How Many More Missing Women? Excess Female Mortality and Prenatal Sex Selection, 1970–2050

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In a widely cited 1990 article, Amartya Sen examined the high ratios of males to females in a number of societies and estimated that "over 100 million women were missing" worldwide (Sen 1990).[1] He concluded that "these numbers tell us, quietly, a terrible story of inequality and neglect leading to the excess mortality of females." This finding is consistent with previous studies identifying elevated mortality among girls and women as the main cause of skewed sex ratios in the populations of several Asian countries (Coale and Banister 1994; Visaria 1971; Das Gupta 1987; D'Souza and Chen 1980). The higher female mortality in these societies is attributable to an entrenched preference for sons over daughters and to gender discrimination affecting females throughout their lives. Parents prefer male children for a host of reasons. Sons perpetuate the patrilineage, have greater earnings potential, provide protection and old-age security, do not incur high dowry costs, and are needed in funerary rituals (Croll 2000).

Sen's article focused on excess mortality among females; it did not mention prenatal sex selection. This is not surprising since for most of human history the sex ratio at birth (SRB) remained nearly stable around a natural level of 105–106 males per 100 female newborns, with only a few known variations among ethnic groups. The main reason for this normal SRB in the past, even in countries with strong son preference, was the lack of effective technologies to influence the sex of births, such as sex-selective abortion and preconception genetic diagnosis. Over recent decades, however, prenatal sex diagnosis and access to sex-selective abortion have become increasingly available and, as a result, sex ratios have risen to more than 115 in a number of Asian countries and in Eastern Europe (Attané and Guilmoto 2007; Bongaarts 2013; Das Gupta et al. 2003; Guilmoto 2012; Hudson and den Boer 2004).

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Today's worldwide number of "missing women"—females who would be alive in the absence of sex discrimination—is therefore the result of a combination of prenatal sex selection and postnatal excess mortality. Both phenomena contribute to the recent rise in the number of missing females in many countries. This trend reflects the adverse impact of gender inequity and has led to widespread concern among human rights advocates, researchers, and policymakers (WHO 2011; Watts and Zimmerman 2002).

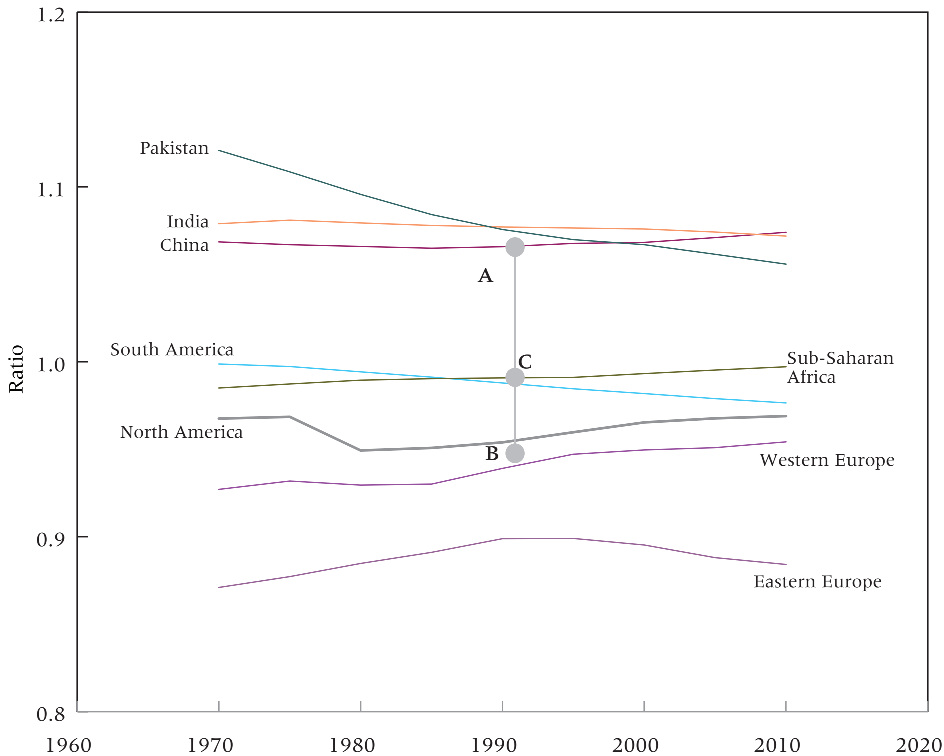
This study presents new estimates of trends in the number of missing females over the last 40 years and makes projections from 2010 to 2050. We also decompose this trend into the contributions made by prenatal and postnatal factors. The concluding sections discuss the implications of our findings for the future level and impact of excess mortality and prenatal sex selection on the female deficit in various countries.

Past estimates of missing females

The ratio of males to females (i.e., the population sex ratio, PSR) varies substantially among regions and countries. As shown in Figure 1, regional populations fall loosely into two clusters with an additional regional outlier. The first cluster consists of China, India, and Pakistan and a limited number of other countries with ratios of males to females well above 1. The second cluster contains sub-Saharan Africa, South America, North America, and Western Europe, with ratios near or slightly below 1. Eastern Europe is the outlier with levels below 0.9. Over time, these ratios have remained fairly constant, although India's PSR has declined significantly and Western Europe and sub-Saharan Africa have experienced slight increases.

Sen (1990) argued persuasively that the elevated sex ratios in several Asian countries were the result of discrimination against girls and women. The difference between the high ratios in these countries and the ratios in the more developed world (which is largely free of such discrimination) provides a simple indicator of the degree of gender discrimination. For example, Sen calculated that China had an 11 percent shortfall of females in 1990 (compare points A and B in Figure 1). Once this shortfall has been determined, the number of missing females is estimated as the number that would have to be added to the existing population of females in order to eliminate this shortfall. In China, the 1990 female population is estimated at 564 million. This number would have to rise to 634 million (564/(1 – 0.11)) to make the sex ratio equal to the one observed in discrimination-free societies of the developed world. The number of missing females in China therefore equaled 70 million (i.e., 634 – 564). This number, combined with similar calculations in South Asia, West Asia, and North Africa, yielded "a great many more than 100 million" missing females in 1990 (Sen 1990).

FIGURE 1 Population sex ratio, selected countries and regions, 1970–2010



SOURCE: Computed by the authors from United Nations (2013a).

Sen initially ignored the effect of the population age structure on the overall PSR of individual countries. But age-specific population sex ratios tend to decline with age because of the female mortality advantage over males at most ages. While the sex ratio of children is usually above 100—reflecting the high sex ratio at birth—the sex ratio of the population declines to below 100 among older adults and the elderly. As a result, in the absence of discrimination the PSR of older populations (e.g., in Europe) is lower than that of younger populations (e.g., in the developing world).

In 1992, Sen revised his estimates in response to a critique by Ansley Coale. Coale (1991) argued that the sex ratio of the developed world was an inappropriate standard for measuring deficits of females in Asia and elsewhere. He agreed that populations in the developed world have little or no gender discrimination, but noted that they were older than populations in the developing world and that this fact reduced their PSR. In addition, parts of the developed world had deficits of men due to the excess male casualties of the two world wars. To address these issues, Sen (1992) dropped the developed world as the reference population and replaced it with sub-Saharan Africa (i.e., he compared points A and C in Figure 1). This change led to a lower number of missing females—44 million for China and 37 million for India—but the world total remained more than 100 million.

Following Sen's original contributions, a number of studies proposed various methodological revisions and innovations. These have resulted in a wide range of estimates of missing females, as shown in Table 1. The estimated numbers of missing females confirm the magnitude of the phenomenon, but variations among these estimates preclude firm conclusions about exact levels and trends. The differences between these estimates are largely the result of alternative estimation procedures used by the various authors. One of the most critical differences among these studies is the reference population used to calculate deficits of females. While Coale used the West model stable populations, Klasen preferred the East model and made allowance for normal variations in SRB levels (Coale 1991; Klasen 1994; Klasen and Wink 2002, 2003). In contrast, Guilmoto (2012) used observed population age distributions in countries without gender discrimination as the reference and computed missing females by age group.[2] Studies that estimate only the annual incidence of missing female births and excess female mortality do not provide comparable figures of missing females. These estimates will be examined in the next section.

