be expected given that the sex ratio at birth in China has been known to be close to 120 in the 1990s. Obviously, the enormity of the problem of sex-selective abortions is much greater in China than in India.

8. Regional Variations

It is well known that there are large regional variations in India's sex composition. Visaria's work had identified the north-western region as one with huge excess of males; a number of recent studies, cited earlier, have also noted such excess in the north-western states, especially Punjab and Haryana, and the absence of such imbalances in the southern and eastern states. After the 2001 census, the Office of the Registrar General, India, mapped the sex ratio of population (India, Registrar General, 2001). Later, the regional variations at the district level have been mapped by India, Registrar General, UNFPA, and MOHFW (2003), Olieveau and Guilmoto (2005) and Guilmoto and Oliveau (2007). The practice of sex-selective abortions has also been known to be more widely prevalent in certain regions, the north-western, and pockets of the western region than the rest of the country. We briefly look at the evidence of sex imbalances in the age composition across states followed by inter-state variations in sex ratio at birth and sex differences in mortality.

The sex ratio of population of all ages and of young ages as revealed by the 2001 census is given in Appendix Table 5. We focus on the sex ratio in the broad 0-14 age group since, as noted earlier, migration becomes a major factor at older ages and in 5-year age groups, age mis-statement distorts the ratio. Punjab and Haryana show a very high ratio, over 115 boys per 1000 girls of ages below 15. In addition, Delhi, Gujarat, Uttar Pradesh, Rajasthan, and Bihar also have high ratios, over 110. Within Uttar Pradesh, the western districts show heavy imbalance as do the western districts of Maharashtra and the northern-western districts of Madhya Pradesh (see the maps in India, Registrar General, UNFPA, and MOHFW, 2003). Essentially, sex imbalance is severe in the north-western region. There are such pockets in Tamil Nadu as well, but for the state as a whole, the ratio is quite close to 105. Overall, the eastern, the north-eastern, the southern regions, show a balanced sex ratio at young ages (given the normal sex ratio at birth of 105 boys per 100 girls, a ratio close to 105 is called as 'balanced').

The analysis carried out at the national level in the preceding sections can be replicated at the state level to estimate the numbers of missing girls and sex-selective abortions; this has been done for Punjab and shown in the Appendix. But instead of such a repetitive exercise for the states, we note the evidence on the two key factors, sex differences in mortality and sex ratio at birth. This can be done only for large states since some of the indicators are available only for large states. Appendix Table 6 gives estimates of sex ratios at birth by the Sample Registration System (SRS) for two time periods, 1998-2000 and 2003-05. Besides, the table also gives the sex ratio at birth of children born to women of ages 20-29 at the 2001 census; this would be close to the sex ratio at birth in the period just before the 2001 census. Sex differences in mortality are presented in Appendix Table 7. Expectation of life at birth in two time periods, 1981-85 and 2000-04, as given by the SRS are shown for males and females. Further, the table also gives infant mortality rate

(IMR) and under-five mortality rate (U5MR) for males and females (available from the NFHS-2).

For a clearer understanding of the regional variations, classifications of states by the levels of sex ratio of 0-14 population in 2001, sex ratio at birth, and sex differences in mortality are presented in Table 6 (6A, 6B, 6C, 6D). The categories are shown in descending order of adverse sex ratio or its proximate determinants. As seen at the national level, the census based estimates of sex ratio at birth are generally lower than the SRS estimates. However, the broad picture is that Punjab, Haryana, Delhi and Gujarat show a very high sex ratio at birth. Uttar Pradesh, Rajasthan and Jammu and Kashmir also show high ratios. On the other hand, the eastern, north-eastern, and southern states show close to normal ratios. Though there are inter-state variations in the expectation of life at birth (Table 6C), no clear regional pattern is seen unlike in the case of the sex ratio at birth. However, the indicators of early childhood mortality, IMR and U5MR for males and females, show higher female mortality in Punjab, Haryana, Uttar Pradesh, and Rajasthan (Table 6D). But beyond this, no association between the sex differences in mortality and sex ratio of population is seen.

Overall, at the state level, Punjab and Haryana, and to a lesser extent Rajasthan and Uttar Pradesh, clearly show a very high sex ratio at birth combined with higher male than female mortality during childhood leading to a severe imbalance in the childhood sex ratio in population. Obviously, in these states, sex-selective abortions and female neglect (or perhaps some female infanticide, though this is difficult to infer conclusively) are responsible for the imbalanced sex ratio. In Gujarat and Delhi, sex-selective abortions seem to be the principal factor since female mortality is not relatively high. Jammu and Kashmir does not show a low female to male ratio during childhood in spite of a high sex ratio at birth. Maharashtra, Bihar and Madhya Pradesh are borderline cases with moderately adverse sex ratios at birth and of child population. The other states, southern, eastern, and north-eastern are characterized by a normal sex ratio at birth. In these states, girls are either better placed compared to boys in child survival or the disadvantage is not large. Thus, neither do these states suffer from sex-selective abortions in a substantial way, nor from excess female mortality, and are well balanced in the sex composition in the young ages. Undoubtedly, the principal problem of sex-selective abortions is in the northern-western region of India.

9. Summary and Concluding Remarks

India's population has long had more men than women in contrast to the western world in which women outnumber men. For some time, especially through the middle of the twentieth century, female mortality was higher than male mortality and this created a severe imbalance. The situation has eased somewhat with female mortality having fallen below male mortality in the last few decades, but even now the female advantage in survival is much smaller than seen in the west. While many western countries at the comparable mortality level showed female life expectancy to be three-four years over male expectancy, this gap is narrow in India, one-two years. Besides, in early childhood, female mortality is higher than male mortality. Since the 1980s, a new factor, that of sex-selective abortions, has emerged due to easy access to sex detection technology. This has raised the sex ratio at birth substantially in favour of males thereby influencing the masculinity ratio in India.

There is clear evidence that the sex ratio at birth has risen in India and is well over the normal ratio of 105 males per 100 females, though the estimates vary. There is independent evidence that sex-selective abortions are practiced widely in some regions. Demographic analysis of the 2001 census data along with information on mortality during the preceding two decades shows that the number of girls below the age of 15 years was short of the western pattern by nearly ten million; this amounts to over five percent of female population in these ages. The relatively higher than western female mortality contributed 3.7 million to the deficit, 38 percent of the total. The rest is primarily due to the higher than normal sex ratio that has arisen in India recently due to sex-selective abortions.

The number of sex-selective abortions in India has been quite large at least since the 1980s. The most likely estimates of annual number of sex-selective abortions, under certain assumptions, are 222 thousand, 254 thousand, 626 thousand, 404 thousand, and 682 thousand during the five quinquennia from 1981-85 to 2001-05. For the 25-year period 1981-2005, roughly the period since access to sex detection technology became easy, over 10 million sex-selective abortions have been performed.