These earlier analyses have yielded considerable new insights, and there is now general agreement that Sen's original method can be improved by taking into account three types of differences between populations: age structure, the natural sex ratio at birth, and mortality level.

Age structure. As noted earlier, in the absence of discrimination against females the population sex ratio varies among populations because of differences in the population age structure. To illustrate this age effect, Figure 2 plots age-standardized sex ratios for selected populations using the 2010 world population as standard. Comparison between Figures 1 and 2 shows,

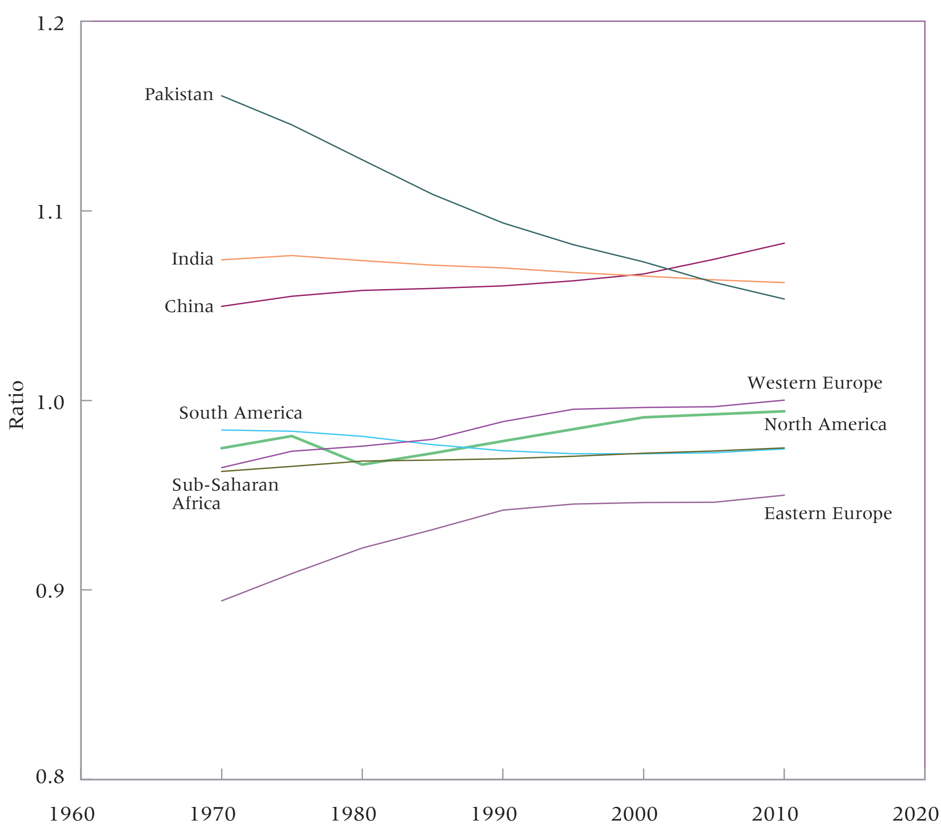
TABLE 1 Previous estimates of the global number of missing females

Author	Number (millions)	Reference year
Sen (1989, 1990)	>>100	1990
Coale (1991)	60	1990
Sen (1992)	>100	1990
Klasen (1994)	92	1990
Klasen and Wink (2002)	102	1990s
Klasen and Wink (2003)	101	ca. 2000
Guilmoto (2012)	117	2010

for instance, that the sex ratios of China, North America, and Europe are rising after standardization. The difference between the first cluster with India, China, and Pakistan and the second cluster with other countries is even more evident in Figure 2 than in Figure 1.

Natural sex ratio at birth. Sen (1990, 1992) and Coale (1991) assumed the sex ratio at birth to be the same in all populations. Although reliable vital registration data are lacking, Klasen (1994) concluded that this is not an accurate assumption. In particular, populations of sub-Saharan African origin tend to have a lower natural sex ratio at birth. SRB values close to 1.03 are commonly observed in African populations with reasonably good birth registration such as South Africa or among the African-American population in the United States. In contrast, the rest of the world has natural ratios of 1.05–1.06. This finding implies that the use of sub-Saharan Africa as the reference population in Sen (1992) yields an overestimate of missing females.

FIGURE 2 Age-standardized population sex ratio, selected countries and regions, 1970–2010



SOURCE: Computed by the authors from United Nations (2013a).

Level of mortality. Sen (1990, 1992) assumed that populations without gender discrimination have a fixed sex ratio. Subsequent research indicates that both population sex ratios and mortality differentials by sex vary by mortality level. In particular, as shown by Alkema et al. (2014) and UN (2011) and confirmed in our analysis, sex ratios of mortality at younger ages in the absence of sex discrimination are positively related to life expectancy.

New methods for estimating missing females should take these three issues into account to avoid methodological biases.

New estimates of missing females

To estimate trends in the number of missing females in a population without bias, it is essential to apply a single method to data for successive years. This method should also address the three issues noted above: the effect of age structure, existing variations in natural SRB levels, and the impact of the overall mortality level. For the present study, we rely on a refinement of Guilmoto's (2012) approach for missing females and develop new methods to estimate excess female deaths and unborn girls. This approach relies on Sen's principle of comparing observed indicators (which may be affected by gender discrimination) with reference or expected values (in the absence of discrimination).[3] Observed values of the SRB and of population and mortality by sex are taken directly from the United Nations 2012 revision (UN 2013a). Expected values are estimated by taking into account differentials by age, region, and mortality level (see Appendix 1 for details). By subtracting expected from observed values, we estimate three indicators: 1) missing females by country, age, and year, 2) excess female deaths by country, age, and period, and 3) missing births by country and period.

Table 2 presents our estimates of the number of missing females worldwide and in the countries and regions with the largest contribution to the global total from 1970 to 2010 (detailed results in Appendix 2). During this period, the world total has risen steadily from 61 million to 126 million and is still rising in 2010. Because female populations have also grown in size, the proportion of missing females in the world has increased only modestly from 3.3 percent to 3.7 percent during the last 40 years.

The relative contribution of different countries to the recent global number of missing females is comparable to previous estimates by Klasen and Wink (2003) and Guilmoto (2012), but we now have detailed time-series estimates since 1970. China and India have by far the largest number of missing girls in 2010 (62 million and 43 million respectively) and they account for 84 percent of the world total. This is the result of their large population sizes and high proportions missing: 9.5 percent in China and 7.4 percent in India. Forty years earlier, however, India had a larger proportion missing than China. Since 1970, the proportion missing increased in China (from 6.9 percent to 9.5 percent), especially after 1990 when the sex ratio at birth started

TABLE 2 New estimates of the number and percent of missing females in selected populations, 1970–2010

	Number missing (in millions)					Percent missing	
	1970	1980	1990	2000	2010	1970	2010
World	61.0	72.2	87.6	105.9	125.6	3.3	3.7
China	27.2	31.8	39.2	49.5	62.3	6.9	9.5
India	21.8	27.1	33.2	38.9	43.3	8.2	7.4
Pakistan	3.5	3.7	4.0	4.4	4.4	12.5	5.2
Bangladesh	2.3	2.9	4.0	4.2	2.4	7.2	3.2
Nigeria	0.2	0.6	1.1	1.4	1.9	0.6	2.5
Indonesia	0.0	0.0	0.0	0.1	1.7	0.0	1.5
Rest of the world	6.1	6.1	6.2	7.4	9.6	0.5	0.5

SOURCE: Computed by the authors. Estimation method described in Appendix I.