This is indeed a very alarming situation. Of course, the occurrence of a large number of sex-selective abortions is not a revelation and there has been public debate on the matter of sex-selective abortions, how this is a reflection of the situation of girls in society and what are the consequences of the resultant sex imbalance. A number of researchers and civil organisations have highlighted this issue in various forums and called for public action. The Pre-Natal Diagnostic Techniques (Regulation and Prevention of Misuse) Act (PNDT Act) was passed in 1994 and amended later. However, this has obviously not been adequate. Son preference is very strong and resort to abortions to achieve a desired sex composition and more particularly, to avoid the birth of daughters, is condoned and even promoted within family and society. Implementation of the act is a difficult proposition under such conditions. Changes in social attitudes and behaviour are rarely rapid. No doubt the phenomenon is restricted to some regions. However, it could spread to other areas as well since son preference is nearly universal. The fact that this practice

is seen in some relatively prosperous areas is quite worrying. Now that India has been experiencing a steady growth in the economy, one must ask whether the tendency to go for sex-selective abortions would become more widespread as incomes rise. A concerted effort by the government, various organisations, and the society as a whole, is in order.

ACKNOWLEDGEMENTS

This paper was prepared at the initiative of the United Nations Population Fund (UNFPA). Discussions with K.M. Sathyanarayana of the UNFPA helped develop some of the ideas and overall shaped the paper. Some of the work, especially on the errors in earlier estimates of sex-selective abortions, is based on discussions with S. Krishnamoorthy. Comments on an earlier draft by Nesim Tumkaya, Christophe Guilmoto, Arvind Pandey and participants in a presentation at the UNFPA India office have been valuable. Harihar Sahoo provided useful technical assistance.

Fig. 1: Trends in Sex Ratio of Population in India for Ages 0-4, 5-9, 10-14, 0-14, Censuses 1901-2001

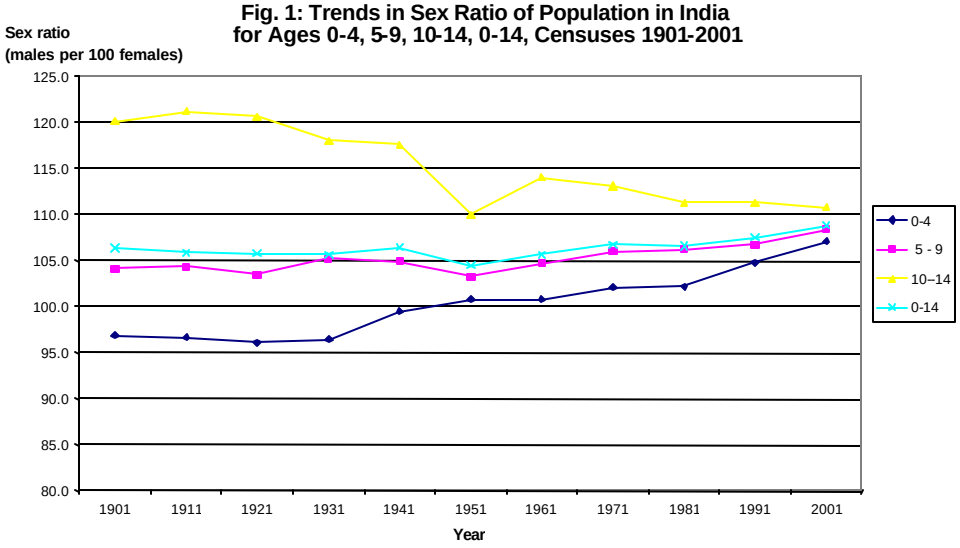

Fig. 2: Sex Ratios at Single Years, 0-14, India, Censuses 1961-2001

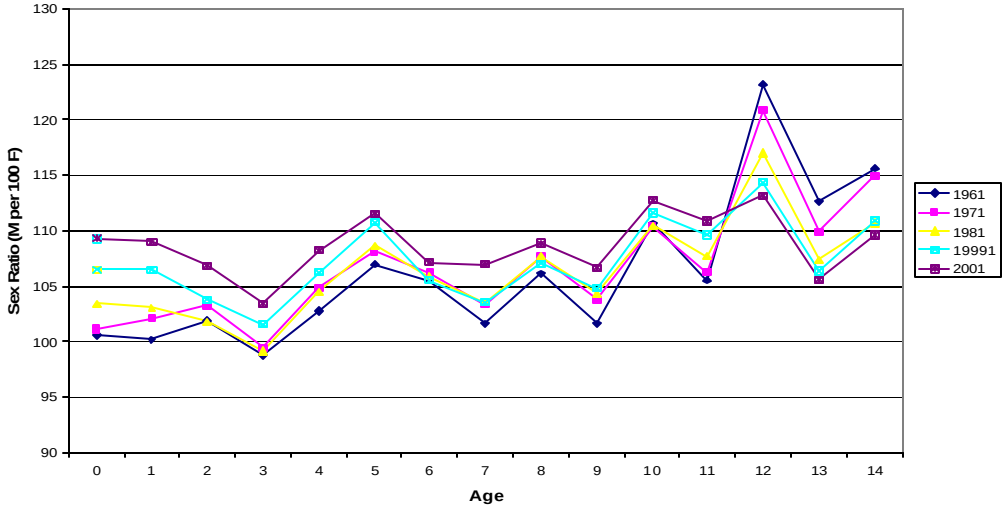

Table 1
Estimates of Sex Ratio at Birth, India, 1981-2005
(Male births per 100 female births)

Years	SRS Estimate	Source and year	Estimate
1982-84	109.8	*Based on*:	
1983-85	110.4	*children ever born to*	
1984-86	109.5	*women of age 20-29*	
1985-87	109.6	Census 1981	107.3
1986-88	109.8	Census 1991	107.4
1987-89	109.9	Census 2001	106.5
1988-90	109.8		
1989-91	110.3	*births last year*	
1990-92	111.1	Census 2001	110.4
1991-93	111.9		
1992-94	113.0	*births during the five*	
1993-95	113.8	*years preceding survey*	
1994-96	113.3	NFHS-1: 1992-93	105.2
1995-97	112.2	NFHS-2: 1998-99	107.0
1996-98	111.0		
1997-99		*births during 1997*	
1998-2000	111.4	SFMS 1998	111.2
1999-2001	111.9		
2000-02	112.1		
2001-03	113.3		
2002-04	113.4		
2003-05	113.6		

Sources:
SRS: Up to 1996-98: Graphs from India, Registrar General (2001);
1998 onwards: India, Registrar General (2003, 2004a, 2004b, 2005b, 2006a, 2006b).
Census: 1981, 1991; cited in Bhat (2002).
2001: Computed from India, Registrar General (2005d).
NFHS-1 and 2: Cited in Arnold *et al*. (2002)
SFMS: India, Registrar General (2005a).