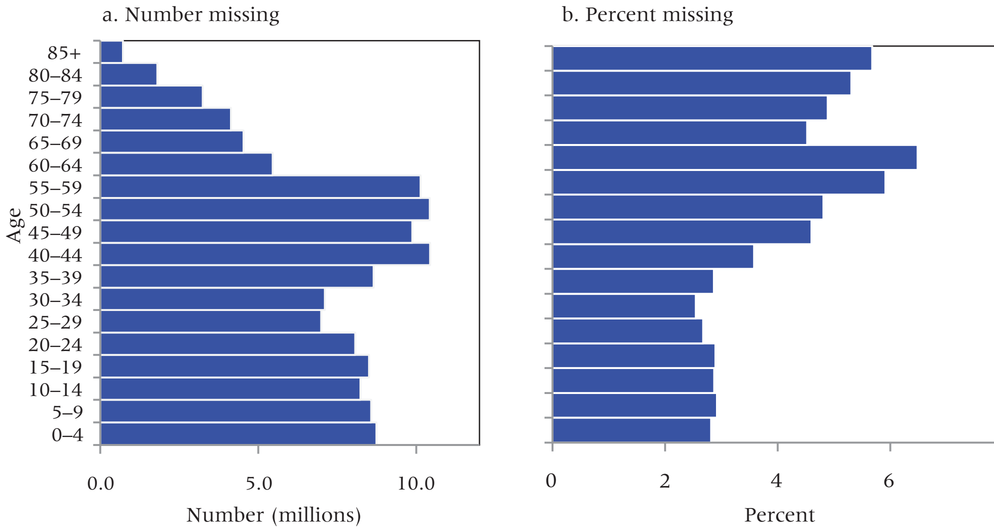
rising. In contrast, the percentage of missing females in India has declined slightly (from 8.2 percent to 7.4 percent) according to our estimates. The roles of excess female mortality and sex imbalances at birth in determining these trends will be discussed below.

The contribution of other countries to the global total of missing females is an order of magnitude smaller. The estimate for Pakistan is 4.4 million. The proportion missing in this country (5.2 percent) is rather high, but it has decreased over time. In the absence of a census since 1998 and of reliable civil registration, Pakistan's figures should be treated with caution. Bangladesh and Indonesia are two other Muslim countries in Asia with significant numbers of missing females, but neither of them has confirmed sex imbalances at birth.

The geographical clustering of missing females is pronounced, with South and East Asia emerging as regions with a clear excess of males in their populations. Countries of Southeast Europe and South Caucasus also have substantial excesses of males in younger cohorts because of prenatal sex selection since the 1990s (Guilmoto and Duthé 2013), but our estimates are limited to larger countries. The only major country outside Asia found in our list is Nigeria, where the number of missing females has significantly increased since 1970 and is now close to 2 million. Population estimates in Nigeria are based on the 2006 census, which showed a large excess of males among the population aged 5–14 years.[4] In addition, female mortality below 5 years is unexpectedly high in Nigeria according to DHS estimates, and recent studies have documented the presence of tangible son preference among mothers (Milazo 2014; Ohagwu et al. 2014).

Comparisons between observed and expected age distributions of females allow the estimation of the age pyramid of missing females for every year. Figure 3 shows the age distribution of the number and percent of missing females for the world in 2010. Clearly, females are missing in large numbers in all age groups below 60 years. The largest number of missing females

FIGURE 3 Age distribution of missing females, world 2010



SOURCE: Computed by the authors from United Nations (2013a).

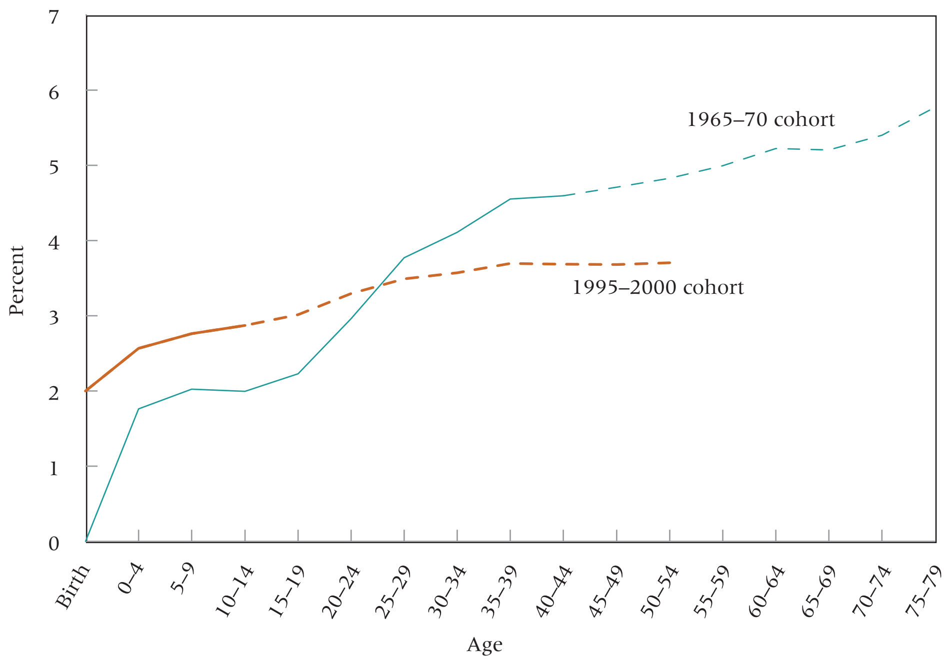
is now found in the age groups 40–59. In each of these four five-year age groups, the gender gap is about 10 million females. The deficit in younger cohorts born during the last 25 years is slightly smaller, ranging from 8.1 to 8.7 million. The proportion missing is around 2.5 to 3 percent until age 40 and then rises, with a peak above 6 percent in age group 55–59.

Interpretation of these age distributions is not straightforward since they reflect the cumulative past effects of both prenatal and postnatal discrimination on different birth cohorts. This issue can be analyzed in more detail by following birth cohorts over time and examining the period conditions that affect the cohorts at different ages.

Figure 4 illustrates this approach by plotting the rising proportion of females missing against age for two distinct birth cohorts. The first cohort consists of all females born in 1965–70 in the world and aged 0–4 years in 1970. This cohort is aged 40–44 years in 2010. Beyond this date, UN projections (dashed lines) are used up to 2050 when the birth cohort reaches 75–79 years.

At the time of its birth, the 1965–70 cohort was not yet affected by prenatal sex selection, but female infanticide was still common in parts of the world. The first major jump in the proportion missing therefore occurs immediately after birth, and excess mortality among infant and young girls creates a deficit of 2 percent of the entire birth cohort by age 10. Another increase in the proportion of missing females is observed from age 15 to 39, with the proportion rising from 2 percent to 4 percent as a result of maternal mortality during the childbearing years. The projection beyond age 45 predicts further attrition among older adult females. By the time these

FIGURE 4 Percent of missing females in the world by age in the birth cohorts of 1965–70 and 1995–2000



SOURCE: Computed by the authors from United Nations (2013a).

females reach age 80, excess mortality since birth has eliminated more than 5 percent of this cohort.

The second birth cohort plotted in Figure 4 consists of all females born in 1995–2000. This group is aged 10–14 years in 2010, and UN projections again complete the series up to 2050 when the cohort reaches 50–54 years. This cohort's proportion of missing females at birth starts at 2 percent rather than at zero for the earlier cohort. The reason for this difference is the substantial level of sex-selective abortion that was practiced in the late 1990s. However, after birth the rise in the proportion missing by age occurs at a slower pace than for the earlier cohort. This reflects the lower excess mortality in the more recent cohort.

These findings suggest that younger cohorts in 2010 have experienced less excess mortality, but also more prenatal sex selection. The next section examines these trends in more detail.

The roles of prenatal and postnatal gender discrimination in the sex imbalance

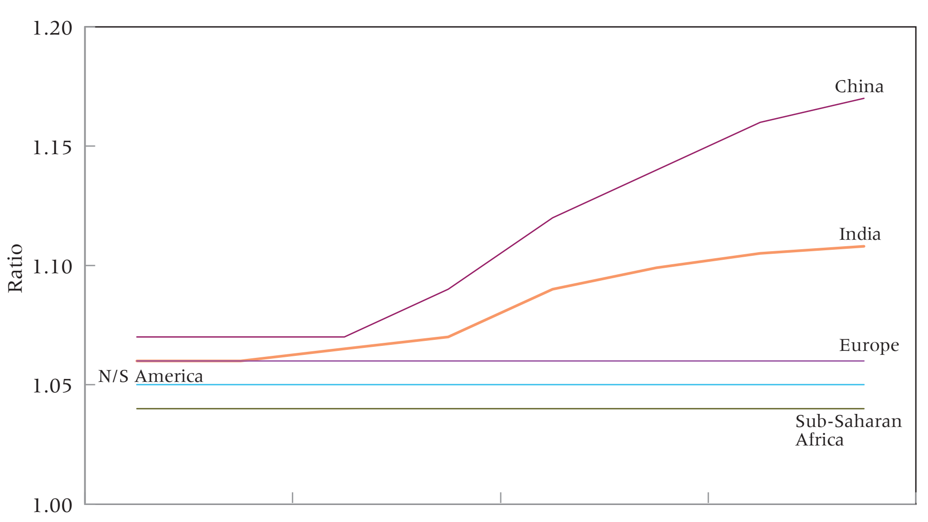
Any attempt to explain levels and trends in the sex ratios of populations and in the number of missing females requires an understanding of the two distinct phenomena—prenatal and postnatal gender discrimination—that are responsible for the loss of females. Our new estimates of missing female births and excess female mortality allow for a further analysis of the role played by these two phenomena in determining the overall number of missing females.

Prenatal sex selection

The sex ratio at birth has risen in recent decades in a substantial number of countries. An extensive literature documents these trends and discusses the determinants and consequences of this occurrence (Guilmoto 2012). An elevated SRB indicates that parents are relying on sex-selective abortion to alter the gender composition of their offspring. Sex-selective abortion is therefore a key cause of missing females.

Figure 5 plots sex ratios at birth for selected populations as estimated by the United Nations. For a large number of countries or regions, the UN's SRB estimates are rounded off to 1.04, 1.05, or 1.06, reflecting a lack of trustworthy sources of the exact level of birth masculinity. The SRBs are also assumed to be stable over the last four decades in most countries. This is a reasonable assumption because in the few countries with reliable vital registration and no significant sex selection of births, fluctuations in SRBs over the years have been modest (Chahnazarian 1988; Grech, Vassallo-Agius, and Savona-

FIGURE 5 Sex ratio at birth, selected countries and regions, 1970–2010



SOURCE: Computed by the authors from United Nations (2013a).

Ventura 2003). For purposes of calculating missing births, we assume below that sex-selective abortion was not practiced until 1980 and that any increase in the SRB after 1980 is the result of sex-selective abortion.

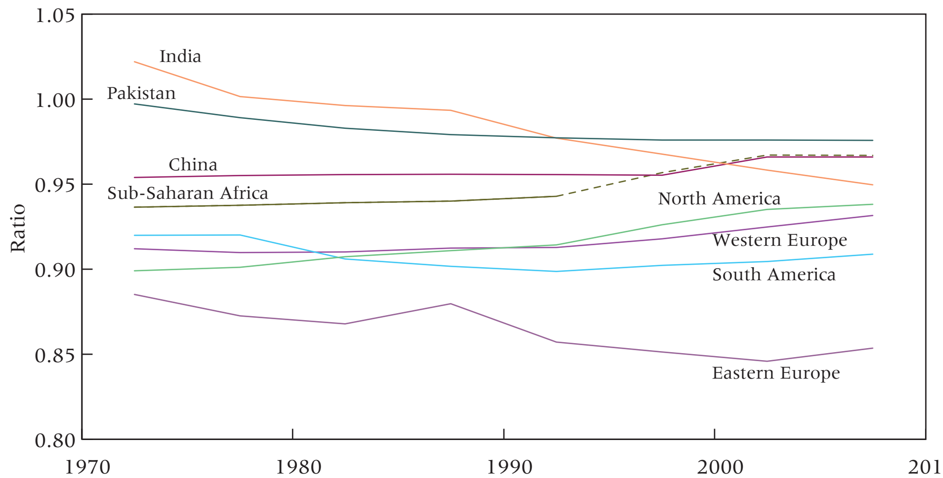
As is evident from Figure 5, a sharp rise in birth masculinity occurred after 1980 when sex-selective abortions became feasible. SRB increases are largest in China and India. Birth masculinity has continued to increase in China and India until the last decade, reaching levels as high as 1.18 in China and 1.11 in India.[5] According to national estimates, the SRB has plateaued since 2005 or even decreased slightly in both China and India, but a possible downturn is not yet reflected in the UN figures (Das Gupta, Chung, and Li 2009). The next largest population with confirmed prenatal sex selection is Vietnam, where the SRB is estimated at 1.12 in 2014. South Korea also reached high SRB levels in the 1990s, but it is the only country in which a sustained downturn in the SRB has been well documented in the past decades.

Sex differences in mortality

Excess mortality among females is often difficult to estimate for want of reliable age- and sex-specific mortality rates in many developing countries. Efforts have mainly focused on sex differentials among children (Sawyer 2012; Alkema et al. 2014; United Nations 2011), but some studies examine a wider age range of mortality as well as causes of death (Anderson and Ray 2010; World Bank 2012). To assess the mortality impact of gender discrimination, we first compare the life expectancy at birth of males and females as estimated by the UN. Figure 6 plots the sex ratio of (male to female) life expectancy (SRLE) for selected countries and regions from 1970 to 2010. The large majority of contemporary populations have SRLEs below 1. This is due to a biological advantage of females over males that results in an excess of male over female mortality at all or nearly all ages in populations that do not practice gender discrimination. The natural level of the SRLE is not easily estimated, in part because it varies somewhat among countries. Coale (1991) examined this issue using model life tables and found that the SRLE varies within a narrow range from 0.924 to 0.946 in these tables as life expectancy rose from 40 to 75 years. This finding suggests that ratios above 0.94 may be caused by discrimination leading to excess female mortality.

The levels and trends for the SRLE plotted in Figure 6 show wide variation among countries. Interestingly, populations loosely cluster in groups similar to those in Figures 1 and 2. There is a cluster of countries with elevated ratios (e.g., China, India, and Pakistan), which is likely the result of gender discrimination. The second cluster consists of the Americas and Western Europe, where gender discrimination is largely absent with SRLE values between 0.90 and 0.94. The outlier is again Eastern Europe with very low ratios. The positive correlation between the SRLE (Figure 6) and the PSR

FIGURE 6 Ratio of male to female life expectancy, selected countries and regions, 1970–75 to 2005–10



SOURCE: Computed by the authors from United Nations (2013a).

(Figures 1 and 2) is to be expected because elevated mortality among females is a key cause of elevated population sex ratios.

The findings for sub-Saharan Africa in Figure 6 seem at first puzzling, because this region's SRLE falls between the two main clusters until 1990, indicating slightly elevated mortality among females. This is in contrast to the evidence in Figure 1, where this region shows no elevated population sex ratio. The most plausible explanation for this finding is that sub-Saharan Africa has a relatively low natural sex ratio at birth (as shown in Figure 5). The normal population sex ratio observed in Figure 1 therefore appears to be the net result of two offsetting forces: a slightly elevated SRLE (shown in Figure 6) and a relatively low natural SRB. A second puzzle in sub-Saharan Africa is the rise in the SRLE after 1990 to levels found in China, India, and Pakistan (see the dashed part of the line in Figure 6). An examination of country trends revealed that increases in SRLEs after 1990 are found almost exclusively in countries with a large AIDS epidemic. These findings are consistent with earlier studies by Anderson and Ray (2010) and World Bank (2012) that provided similar explanations.