Table 2
Estimation of Missing Girls in India, 2001
(All population figures are in thousands)

	Age Group				
	0 year	1-4 years	5-9 years	10-14 years	0-14 years
Persons (TP_i)	16,561	93,886	128,317	124,847	363,611
Males (MP_i)	8,648	48,471	66,735	65,632	189,487
Females (FP_i)	7,913	45,414	61,582	59,214	174,123
(Under Western mortality differential [a])					
ESR^W_i *(from endnote 5)*	*104.2973*	*103.4049*	*102.9477*	*102.5768*	
$EFP^W_i = 100*MP_i / ESR^W_i$	8,292	46,875	64,824	63,984	183,9753
Number of missing girls $= EFP^W_i - FP_i$	379	1,461	3,242	4,770	9,852
(Under actual mortality differential [b])					
ESR_i *(from endnote 5)*	*104.7292*	*104.8393*	*105.0338*	*105.5756*	
$EFP_i = 100* MP_i / ESR_i$	8,257	46,234	63,536	62,167	180,195
Number of missing girls $= EFP_i - FP_i$	345	820	1,955	2,953	6,071
Contribution of excess female mortality (over western level) $= EFP^W_i - EFP_i$	34	641	1,287	1,817	3,781
Implied SRB # $= 105* EFP_i / FP_i$	*109.6*	*106.9*	*108.3*	*110.2*	*108.7*
Corresponding Period of births	*2000*	*1996-99*	*1991-95*	*1986-90*	*1986-2000*

NSRB = 105.
a: Female life expectancy in the appropriate time periods assumed to be corresponding to the given male life expectancy in the period in accordance with the West Model of the Princeton Model Life tables (see the last column of Appendix Table 3).
b: Female and male life expectancies as given from the SRS life tables for the appropriate time periods (see Appendix Table 3).
#: Computed from eq.(3). This sex ratio at birth would yield the given sex ratio for the age group accounting for Indian mortality differentials and if there are no errors of age mis-statement and enumeration.
Note: Values of males and females may not add up to total exactly and values of missing females may differ from the subtraction of actual female population from expected population as shown due to rounding.

Table 3
Estimation of Sex-Selective Abortions, India, 1981-2005
(Populations, births, and sex-selective abortions are in thousands)

	Period				
	1981-85	1986-90	1991-95	1996-2000	2001-05
Mid-period population	718,265	799,382	885,753	976,518	1,076,584
CBR@	*33.6*	*31.4*	*28.9*	*26.6*	*24.6*
LB[a]	120,669	125,503	127,991	129,877	132,420
SRB (SRS)@	*109.6*	*109.8*	*113.0*	*111.0*	*113.4*
SRB(adjusted)$	*107.0*	*107.2*	*110.4*	*108.4*	*110.7*
MB[b]	62,375	64,932	67,159	67,556	69,572
FB = LB – MB	58,294	60,571	60,832	62,321	62,848
EFB[c]	59,404	61,840	63,961	64,339	66,259
No. of sex-selective abortions SSA = EFB – FB	1,110	1,269	3,129	2,018	3,412
Annual no. of sex selective abortions	222	254	626	404	682
Sex-selective abortions as percent of female births	*1.9*	*2.1*	*5.1*	*3.2*	*5.4*

NSRB = 105.

@: Average for the five year period; computed from India, Registrar General (1999, 2002, 2003, 2004a, 2004b, 2005b, 2006a, 2006b).

$: Adjusted as 0.9766* SRB (SRS); the factor 0.9766 = (108.7/111.3) is the ratio of implied average estimates of SRB (from Table 2) to the reported average SRS estimates of SRB for the 15-year period 1986-2000.

a: LB = Number of live births in the period = Mid-period population * CBR * 5 /1000.

b: MB = Male live Births = LB * SRB(adjusted) / [100 + SRB(adjusted)].

c: EFB = Expected number of Female Live Births = MB*100/ 105.
FB = Actual Number of Female Live Births = LB – MB.

Table 4
Summary of Results on the Number of Sex-Selective Abortions, India

(Number of sex-selective abortions in thousands)

Period	NSRB =105				NSRB = 106			
	SRB (SRS)		**SRB (Adjusted)**		SRB (SRS)		SRB (Adjusted)	
	Total	Annual	**Total**	**Annual**	Total	Annual	Total	Annual
1981-85	2522 *(4.4)*	504	**1110** ***(1.9)***	**222**	1955 *(3.4)*	391	550 *(0.9)*	110
1986-90	2735 *(4.6)*	547	**1269** ***(2.1)***	**254**	2145 *(3.6)*	429	686 *(1.1)*	137
1991-95	4578 *(7.6)*	916	**3129** ***(5.1)***	**626**	3968 *(6.6)*	794	2525 *(4.2)*	505
1996-2000	3517 *(5.7)*	703	**2018** ***(3.2)***	**404**	2903 *(4.7)*	581	1411 *(2.3)*	282
2001-05	4964 *(8.0)*	993	**3411** ***(5.4)***	**682**	4332 *(7.0)*	866	2787 *(4.4)*	557
1981-2005	18317 *(6.1)*	733	**10938** ***(3.6)***	**437**	15303 *(5.1)*	612	7958 *(2.6)*	318

Note:
Figures in parentheses are sex-selective abortions as percent of female births in the period.
SRB(SRS): Sex ratios at birth from the SRS
SRB (Adjusted): Sex ratios at birth adjusted using implied (reverse survival) sex ratios; see Table 3.
Figures in bold type are the most likely estimates, taken from Table 3.

Table 5
Comparative Estimates of Sex Selective Abortions in India

Source	Based on	Normal SRB (Males per 100 Females)	Period	Sex-selective abortions		
				Number (in thousands)		As % of female births $
				Total	Annual	
For the late 1990s						
Arnold *et al.* –A	NFHS-2	105	1996-98		106	0.8
- B	NFHS-2	105	1996-98		117	0.9
Jha *et al*. - A	SFMS	105.3	1997	590	590	4.5
- B	SFMS	102.6	1997	740	740	5.6
Bhat and Zavier	NFHS-2	106 105 104 103	1996-98 “ “ “			1.5 2.3 3.1 3.9
This paper - A (adjusted SRB)	**2001 census**	**105**	**1996-2000**	**2,018**	**404**	**3.2**
“	“	106	1996-2000	1,411	282	2.3
This paper – B (SRS SRB)	“	105	1996-2000	3,517	703	5.7
“	“	106	1996-2000	2,903	581	4.7
For the 20-year period 1986-2005						
Jha *et al*. - C	SFMS	Approx 105	1986-2005	10,000	500	4.2
This paper - A (adjusted SRB)	**2001 census**	**105**	**1986-2005**	**9,827**	**491**	**4.0**
“	“	106	1986-2005	7,409	370	3.0
This paper – B (SRS SRB)	“	105	1986-2005	15,794	790	6.5
“	“	106	1986-2005	13,348	667	5.5

Note:
SRS SRB: Sex ratios at birth from the SRS
Adjusted SRB: Sex ratios at birth adjusted using implied (reverse survival) sex ratios.
Figures shown in bold letters are the most likely new estimates.
$: The percentages are computed from the estimates in various papers to facilitate meaningful comparisons.

Sources: Arnold *et al*. (2002), Jha *et al*. (2006), Bhat and Zavier (2007), and Table 4 in this paper.

Table 6

Variations in Sex Ratio of Population, Sex Ratio at Birth and Sex Differences in Life Expectancy and Early Childhood Mortality, Large States of India

A. States Classified by Sex Ratio of Population in Ages 0-14, 2001 Census

Sex ratio (males per 100 females) in the range	States
More than 115	PJ, HR
(110, 115]	DL, GJ, UP, RJ, BH
(107.5, 110]	MH, MP, UT, HP,
(105, 107.5]	NG, JK, JH, TN, GO
(102.5, 105]	WB, KN, AP, AS, MN, OR, TR, AR, KL, MZ, SK, CH, MG

AP: Andhra Pradesh; AR: Arunachal Pradesh; AS: Assam; BH: Bihar; CH: Chhattisgarh DL: Delhi; GJ: Gujarat; GO: Goa HR: Haryana; HP: Himachal Pradesh; JK: Jammu & Kashmir; JH: Jharkhand; KN: Karnataka; KL: Kerala; MP: Madhya Pradesh; MH: Maharashtra; MN: Manipur MG: Meghalaya MZ: Mizoram NG: Nagaland OR: Orissa; PJ: Punjab; RJ: Rajasthan; SK: Sikkim TN: Tamil Nadu; TR: Tripura; UP: Uttar Pradesh; UT: Uttarakhand; WB: West Bengal.