The SRLE can also be affected by unhealthy behaviors, in particular smoking, alcohol abuse, and violence, provided these behaviors differ by sex. The very low level of the SRLE in Eastern Europe is a clear example of this. High levels of unhealthy behaviors in this region, particularly among males, have been well documented (Eberstadt and Shah 2009; Meslé and Vallin 2002; Meslé 2004; Murphy 2011; Oksuzyan et al. 2014). The slight increases in the SRLE in North America and Western Europe after 1990 are probably the result of differences between males and females in smoking. In particular, male smoking mortality declined after the 1980s following declines in smoking starting in the 1960s and 1970s. In contrast, female smoking-attributable mortality rose throughout the 1990s and 2000s (Bongaarts 2014). These gender-differentiated patterns of the smoking epidemic led to a rising SRLE in regions where gender discrimination is low. Another possible explanation for the rise in the most developed countries is that the expected gap between male and female survival rates diminishes as countries reach high levels of life expectancy.

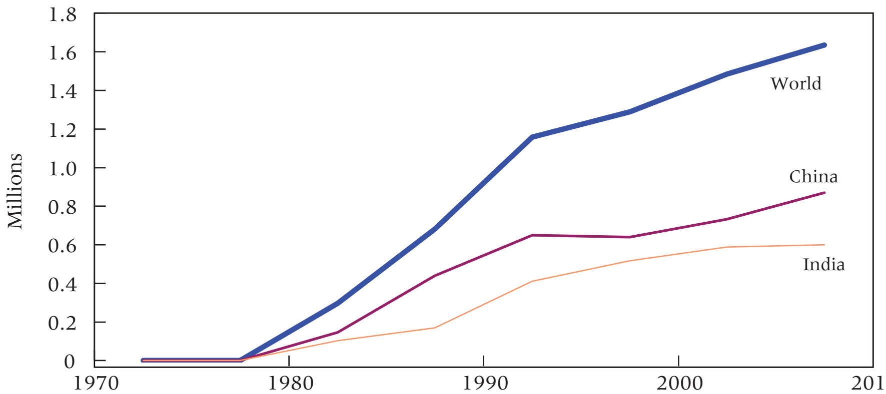
Missing females: prenatal and postnatal factors

The preceding discussion identified the pre- and postnatal discrimination processes that cause females to become missing. While often discussed together as manifestations of gender inequity, these processes are associated with different social practices and have distinct demographic implications. An additional important question is whether they substitute for or reinforce each other (Goodkind 1996). We now examine how much each of these processes contributes to the overall counts of missing females. The two indicators of gender discrimination (SRB and SRLE) are converted into the corresponding numbers of missing females to assess their respective influence on the overall deficit of females (detailed results in Appendix 2).

Prenatal discrimination. The annual number of missing girls at birth is calculated as the number of female births that would have to be added to the observed number in order for the sex ratio to return to its normal level. This calculation is straightforward because estimates of the SRB and the numbers of male and female births by year are available from the UN for all countries. We use pre-1980 SRB figures as estimates of the natural SRB levels in each country. Results for the world as well as China and India are plotted in Figure 7. The global annual number of missing female births rose from near zero in the late 1970s to more than one million per year in the period after 1990, reaching 1.6 million per year in 2005–2010. India and China accounted for 90 percent of this total. The cumulative number of females missing at birth between 1980 and 2010 exceeds 30 million.

Postnatal discrimination. In contrast to unborn girls, excess female mortality is an ancient mechanism of discrimination. It is therefore not surprising that the total number of estimated excess female deaths has remained high during 1970–2010, ranging between 1.7 and 2 million deaths per year (see Figure 8). A slight increase from the 1970s led to the peak reached in 1985–89. The number then declined gradually to the late 2000s, in spite of the continuous increase in the female population at risk. This downturn may be associated with the rise of prenatal sex selection during the 1980s, as an increasing proportion of unwanted girls were aborted before birth.[6]

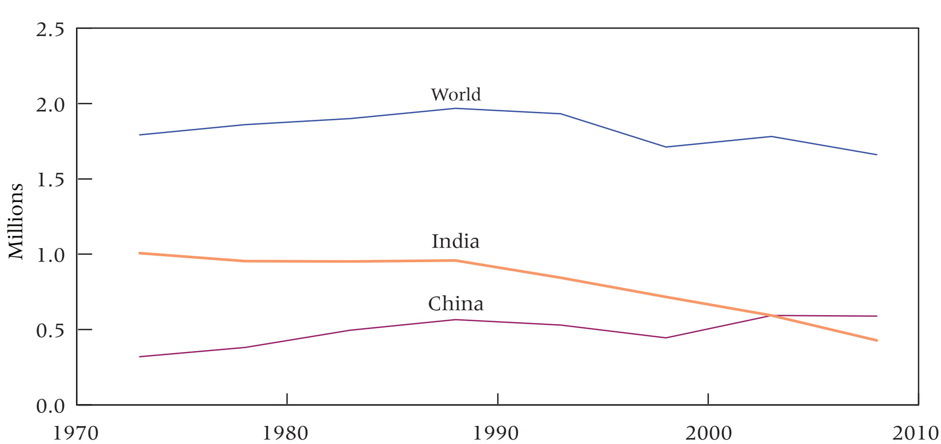
FIGURE 7 Annual number of missing female births, 1970–75 to 2005–10



SOURCE: Computed by the authors from United Nations (2013a).

China and India accounted for 71 percent of all excess female deaths estimated for the period 1970–2010, but this proportion declined between 1970 and 2010 while the combined share of other countries—mostly Bangladesh, Indonesia, Nigeria, and Pakistan—rose over time. In 1970–1975, India's numbers were double those of China, but over the past four decades these two countries have converged to near half a million per year. India is characterized by excess female deaths at younger ages, especially below 5 years. As a result, the decline in India's fertility in recent decades has contributed to the decline in excess deaths. In contrast, the burden of excess female mortality in China points to the primary role of excess mortality above age 30.

FIGURE 8 Annual number of excess female deaths, 1970–75 to 2005–10



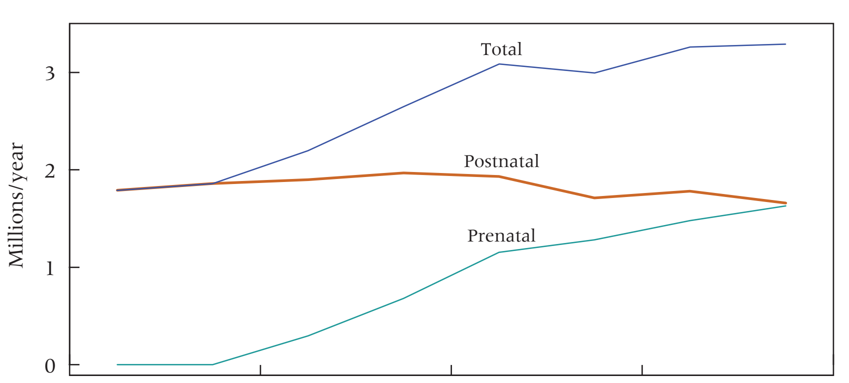
SOURCE: Computed by the authors from United Nations (2013a).

New missing females. Estimates of the total annual number of newly missing females are obtained by adding the annual numbers missing before and after birth for each period since 1970. As shown in Figure 9, this total rose from less than 2 million in the late 1970s to well over 3 million after 1990 and reached 3.3 million per year during 2005–2010.[7] This increase in the number of new missing females after 1980 is primarily due to the introduction of prenatal sex selection and the rise in the sex ratio at birth that resulted. In most years since 1970, many more females have gone missing after than before birth, but the difference has narrowed over time, with the number of missing female births now equivalent to the number of excess female deaths.

Consistency of estimates. The three series of data discussed above are obtained with different estimation procedures. Missing females are deduced from age-specific population sex ratios, missing female births from SRB levels, and excess female deaths from mortality rates by sex. To conclude this section, we attempt to reconcile the annual estimates of missing deaths and births in Figure 9 (flows) with the total number of missing females in Figure 1 (stocks). This comparison is not straightforward because missing females are counted regardless of when in the past or at which age they went missing. That is, a woman counted as missing in 2010 at, say, age 25 could have been the result of a sex-selective abortion in 1985, or she could have died from inferior treatment or neglect at any age since she was born.