Source: Obtained from Appendix Table 5.

B. States Classified by Sex Ratio at Birth

SRB (Males per 100 females) in the range	SRS: 1998-2000	SRS: 2003-05	2001 Census (from children ever born to women of ages 20-29)
120 or higher	HR, PJ	DL, HR, JK, PJ	
[115, 120)	UP, GJ, RJ	BH, UP, HP, GJ, RJ	HR, PJ
[109, 111)	MH. MP, HP	AP, KL, MP, AS, KN	JK, DL
[107, 109)	TN, KL, OR	OR, WB	BH, MH, HP, RJ
[105, 107)	WB, KN	CH. TN	MP, UP, UT
Less than 105	AS, AP	-	CH, OR, KL, AS, WB, JH, AP, TN, KN

Source: Obtained from Appendix Table 6.

Cont…

Table 6 (Cont.)

C. States Classified by Sex Differences in Life Expectancy

Life expectancy for males, e_0^{0M}, in the range	**1981-85**	**2000-04**
Greater than e_0^{0F}	AS,BH, HR, OR, UP	BH, MP, UP
$[e_0^{0F} - 1, e_0^{0F})$	MP, RJ, TN	AS, HR, HP, OR
$[e_0^{0F} - 2, e_0^{0F} - 1)$	PJ, WB	GJ, RJ, WB
$[e_0^{0F} - 3, e_0^{0F} - 2)$	AP, KN, MH	AP, MH, PJ, TN
Less than or equal to $e_0^{0F} - 3$	GJ, KL	KN, KL

Source: Obtained from Appendix Table 7.

D: States Classified by Sex Differences in Early Childhood Mortality

Male Infant Mortality Rate (IMR^M) in the range	**States**	**Male Under-five Mortality Rate ($U5MR^M$) in the range**	**States**
Less than $IMR^F - 10$	PJ. HR	Less than $U5MR^F - 10$	PJ, UP, RJ, HR
$[IMR^F - 10, IMR^F - 5)$	-	$[U5MR^F - 10, U5MR^F - 5)$	AP, BH,MP
$[IMR^F - 5, IMR^F)$	TN, UP	$[U5MR^F - 5, U5MR^F)$	TN, JK, MH
$[IMR^F, IMR^F + 5)$	AP, BH, JK, MH, RJ	$[U5MR^F, U5MR^F + 5)$	GJ
$[IMR^F + 5, IMR^F + 10)$	KL, MP	$[U5MR^F + 5, U5MR^F + 10)$	DL, WB
Greater than or equal to $IMR^F + 10$	GJ, DL, HP, AS, KN, OR,WB	Greater than or equal to $U5MR^F + 10$	AS, HP, KN, KL, OR

IMR^F : Female Infant Mortality Rate
$U5MR^F$: Female Under-five Mortality Rate.

Source: Obtained from Appendix Table 7.

APPENDIX TABLE 1

Sex Ratio of Population in Various Age Groups, India, 1901-2001

Year	Age Group							
	0-4	5-9	10-14	0-14	15-34	35-54	55+	All
Females per 1000 males								
1901	1032	960	832	940	991	953	1119	972
1911	1034	958	825	944	988	926	1067	963
1921	1040	966	829	945	978	913	1029	955
1931	1037	950	847	946	982	889	1000	950
1941	1005	953	850	939	979	895	973	945
1951	992	968	909	957	968	886	972	947
1961	992	955	877	946	972	874	958	941
1971	979	943	884	937	961	872	917	930
1981	978	941	898	938	944	903	952	934
1991	954	937	898	930	948	879	938	927
2001	934	923	902	919	940	901	1031	933
Males per 100 females								
2001	107.1	108.4	110.8	108.8	106.3	111.0	97.0	107.2

Note: The sex ratios for 1901 to 1991 are given in terms of females per 1000 males as these were available in this form as per the Indian census convention and hence are reproduced as such. For 2001, the females per 1000 male ratios as well as the standard males per 100 female ratios are given.

Sources: 1901-91: Censuses 1901 to 1991, Bhat (2002).
2001: Computed from India, Registrar General (2005c).

APPENDIX TABLE 2

Sex Ratio of Population at Single Years of Age in the range 0-14, Indian Censuses, 1961-2001
(Males per 100 females)

	Census Year				
Age	**1961**	**1971**	**1981**	**1991**	**2001**
0	101	101	103	106	109
1	100	102	103	107	109
2	102	103	102	104	107
3	99	99	99	102	103
4	103	105	105	106	108
5	107	108	109	111	112
6	106	106	106	106	107
7	102	103	104	104	107
8	106	108	108	107	109
9	102	104	104	105	107
10	111	110	110	112	113
11	106	106	108	110	111
12	123	121	117	114	113
13	113	110	107	106	106
14	116	115	111	111	110
1-4	101	102	102	104	107
0-4	101	102	102	105	107
5-9	105	106	106	107	108
10-14	114	113	111	111	111
0-14	106	108	107	108	109

Sources: Computed from India, Registrar General (1963, 1976, 1987, 1998).

APPENDIX TABLE 3

Life Expectancy at Birth by Sex in India, 1901-2004

	Expectation of Life at Birth			
Period	Persons	Male	Female (Actual)	Female (Expected)*
1911-21	20.1	19.4	20.9	21.4
1921-31	26.8	26.9	26.6	29.2
1931-41	31.8	32.1	31.4	34.6
1941-51	32.1	32.4	31.7	34.9
1951-61	41.3	41.9	40.6	44.8
1961-71	45.6	46.4	44.7	49.3
1970-75	49.7	50.5	49.0	53.9
1976-80	52.3	52.5	52.1	55.7
1981-85	55.4	55.4	55.7	58.9
1986-90	57.7	57.7	58.1	61.3
1991-95	60.3	59.7	60.9	63.4
1996-2000	61.9	61.0	62.7	64.8
2000-04	63.0	62.1	63.7	65.9

***:** Female life expectancy corresponding to the given male life expectancy and its paired value in the Regional Model Life tables, Model West; obtained by interpolation from the series of model life tables, Coale and Demeny (1966).

Sources:
1901-71: India, Department of Family Welfare (1977).
1971-2004: India, Registrar General (1999, 2007).

APPENDIX TABLE 4

Infant and Under-Five Mortality Rates by Sex, India 1982-2005

Year(s)	Female IMR	Male IMR	Year(s)	Female IMR	Male IMR
Estimates by the Sample Registration System (SRS)					
1982	104	106	1996	73	71
1983	105	105	1997	72	70
1984	104	104	1998	73	70
1985	98	96	1999	71	70
1982-85	*103*	*103*	2000	69	67
1986	97	96	*1996-2000*	*72*	*70*
1987	96	96	2001	68	64
1988	94	96	2002	65	62
1989	90	92	2003	64	57
1990	81	78	2004	58	58
1986-90	*92*	*92*	2005	61	56
1991	80	81	*2001-05*	*63*	*59*
1992	80	79			
1993	75	73			
1994	73	75			
1995	76	73			
1991-95	*77*	*76*			
Estimates from Surveys					
Survey	*Reference period*	*IMR*		Under-Five Mortality Rate (U5MR)	
		Female	Male	Female	Male
NFHS-1	1983-92	84	89	122	115
NFHS-2	1988-98	71	75	105	98
SFMS	1997	73	70	102	90

IMR: Infant Mortality Rate (infant deaths per 1000 live births)
U5MR: Under-Five Mortality Rate:
= 1000*Proportion of children dying before completing five years of age
= 1000* ($_5 q_o$) in life table notation.
Sources:
SRS: India, Registrar General (1999, 2002, 2003, 2004a, 2004b, 2005b, 2006a, 2006b).
NFHS-1: IIPS (1995); NFHS-2: IIPS and ORC Macro (2000).
SFMS: India, Registrar General (2005a).

APPENDIX TABLE 5

Sex Ratio of Population in Various Age Groups, India and States, 2001 Census
(Males per 100 females)

State /Region	Age Group				
	All ages	0-4	5-9	10-14	0-14
Andhra Pradesh	102.2	103.6	103.6	106.7	104.7
Arunachal Pradesh	112.0	102.6	105.5	103.8	104.1
Assam	107.0	103.0	104.2	106.4	104.5
Bihar	108.8	104.5	109.9	117.2	110.4
Chhattisgarh	101.1	102.5	102.1	104.7	103.1
Delhi	121.8	114.9	114.7	115.1	114.9
Goa	104.1	106.8	104.9	104.4	105.4
Gujarat	108.7	112.6	112.6	113.4	112.9
Haryana	116.1	122.4	119.8	115.2	118.9
Himachal Pradesh	103.3	112.5	109.1	105.0	108.6
Jammu & Kashmir	112.1	106.6	105.7	106.8	106.4
Jharkhand	106.3	102.5	105.2	110.1	105.9
Karnataka	103.6	105.5	103.7	105.2	104.8
Kerala	94.5	104.0	103.7	104.2	104.0
Madhya Pradesh	108.8	106.6	107.2	113.1	108.9
Maharashtra	108.5	109.5	107.6	110.3	109.2
Manipur	102.2	104.4	104.3	104.4	104.4
Meghalaya	102.9	102.6	102.6	102.6	102.6
Mizoram	107.0	102.8	104.3	103.3	103.4
Nagaland	111.1	102.2	107.8	109.1	106.8
Orissa	102.9	104.3	104.8	104.1	104.4
Punjab	114.2	125.9	121.8	116.4	120.8
Rajasthan	108.6	109.5	110.9	113.4	111.4
Sikkim	114.3	105.2	101.0	103.8	103.2
Tamil Nadu	101.3	105.7	105.5	105.5	105.6
Tripura	105.5	103.5	104.1	104.8	104.2
Uttar Pradesh	111.4	107.6	111.9	116.1	112.0
Uttarakhand	104.6	110.4	10.5	107.4	108.7
West Bengal	107.1	103.5	104.6	106.3	104.9
India	107.2	107.1	108.3	110.9	108.8

Source: Computed from India, Registrar General (2005c).

APPENDIX TABLE 6

Sex Ratio at Birth in Large States, India

(Male births per 100 female births)

State	SRS Estimates		Census 2001
	1998-2000	2003-05	Based on children ever born to women of ages 20-29
Andhra Pradesh	104.2	109.1	104.1
Assam	101.6	110.3	103.7
Bihar	111.6@	115.6	107.0
Chhattisgarh	@	105.6	102.6
Delhi	Na	120.3	110.7
Gujarat	117.5	118.5	111.6
Haryana	125.5	120.6	115.7
Himachal Pradesh	110.9	116.5	108.9
Jammu & Kashmir	na	121.4	109.3
Jharkhand	@	114.5	104.0
Karnataka	106.2	110.5	104.9
Kerala	107.5	109.6	103.7
Madhya Pradesh	110.3@	109.8	106.2
Maharashtra	109.5	114.7	107.9
Orissa	107.8	107.3	103.5
Punjab	126.3	124.8	117.5
Rajasthan	114.0	119.2	108.9
Tamil Nadu	107.4	106.0	104.8
Uttar Pradesh	115.2@	116.0	106.7
Uttarakhand	@	na	106.7
West Bengal	105.0	108.0	104.0
India	111.4	113.6	106.5

@: For the undivided state; Bihar including Jharkhand, Madhya Pradesh including Chhattisgarh, and Uttar Pradesh including Uttarakhand.
na: Not available.

Sources:
SRS 1998-2000: India, Registrar General (2003)
2003-05, India, Registrar General (2006b).
Census 2001: Computed from India, Registrar General (2005d).

APPENDIX TABLE 7

Sex Differentials in Mortality in Large States, India

	Expectation of Life at Birth				Infant Mortality Rate		Under-five Morality Rate	
	1981-85		2000-04		From NFHS-2 for 1988-98			
	Male	Female	Male	Female	Male	Female	Male	Female
Andhra Pradesh	57.2	59.8	62.4	65.0	73	69	88	95
Assam	52.0	51.9	58.0	58.6	67	56	87	72
Bihar	54.2@	51.5@	61.8	59.9	76@	76@	105@	116@
Delhi	Na	na	na	na	51	40	61	53
Gujarat	55.5	59.3	62.7	64.8	69	59	92	89
Haryana	61.5	59.0	65.3	65.8	53	66	66	94
Himachal Pradesh	na	na	66.1	66.8	45	34	53	43
Jammu & Kashmir	na	na	na	Na	64	62	77	81
Karnataka	59.7	62.0	63.1	66.7	70	54	90	77
Kerala	65.4	71.5	71.0	76.1	25	17	31	21
Madhya Pradesh	51.5@	51.9@	57.5	57.2	97@	88@	142@	148@
Maharashtra	59.6	62.1	65.5	67.8	55	52	69	71
Orissa	53.1	53.0	58.9	58.9	95	84	121	110
Punjab	62.6	63.6	67.8	69.8	49	65	55	87
Rajasthan	53.3	53.8	60.9	62.0	89	87	116	135
Tamil Nadu	56.5	57.4	64.6	66.8	50	52	62	67
Uttar Pradesh	51.4@	48.5@	59.9	59.0	95@	96@	121@	144@
West Bengal	56.4	58.0	63.7	65.2	57	44	75	67
India	55.4	55.7	62.1	63.7	75	71	98	105

@: For the undivided state; Bihar including Jharkhand, Madhya Pradesh including Chhattisgarh, and Uttar Pradesh including Uttarakhand.
na: Not available.

Sources: Life expectancy: SRS estimates: India, Registrar General (1999, 2007)
Infant Mortality rate and Under-five mortality rate: NFHS-2: referring to the 10-year period before the survey, i.e., 1988-98: IIPS and ORC Macro, state reports.

APPENDIX P

Estimates for Punjab

Since the practice of sex-selective has been reported to be widely prevalent in Punjab, we provide below estimates for this state. It has been observed earlier by Visaria that the sex ratio in the northwestern parts of India was very adverse to females in the past. This was primarily attributed to relatively higher female morality. However, recent estimates from the SRS, NFHS, and the census show that the sex ratio at birth is very high. In the 1980s, the sex ratio at birth was reported to be well over 110 according to the SRS; the 1991 census also showed a high ratio for recent births (Table P-1-A). More recently, the ratio has crossed 120 as estimated by the SRS. Other estimates are also fairly high.