As a first step in this reconciliation process, we compare the number of missing females in 2010 (126 million) with that in 1970 (61 million). The increase of 65 million between 1970 and 2010 should be attributable to prenatal sex selection and excess female mortality during these four decades. The cumulative number of newly missing females during 1970–2010 includes 35

FIGURE 9 Annual number of newly missing females, 1970–75 to 2005–10



SOURCE: Computed by the authors from United Nations (2013a).

million missing births and 72 million excess female deaths. But this total of 108 million is clearly larger than the observed increase of 65 million in missing females during the same period. This apparent discrepancy is explained by attrition affecting all these numbers over the years. Missing females can be counted as missing only for finite periods, and their number shrinks over the years unless new additions are made. This confounding factor can be estimated by modeling missing females, missing female births, and excess female deaths exactly as one would model any population subject to attrition through mortality according to its age structure.[8]

Our estimate of attrition of missing females is 48 million between 1970 and 2010. Adding the 108 million missing births and excess deaths to the 61 million missing females in 1970 and subtracting 48 million for attrition yields an estimate of 121 million missing females in 2010. The gap between this indirect estimate and the earlier direct estimate of 126 million is rather modest. This exercise therefore demonstrates a large degree of consistency between, on one side, the number of missing females at various dates and, on the other, the number of excess female deaths and the number of missing female births.

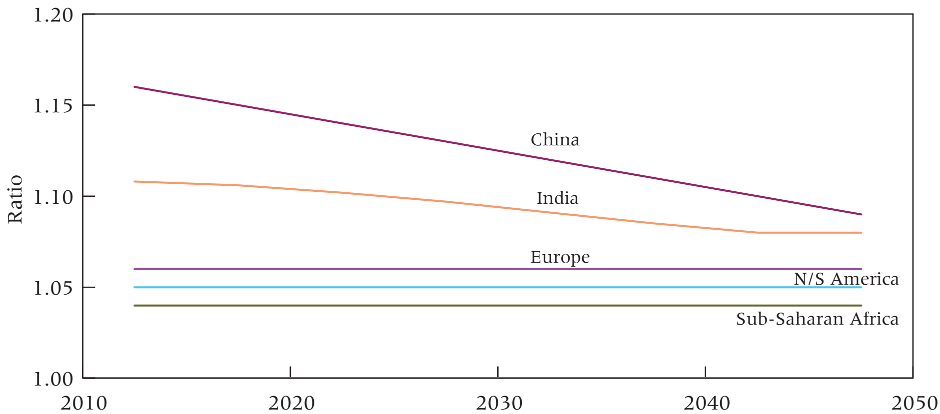
How many more missing females?

To assess future trends in the number of missing females, we rely on the medium-variant population projections of the United Nations (2013a). For the moment, we simply accept the UN assumptions made for future demographic trends and will comment later on their plausibility.

Prenatal sex selection. In 2010, prenatal sex selection had a role comparable to that of excess mortality in demographic sex imbalances. Consequently, the evolution of the SRB is of major importance to the number of missing females in the future. There are now early signs of a stabilization or perhaps even a decrease in the SRB in China and India, but it is difficult to predict the pace of decline in these two countries in the future (Das Gupta, Chung, and Li 2009). South Korea provides the only case of the SRB returning to normal, and the decline took less than two decades. In contrast, the United Nations postulates a slower rate of decline in China and India as shown in Figure 10. In particular, China's SRB is assumed to decline linearly after 2010, but to remain elevated at least until 2050 when it reaches 1.09. For India a broadly similar slow decline is expected but at a slower pace to reach 1.08 in 2050. These estimates may appear pessimistic, but it would probably be even less reasonable to assume that SRB levels will remain at their current skewed level for several more decades.

Excess female mortality. Figure 11 plots the projected trend in the male–female ratio of life expectancy. In general, trends converge slowly from their 2010 levels to the natural level of about 0.94. A key exception is China, which remains elevated at 0.97. This assumption will have major consequences for

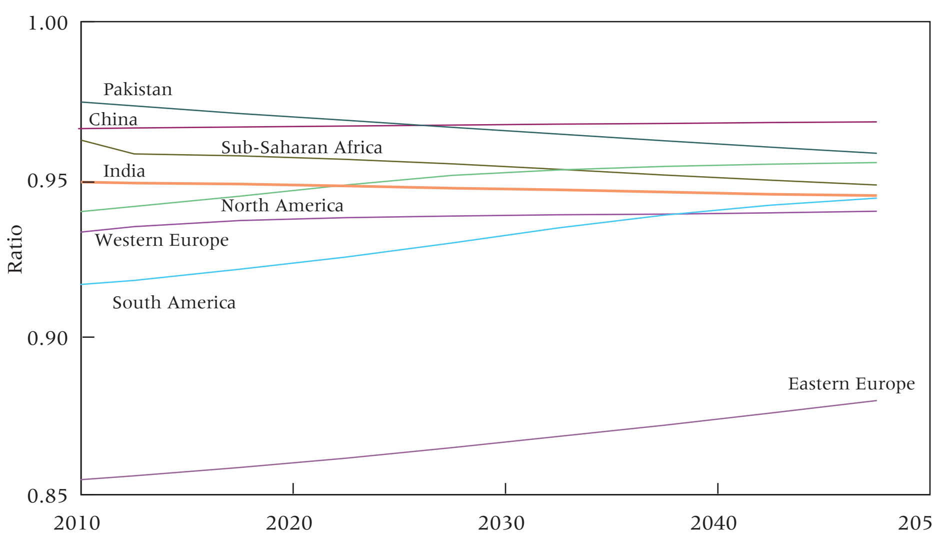
FIGURE 10 Projected sex ratio at birth, selected countries and regions, 2010–15 to 2045–50



SOURCE: Computed by the authors from United Nations (2013a).

the predicted number of excess female deaths in the coming decades. Surprisingly, the projection for North America moves from normal in 2010 to slightly elevated in 2050. It is unclear why this is the case, but it may be an outcome of a projection method that extrapolates the rising past trend in the SRLE in North America (see Figure 6), without adequately taking into account the temporary distorting role of smoking (see Bongaarts 2014 for further details).

FIGURE 11 Projected male–female ratio in life expectancy, selected countries and regions, 2010–15 to 2045–50

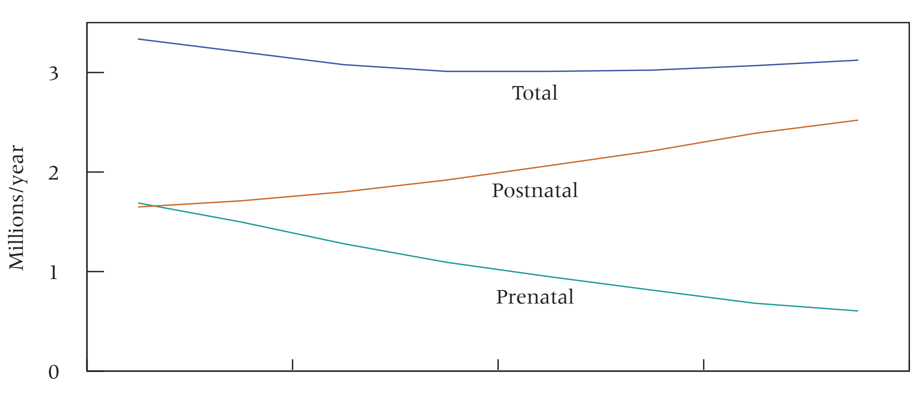


SOURCE: Computed by the authors from United Nations (2013a).

Missing females. The total annual numbers of newly missing females attributable to elevated sex ratios at birth and excess mortality are presented in Figure 12 (detailed results in Appendix 2). The decline in SRBs assumed everywhere by the United Nation translates into substantial declines in the number of missing female births, falling from 1.7 million to 0.6 million per year between 2010 and 2050. In contrast, the number of excess deaths rises substantially. Because of these opposite trends, the overall number of newly missing females remains more or less constant over time at around 3 million. This finding is likely attributable in part to the rapid aging of populations everywhere, but China takes a major role in this increase because of the pessimistic assumption of persistent excess female mortality.

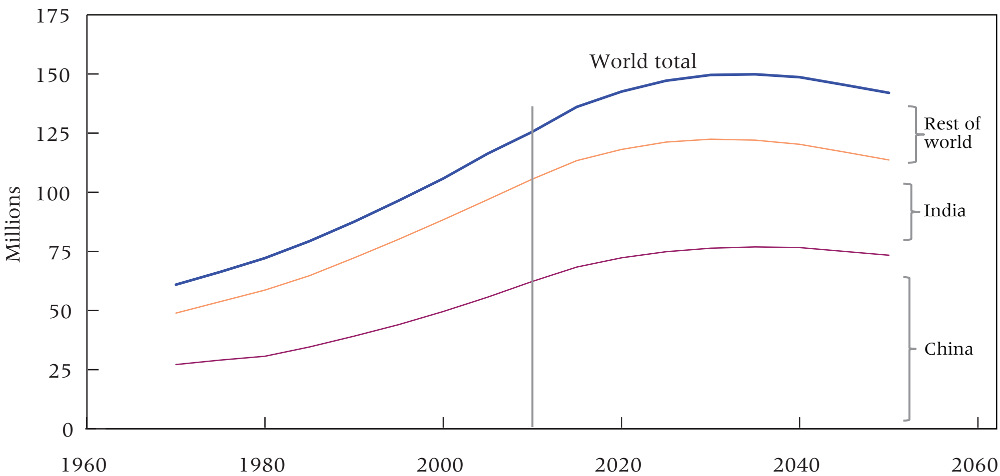
The total number of missing females worldwide is projected to grow from 126 million in 2010 to a maximum of 150 million in 2035 before declining slowly to 142 million in 2050.[9] As Figure 13 demonstrates, this post-2010 increase is largely caused by the parallel rise in the number of missing females in China, expected to increase from 62 million in 2010 to 77 million in 2035. In contrast, India's contribution to the overall deficit of females is forecast to decline from 34 percent today to 28 percent in 2050.[10] This evolution is mostly driven by assumptions related to mortality trends in China. In spite of China's rapid progress in longevity, the assumed persistence of a relative female disadvantage will lead to a rise in the number of excess female deaths in China from 0.6 million per year in 2010 to 1 million in 2050. A majority of these excess deaths are among females above age 40, contrary to what was observed in India or sub-Saharan Africa where mortality among children and young adults plays a larger role.

FIGURE 12 Projected annual number of newly missing females worldwide, 2010–15 to 2045–50



SOURCE: Computed by the authors from United Nations (2013a).

FIGURE 13 Estimated and projected number of missing females, 1970–2050



SOURCE: Computed by the authors from United Nations (2013a).

Discussion

Our main findings are that the global number of missing females has risen continuously since 1970 and that it is expected to rise further in the coming two decades. The number grew from 61 million in 1970 to 126 million in 2010 and is expected to peak at 150 million in 2035 before declining to 142 million by mid-century.

The two driving forces of this formidable increase are prenatal sex selection and postnatal excess mortality. Prenatal sex selection is a relatively new practice that grew rapidly after 1990 when access to inexpensive and reliable ultrasound to determine the sex of the fetus allowed couples to resort to sex-selective abortions. The highest rates of prenatal selection are found in countries such as Armenia, Azerbaijan, China, India, and Vietnam with 1) strong son preference, 2) ready access to prenatal diagnosis, and 3) low fertility (Guilmoto 2009). All three of these conditions have to be present for prenatal sex selection to reach significant levels. Son preference alone is not enough. For example, sex ratios at birth are near normal in some Asian countries (e.g., Afghanistan) or Indian states (e.g., Bihar and Uttar Pradesh), despite strong son preferences. The main reason is the lack of access to sex-selective abortions or high fertility (Bongaarts 2013).

For future decades, the UN projects the sex ratio at birth to decline, thus making 2005–2015 the peak period for prenatal sex selection. In this study, we have followed the UN projections, but we emphasize that the actual future trends could be higher or lower in aggregate and will likely differ substantially from current projections in a number of countries. Projections of future sex ratios at birth are difficult to make because they are affected by a number of factors, such as access to technology, wider availability of medical abortion, fertility decline, and reductions in son preference occasioned by social development, greater equity, and laws prohibiting sex selection. While it is probably correct to predict an overall future decline of birth masculinity, there will likely also be countries with future increases in sex-selective abortion in or outside Asia and Eastern Europe. The potential for rising SRBs exists in parts of Africa where elevated life expectancy ratios point to latent son preference. In addition, desired sex ratios at birth measured in DHS surveys show elevated SRBs in Chad, DRC, Ethiopia, Ghana, Guinea, Mali, Mauritania, Niger, Nigeria, Rwanda, and Senegal (Bongaarts 2013).

Excess female mortality has historically been the primary cause of missing females and has remained so until today, despite the mounting impact of prenatal sex selection. In 2010, the impact of excess mortality remains considerable and is equivalent to the impact of prenatal sex selection. The toll of excess mortality has not declined significantly in absolute numbers over recent decades, staying close to 2 million female deaths per year between 1970 and 2010. This stabilization is due to a general decline in mortality levels—resulting in a lower absolute impact on excess deaths—combined with the compensating rise in excess deaths from a growing population of females. Excess female deaths are likely to remain substantial, and our projections to 2050 in fact suggest an increase.

This overview of global trends conceals wide variations among and within countries. We briefly comment on our findings for the largest populations, starting with China which has always been, and is expected to remain, the largest contributor to missing females in the world. Its contribution has increased since 1970, and 50 percent of missing females in the world in 2010 were missing in China. This proportion is expected to remain nearly stable over the next decades. Prenatal sex selection has also played a major role in the size of the gender gap in China. Its SRB started rising in the 1980s and soon became the highest in the world. According to China's official statistics, the SRB was 120 male births per 100 female births during the last decade, and signs of decline are still modest. As a result of sub-replacement fertility, the number of births in China has rapidly diminished, but sex selection in this country still accounts for more than half of the total of unborn girls in the world. Excess female deaths are expected to replace sex selection as the main source of sex imbalances in China during the next decade. The projected global increase in the number of excess female deaths is driven largely by trends in China.

In contrast, the toll of excess female deaths has been declining in India since 1970. This is largely the consequence of a steep decline in overall mortality and in the sex difference in mortality in India from very high levels. Prenatal sex selection has recently emerged as another powerful source of sex imbalances in India, although the rise in birth masculinity was slower and geographically more circumscribed than in China. There are, however, signs of decline in parts of the country (Kumar and Sathyanarayana 2012). SRB declines and further reductions in excess mortality are expected to lead to a sizable decline in the numbers of missing females. By 2050, missing females are expected to represent 5 percent of the female population of India as against 11 percent in China.

Given the dominant demographic weight of China and India, we only briefly examine the situation in the rest of the world. Unsurprisingly, two other countries in South Asia (Pakistan and Bangladesh) where excess female mortality has long been reported appear in Table 2 among countries with more than one million missing females in 2010. There is, however, little prenatal sex selection in these two countries, even if the Pakistan context is poorly documented in the absence of reliable vital statistics and of a recent census. Interestingly, Indonesia also had more than one million missing females in 2010. Its population sex ratio has risen continuously over the last 30 years, and men now outnumber women in the country. When examined more closely, the vast Indonesian archipelago appears to be heterogeneous in terms of gender systems and has distinct pockets of high female mortality and high sex ratios at birth (Guilmoto, forthcoming).