Punjab does not show a departure from the national pattern in sex differentials in mortality (Table P-1-B). The life expectancy is higher for females than for males with a narrow gap as seen nationally. However, in early childhood mortality, the female disadvantage in Punjab is greater than average as seen from the NFHS estimates (Appendix Table 7).

Applying the demographic methodology to the 2001 census age distribution of Punjab, with the SRS male and female mortality levels, it is seen that for the 0-14 age range, 529 thousand girls were missing in a population of 3,450 thousand girls (Table P-2). This amounts to 15.5 percent of enumerated girls in this age group, a much greater degree than the all-India level of 3.5 percent. Implied sex ratios computed for Punjab resemble the direct SRS estimates quite well for some of the periods (the entire series is not available for Punjab). The implied estimate of SRB for Punjab for 2000 is 128.7, close to the SRS estimate of 128.9 for 2001-03; for 1996-1999 the implied SRB is 125.6 compared to the SRS estimate of 126.2 for 1998-2000; for 1986-90 the implied SRB is 116.8 and for 1982-86 the SRS estimate is 114.8. Overall, the SRS estimates for Punjab are close to the implied estimates in contrast to the all-India picture which showed the SRS estimates to be consistently higher than the implied ones. Hence, unlike the case of India, no correction has been applied to the SRB estimates for Punjab and these are taken for the periods 1981-86 and 2001-05 and the implied estimates for the periods 1986-90, 1991-95, and 1996-2000.

Estimates of the number of sex-selective abortions for Punjab (Table P-3) show, as expected, a very high incidence, over 20 thousand per year in the 1980s rising to over 40 thousand annually since the 1990s (assuming the NSRB to be 105). This amounts to about 10 percent of female births in the 1980s and over 20 percent during 2001-05, more than three times the level for India as a whole and even higher than the level estimated for China by Cai and Lavely (2003). In the recent years, for every five girls born, one female foetus is aborted in Punjab.

Table P-1
A. Estimates of Sex Ratio at Birth, Punjab, 1981-2005
(Male births per 100 female births)

Source and years	Estimate	Source and year	Estimate
Sample Registration System (SRS)		*Based on children ever born to women of ages 20-29*	
1982-86	114.8	Census 1981	110.4
		Census 1991	112.1
1998-2000	126.2	Census 2001	117.5
1999-2001	129.0	*Based on births last year*	
2000-02	129.0	Census 2001	127.0
2001-03	128.9	*Based on births during the five years preceding survey*	
2002-04	125.5	NFHS-1: 1992-93	114.1
2003-05	124.8	NFHS-2: 1998-99	116.2

Sources:
SRS: 1982-86: cited in Bhat (2002);
1998 onwards: India, Registrar General (2003, 2004a, 2004b, 2005b, 2006a, 2006b).
Census: 1981, 1991: cited in Bhat (2002);
2001: Computed from India, Registrar General (2005d).
NFHS-1 and 2: Cited in Arnold *et al*. (2002).

B. Estimates of Life Expectancy, Punjab, 1970-2004

	Expectation of Life at Birth			
Period	Persons	Male	Female (Actual)	Female (Expected)*
1970-75	57.9	59.0	56.8	62.7
1976-80	60.5	60.9	60.2	64.7
1981-85	63.1	62.6	63.6	66.4
1986-90	65.2	64.7	66.9	68.6
1991-95	67.2	66.1	68.4	70.1
1996-2000	68.5	67.3	69.6	71.2
2000-04	68.9	67.8	69.8	71.7

Source: 1971-2004: India, Registrar General (1999, 2007).
*: See footnote to Appendix Table 3.

Table P- 2
Estimation of Missing Girls in Punjab, 2001

	Age Group				
	0 year	1-4 years	5-9 years	10-14 years	0-14 years
Persons (TP_i)	313,890	1,814,848	2,657,368	2,831,770	7,617,876
Males (MP_i)	176,541	1,009,958	1,458,964	1,522,899	4,168,362
Females (FP_i)	137,349	804,890	1,198,404	1,308,871	3,449,514
(Under Western mortality difference [a])					
ESR^W_i *(from endnote 5)*	*104.4639*	*103.9976*	*103.5899*	*103.3198*	
$EFP^W_i = 100*MP_i / ESR^W_i$	168,997	971,136	1,408,404	1,473,966	4,022,503
Number of missing girls $= EFP^W_i - FP_i$	31,648	166,246	210,000	165,095	572,989
(Under actual mortality difference [b])					
ESR_i *(from endnote 5)*	*104.8802*	*104.9317*	*104.7608*	*104.6402*	
$EFP_i = 100* MP_i / ESR_i$	168,326	962,491	1,392,662	1,455,367	3,978,847
Number of missing girls $= EFP_i - FP_i$	30,977	157,601	194,258	146,496	529,333
Contribution of excess female mortality (over western level) $= EFP^W_i - EFP_i$	671	8,645	15,742	18,599	43,657
Implied SRB # $= 105* EFP_i / FP_i$	*128.7*	*125.6*	*122.1*	*116.8*	*121.1*
Corresponding Period	*2000*	*1996-99*	*1991-95*	*1986-90*	*1986-2000*

NSRB = 105.

a: Female life expectancy in the appropriate time periods assumed to be corresponding to the given male life expectancy in the period in accordance with the West Model of the Princeton Model Life tables (see the last column of Table P-1-B).

b: Female and male life expectancies as given from the SRS life tables for the appropriate time periods (see Appendix Table P-1-B).

#: Computed from eq. (3). This sex ratio at birth would yield the given sex ratio for the age group accounting for Indian mortality differentials and if there are no errors of age mis-statement and enumeration.

Note: Values of males and females may not add up to total exactly and values of missing females may differ from the subtraction of actual female population from expected population as shown due to rounding.

Table P- 3
Estimation of Sex-Selective Abortions, Punjab, 1986-2005
(Populations, births, and sex-selective abortions are in thousands)

	Period				
	1981-85	1986-90	1991-95	1996-2000	2001-05
Mid-period population	17,545	19,284	21,166	23,196	25,421
CBR@	*29.94*	*29.94*	*28.36*	*26.14*	*22.52*
LB[a]	2,626	2,734	2,766	2,612	2,527
SRB $	*114.8*	*116.8*	*122.0*	*126.0*	*127.3*
MB[b]	1404	1473	1520	1456	1415
FB = LB – MB	1223	1262	1246	1156	1112
EFB[c]	1337	1403	1448	1387	1348
No. of sex-selective abortions SSA = EFB – FB	114	141	202	231	236
Annual no. of sex selective abortions	23	28	40	46	47
Sex-selective abortions as percent of female births	*9.3*	*11.2*	*16.2*	*20.0*	*21.2*

NSRB = 105.

@: Average for the five year period; computed from India, Registrar General (1999, 2002, 2003, 2004a, 2004b, 2005b, 2006a, 2006b)

$: For 1986-2000: Implied SRB from Table P-2; for 1981-85: SRS value for 1982-86; for 2001-05: average of SRS values for 2001-03 and 2002-04.

a: LB = Number of live births in the period = Mid-period population * CBR * 5 /1000.

b: MB = Male live births = LB * SRB /(100 + SRB).

c: EFB = Expected number of female live births = MB*100/ 105.
FB = Actual number of female live births.

REFERENCES

Agnihotri, Satish B., 2000. ***Sex Ratio Patterns in the Indian Population- A Fresh Exploration.*** New Delhi: Sage.

Agnihotri, Satish B., 2003. "Survival of the Girl Child- Tunnelling out of the Chakravyuha", ***Economic and Political Weekly, 38***: 4351-60.

Arnold, Fred, Sunita Kishor,and T.K. Roy, 2002. "Sex Selective Abortions in India", ***Population and Development Review 28(4)***: 759-85.

Bhat, P.N. Mari, 2002. "On the Trail of Missing Indian Females I: Search for Clues, II: Illusion and Reality", ***Economic and Political Weekly, 37***: 5105-18, 5244-63.

Bhat, P.N.M., 2006. "Sex Ratio in India" Correspondence, ***Lancet 367***: 1725-26.

Bhat, P.N. Mari and A.J. Francis Zavier, 2007. "Factors Influencing the Use of Prenatal Diagnostic Technique and the Sex Ratio at Birth in India", ***Economic and Political Weekly 42***: 2292-2303.

Cai, Yong and William Lavely, 2003. "China's Missing Girls: Numerical Estimates and Effects on Population Growth", ***The China Review 3(2)***: 13-29.

Coale, Ansley J. 1991. "Excess Female Mortality and the Balance of Sexes: An Estimate of the Number of 'Missing Females'", ***Population and Development Review 17 (1)***: 35-51.

Coale, Ansley J. and Paul Demeny, 1966. ***Regional Model Life Tables and Stable Populations***. Princeton: Princeton University Press.

Das Gupta M. and M. Bhat, 1997. "Fertility Decline and Increased Manifestation of Sex Bias in India", ***Population Studies 51(3)***: 307-15.

Dubuc, Sylvia and David Coleman, 2007. "An Increase in the Sex Ratio of Births to India-born Mothers in England and Wales: Evidence for Sex-Selective Abortions, ***Population and Development Review 33(2)***: 383-400.

Ganatra, B. S. Hirve and V.N. Rao, 2001. "Sex-selection Abortion: evidence from a community based study in Western India", ***Asia-Pacific Population Journal 16***: 109-24.

George, Sabu, Rajaratnam Abel and B.D. Miller, 1992. "Female Infanticide in Rural South India", ***Economic and Political Weekly, 27***: 1153-1156.

Griffiths, Paula, Zoe Matthews, and Andrew Hinde, 2000. "Understanding the Sex Ratio in India: A Simulation Approach", ***Demography 37(4):*** 477-488.

Guillot, Michel, 2002. "The Dynamics of the Population Sex Ratio in India, 1971-96", ***Population Studies 56(1)***: 51-63.

Guilmoto, Christophe Z., and S. Oliveau, 2007. "Sex Ratio Imbalances Among Children at Micro-Level: China and India Compared", Paper presented at the 2001 Annual Meeting of the Population Association of America, New York, March 29-31.

India, Department of Family Welfare, 1977. ***Family Welfare Programme in India Yearbook, 1976-77***. New Delhi: Ministry of Health and Family Welfare.

India, Registrar General, 1963. ***Census of India 1961, Paper No. 2 of 1963. Age Tables.*** Delhi: Controller of Publications.

India, Registrar General, 1976. ***Census of India 1971, Series 1 India, Part II-C(ii) Social and Cultural Tables (Table C-II, C-III Part A and B)***. New Delhi: Controller of Publications.

India, Registrar General, 1987. ***Census of India 1981, Series 1 India, Part IV A- Social and Cultural Tables (Tables C1 to C6)***. New Delhi: Controller of Publications.

India, Registrar General, 1998. ***Census of India 1991, Series 1 India, Part IV A - C Series, Social and Cultural Tables Vol. 2***. New Delhi: Controller of Publications.

India, Registrar General, 1999. ***Compendium of India's Fertility and Mortality Indicators 1971-1997 based on the Sample Registration System (SRS)***. Delhi: Controller of Publications.

India, Registrar General, 2001***. Provisional Population Totals, Paper 1 of 2001, Census of India 2001 Series-1 India.***. Delhi: Controller of Publications.

India, Registrar General, 2002. ***Sample Registration System Statistical Report 1999.*** Delhi: Controller of Publications.

India, Registrar General, 2003. ***Sample Registration System Statistical Report 2000, Report No. 5 of 2003.*** Delhi: Controller of Publications.

India, Registrar General, 2004a. ***Sample Registration System Statistical Report 2001, Report No. 1 of 2004.*** Delhi: Controller of Publications.

India, Registrar General, 2004b. ***Sample Registration System Statistical Report 2002, Report No.3 of 2004.*** Delhi: Controller of Publications.

India, Registrar General, 2005a. ***Sample Registration System- Special Fertiliy and Mortality Survey, 1998. A Report of 1.1 Million Indian Households.*** Delhi: Controller of Publications.

India, Registrar General, 2005b. ***Sample Registration System Statistical Report 2003, Report No. 1 of 2005.*** Delhi: Controller of Publications.

India, Registrar General, 2005c. ***Table C14, 2001 Census CDs.***

India, Registrar General, 2005d. ***Table F1, 2001 Census CDs***

India, Registrar General, 2006a. ***Sample Registration System Statistical Report 2004, Report No. 1 of 2006.*** Delhi: Controller of Publications

India, Registrar General, 2006b. ***Sample Registration System Statistical Report 2005, Report No. 2 of 2006.*** Delhi: Controller of Publications

India, Registrar General, 2007. ***SRS Based Abridged Life Tables 2000-2004, SRS Analytical Studies Report No. 1 of 2007.*** Delhi: Controller of Publications.

India, Registrar General, UNFPA, and MOHFW, 2003. ***Mapping the Adverse Child Sex Ratio in India.*** New Delhi: UNPF.

International Institute for Population Sciences (IIPS), 1995. ***National Family Health Survey (MCH and Family Planning), India, 1992-93***. Bombay: IIPS.

International Institute for Population Sciences (IIPS) and ORC Macro, 2000. ***National Family Health Survey -2, India, 1998-99.*** Mumbai: IIPS.

Jha, Prabhat, Rajesh Kumar, Priya Vasa, Neeraj Dhingra, Deva Thiruchelvam, Rahim Moineddin, 2006."Low Male-to-Female Sex Ratio of Children Born in India: National Survey of 1.1 Million Households", ***Lancet 367*****:** 211-218.

Kundu, Amitabh and M.K. Sahu, 1991. "Variations in the Sex Ratio: Development Implications", ***Economic and Political Weekly, 26***: 2341-42.

Krishnamoorthy, S., 2006. "Accounting for the Sex Ratio of India", in Arvind Pandey (*ed*.) ***Biostatistical Aspects of Health and Population***. New Delhi: Hindustan Publishing Corporation.

Mayer, Peter, 1999. "India's Falling Sex Ratios", ***Population and Development Review 25 (2)***: 323-43.

Miller, Barbara D., 1989. "Changing Patterns of Juvenile Sex Ratios in Rural India, 1961 to 1971", ***Economic and Political Weekly, 24***: 1229-36.

Nair, P. Mohanachandran, 1996. "Imbalance of Sex Ratio of Children in India", ***Demography India 25(2)***: 177-187.

Oliveau S. and Christophe Z. Guilmoto, 2005. "Spatial Autocorrelation and Demography; Exploring India's Demographic Parameters", Paper presented at the International Population Conference, Tours, France, July 2005.

Pandey, Arvind, 2007. Personal communication.

Premi, Mahendra K., 2001. "The Missing Girl Child". ***Economic and Political Weekly, 36***: 1875-80.

Rajan S. Irudaya, U.S. Mishra, and K. Navaneetham, 1991. "Decline in Sex Ratio: An Alternative Explanation Revisited", ***Economic and Political Weekly, 26***: 2963-64.

Raju, Saraswati and Mahendra K. Premi, 1992."Decline in Sex Ratio: Alternative Explanation Re-examined", ***Economic and Political Weekly, 27***: 911-12.

Sudha S. and S. Irudaya Rajan, 1998. "Intensifying Masculinity of Sex Ratio in India: New Evidence 1981-1991. Working Paper, Centre for Development Studies, Thiruvananthapuram.

United Nations, 1982. ***Model Life tables for Developing Countries,*** New York: United Nations.

Visaria, Leela, 2007. "Deficit of Girls in India: Can It Be Attributed to Female Selective Abortion?" in Tulsi Patel *(ed.)*, ***Sex-Selective Abortion in India***, New Delhi: Sage.

Visaria, Pravin, 1968. ***Sex Ratio of India's Population, 1961 Census Monograph***, Delhi: Controller of Publications.

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[1] Bhat (2002) has provided such estimates based on India's 1991 census age-sex distributions. This analysis can be carried further using the 2001 distribution.

[2] Coale (1991) estimated the number of missing females caused by excess female mortality in India as 22.8 million in 1991 (and in China as 29.1 million in 1990) applying such techniques. Griffiths *et al*. (2000) followed a similar approach using stable population models. Nair (1996) used standard male-female childhood mortality differentials to assess the number of missing females. Cai and Lavely (2003) have applied this procedure to estimate the numbers of missing females for China based on the 2000 census.

[3] Guillot (2002) and Krishnamoorthy (2006) have shown how the female deficit can be decomposed into contributions of various factors.

[4] This was the approach adopted by Sudha and Rajan (1996) for the 1991 Indian census data.
Note that though the formula shows NSRB, the normal sex ratio at birth, the computed value of the implied SRB does not depend on the values of NSRB used since the value get cancelled with NSRB appearing in the denominator of the computation of the EFP_i term.

[5] The essential formulation for the age groups is as follows. Let ,
${}_nL_x$ (F, k) = Person years lived between exact ages x and x+n from the female life table for time period k,
${}_nL_x$ (M, k) = Person years lived between exact ages x and x+n from the male life table for time period k,
The age groups are conventional; that is, i = 1 for age 0; i = 2 for ages 1-4; i = 3 for ages 5-9; and i = 4 for ages 10-14.
Further, k, the time period, is taken as a five-year period; k = 1 corresponds to time t - 15 to t - 10, k = 2 corresponds to time t - 10 to t - 5, and k = 3 corresponds to time t - 5 to t .
The expected sex ratios, ESR_i values, can then be computed as given below.
The population in age group 1 (0 year) at time t are survivors of births during t - 1 to t.

$$ESR_1 = \{NSRB/100\} * \{{}_1L_0(M,3) / {}_1L_0(F,3)\}.$$

Those in age group 2 (1-4 years) at time t are survivors of births during t - 5 to t - 1 and,

$ESR_2 = \{NSRB/100\} * \{{}_4L_1(M,3) / {}_4L_1(F,3)\}$.

Those in age group 3 (5-9 years) at time t are survivors of births during t - 10 to t - 5, and

$ESR_3 = \{NSRB/100\} * \{{}_5L_0(M,2) / {}_5L_0(F,2)\} * \{ [{}_5L_5(M,3) / {}_5L_5(F,3)] / [{}_5L_0(M,3) / {}_5L_0(F,3)] \}$.

Those in age group 4 (10- 14) at time t are survivors of births during t - 15 to t - 10, and

$ESR_4 = \{NSRB/100\} * \{{}_5L_0(M,1) / {}_5L_0(F,1)\} * \{ [{}_5L_5(M,2) / {}_5L_5(F,2)] / [{}_5L_0(M,2) / {}_5L_0(F,2)] \} * \{ [{}_5L_{10}(M,3) / {}_5L_{10}(F,3)] / [{}_5L_5(M,3) / {}_5L_5(F,3)] \}$.

[6] Since the SRS life expectancies are for calendar years, strictly speaking, the ESR_i values computed refer to January 1, 2001. However, the actual age distributions are available for the date of census, that is, March 1, 2001. A shift of mere two months is not likely to change the ESR_i much and hence it is safe to apply these to the actual 2001 census age–sex distribution.

[7] The implied sex ratio does not depend on the value of the normal sex ratio at birth used. Thus, any error in the values of the normal sex ratio has no bearing on the implied ratio. See footnote 2.

[8] An earlier analysis of the 1981 and 1991 census data also cautioned against using the single-year sex ratios (Sudha and Rajan, 1998). Instead, the two-year age group, 0-1, was used and the implied sex ratios were found to be 103 and 107 prior to 1981 and 1991 respectively.

[9] Since the SRS estimates are higher than what the census distributions suggest, the correction adjusts these downwards. The fact that the SRS overestimates the SRB means that there is omission of female births (more precisely, a greater omission of female births than male births) by about 2 percent. This also means that the SRS crude birth rate is underestimated, and by implication so is the number of sex-selective abortions. But this effect is quite small.

[10] The expected numbers of female births have been computed by Jha *et al*. (2006) for the end-points of the range 950-975 of female to male ratios at birth as:

for female to male ratios at birth of 950 (NSRB = 105.3)

EFB = LB *100/(100+NSRB) = 28.0 *100/ (205.3) = 13.64 million (rounded to 13.6),

and since actual number of female births is 13.1 million, a deficit of 0.54 million, given as 0.59 million in the paper (ignoring male excess at some sex compositions and rounding off),

and for female to male ratios at birth of 975 (NSRB of 102.6)

EFB = LB* 100/ (100+NSRB) = 28.0 * 100/ (202.6) = 13.82 million (rounded to 13.8),

and since the number of female births is 13.1 million, a deficit of 0.72 million, given as 0.74 million in the paper (ignoring male excess at some sex compositions and rounding off).

[11] This can be seen by verification.

Since LB = 25,926,570 (as noted in the paper) and the observed SRB is 106.9, we get

MB = LB * SRB/ (SRB + 100) = 25,926,570 * (106.9/206.9) = 13,395,603, and

FB = LB – MB = 25,926,570 – 13, 395,603 = 12,530,967,

and since the estimated value of SSA = 117,000,

EFB = FB + SSA = 12,530,967 + 117,000 = 12,647,967.

Then, we must have, in the absence of sex-selective abortions

NSRB = 100 * MB / EFB = 100 * 13,395,603/ 12,647,967 = 105.9.

Note that this is not 105 as assumed in the computations.

[12] Note that expected female live births in the absence of sex-selective abortions assuming a normal sex ratio of birth (NSRB) of 105 is given by

EFB = MB* 100 /NSRB = 13,395,603 * 100 / (105) = 12,757,717,

and hence, the number of sex-selective abortions is

SSA = EFB – FB = 12,757,717 – 12,530,967 = 226, 750.