In addition, our estimates point to some lesser-known aspects of the global deficit of females. Sub-Saharan Africa has not been affected by the emergence of prenatal sex selection over recent decades, and its contribution to sex imbalances is often underplayed because the region's low natural sex ratio at birth significantly reduces its population sex ratio. But Nigeria has clearly emerged as a country with an unexpectedly high proportion of males. The number of missing females reached one million in 1990 and was nearing 2 million in 2010. The number is projected to rise to 5.2 million by 2050. The existence of excess female mortality is confirmed in the last DHS rounds, which have shown child mortality to be higher among girls than boys in Nigeria. Similar trends are seen for sub-Saharan Africa as a whole, and, according to our projections, the region will account for more than 10 percent of all excess female deaths in the world from 2015 onward. This expectation is supported by other studies (Klasen and Wink 2003; World Bank 2012).

In contrast, the situation in Eastern Europe points to an unexpected excess in male mortality.[11] While the shorter male longevity found in Eastern Europe is caused by behavioral factors other than discrimination, the demographic result is symmetrical to what is observed in Asia, with a distinct surplus of females in many Eastern European countries. There is an apparent deficit of about 13 million men in Eastern Europe out of a combined population of 139 million men in 2010.[12] This imbalance seems more pronounced than the deficit of females observed in several Asian countries mentioned here.

Conclusion

Sen's original estimate of the worldwide number of missing females was so large that it was greeted with considerable skepticism. However, subsequent research and our new estimates confirm that Sen was close to the mark, thus documenting the massive extent of gender discrimination, particularly in Asia. Despite a range of policies and programs to improve the status of females in recent decades, these efforts have been unsuccessful in halting the rise in the number of missing females. Since 1990, the number of missing females has risen by 43 percent (38 million) to 126 million in 2010, and we project a further increase of 24 million to 150 million in 2035.

These numbers are considerable and exceed all figures associated with well-documented demographic catastrophes such as world wars, genocides, famines, or major epidemics. But the global deficit of females is not the result of uncontrollable phenomena. Sex selection and excess mortality are central features of specific demographic systems with pervasive gender discrimination (on China, see Lee and Wang 1999). The fairly recent emergence of prenatal sex selection represents a more deliberate and effective practice of discrimination compared to excess female mortality, which remains a more passive form of bias achieved through neglect or lack of adequate care. Our estimates suggest that sex selection has not replaced postnatal discrimination, but has aggravated it by raising the proportion of girls missing among the younger birth cohorts. Our projections beyond 2010 postulate an immediate decline in prenatal sex selection, but the number of missing females will continue to rise and will peak only after two decades.

The recent literature on gender discrimination emphasizes prenatal sex selection in part because it is a relatively new practice. This emphasis has led to a lack of attention to persistent postnatal discrimination and untimely female mortality. The process of sex-selective abortion is now well known, and sex selection has received attention from policymakers at international agencies and national government authorities. Nevertheless, effective solutions to curb this practice remain elusive. Institutional responses to excess deaths must include improvements in the provision of health care, but the issue of discrimination should also be confronted with much greater vigor. However, the practices leading to excess mortality among females are often poorly understood, thus limiting the effectiveness of policy interventions. There is an urgent need for more research on the persistence of discriminatory practices that are responsible for 1.7 million unnecessary female deaths every year.

Appendix 1

Methods for estimating missing females, excess female deaths, and missing female births

This appendix summarizes the methods used for our estimation and identifies some of its limitations. In the absence of established "normal" distributions of population or deaths by sex, all methods used here are based on a systematic comparison between observed values in countries with and without presumed gender discrimination. Missing females or excess deaths are therefore computed as the difference between observed figures and expected figures drawn from countries with a similar mortality level but no known discrimination. Computations are done separately for all age groups and periods. Global and regional estimates are obtained by summing values of missing females, excess female deaths, and missing female births in countries with positive totals. Computing the exact number of missing females is difficult because, apart from sex selection and excess mortality, the sex ratio of the population at a given age is also affected by differentials in the natural SRB and migration, as well as by various measurement issues linked to age misstatement and underenumeration.

Sources. All estimates and projections of population and mortality rates by age and sex and the sex ratios at birth are taken from 2012 *World Population Prospects* (UN 2013a). For consistency, we have not tried to correct United Nations data or to incorporate other data such as life tables from the WHO.

Countries. Countries were divided in several groups. A first group comprised countries with a population below 5 million in 2010, and all of them were excluded from our dataset. Below this population size, age groups by sex tend to be small and more sensitive to migration-induced fluctuations and estimation errors. We have also observed that the quality of our modeling of sex ratios and mortality rates declines sharply with population size. We have also excluded Saudi Arabia and the United Arab Emirates, which have a largely male population due to the presence of labor migrants. A second group includes countries from Eastern Europe, characterized by high male mortality unrelated to sex discrimination. This region is therefore excluded from our reference group.[13] A third group, also excluded from our reference group, comprises countries with known prenatal sex selection or excess female mortality and population sizes above 5 million: Afghanistan, Azerbaijan, Bangladesh, China, India, Nepal, Pakistan, Singapore, South Korea, Taiwan, and Vietnam. All other 93 countries constitute our reference group, which is deliberately selected to include many countries outside the developed world to ensure that reference countries cover a range of development and mortality levels.

The reference countries are: Algeria, Angola, Argentina, Australia, Austria, Belgium, Benin, Bolivia, Brazil, Burkina Faso, Burundi, Cambodia, Cameroon, Canada, Chad, Chile, Colombia, Côte d'Ivoire, Cuba, Democratic Republic of the Congo, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Eritrea, Ethiopia, Finland, France, Germany, Ghana, Greece, Guatemala, Guinea, Haiti, Honduras, Indonesia, Iran, Iraq, Israel, Italy, Japan, Jordan, Kazakhstan, Kenya, Kyrgyzstan, Laos, Libya, Madagascar, Malawi, Mali, Mexico, Morocco, Mozambique, Myanmar, Netherlands, Nicaragua, Niger, Nigeria, North Korea, Papua New Guinea, Paraguay, Peru, Philippines, Portugal, Rwanda, Senegal, Serbia, Sierra Leone, Somalia, South Africa, South Sudan, Spain, Sri Lanka, Sudan, Sweden, Switzerland, Syria, Tajikistan, Thailand, Togo, Tunisia, Turkey, Turkmenistan, Uganda, United Kingdom, Tanzania, United States, Uzbekistan, Venezuela, Yemen, Zambia, and Zimbabwe.

Period. We have restricted our computations to the 1970–2050 period. Prior to 1970, the sex ratios of several populations were severely affected by the impact of previous wars or crises. In addition, estimates for the 1950s and 1960s are of poorer quality because of the absence of reliable census and vital registration data during this period. We have limited our projection to 2050 since the cumulative impact on our estimates of United Nations parameters beyond 2010 becomes considerable. The discussion in this article suggests that estimates of sex imbalances up to 2050 are already raising questions about the reliability of forecasting assumptions built into the United Nations models.

Missing females. For all age groups and years, we fit a linear regression to estimate the expected sex ratio by life expectancy level using the reference group described earlier. We use the log of the sex ratio as the dependent variable for better results. In addition, we correct the effect of the low natural SRB observed in sub-Saharan Africa, which reduces the sex ratio for all age groups. To correct the effect of lower birth masculinity on age-specific sex ratios, natural levels of the sex ratio at birth are assumed lower by 0.025 in sub-Saharan Africa (see below).

The first result of our modeling is a series of expected age-specific sex ratios by age, country, and year. We apply these ratios to the observed male population to deduce the expected female population and the number of missing females by comparison with observed values.

Excess female deaths. Our method is again based on comparison with the reference population. We first compute the expected female mortality rates by fitting regression models linking the sex ratio of mortality rates (as log) to life expectancy for the 19 age groups and 16 five-year periods (i.e., 304 separate regressions). We then use these expected mortality rates to compute the number of excess female deaths for each age group, period, and country.

Missing female births. Estimates by year and country are derived from observed and expected sex ratios at birth. The expected ratio is set equal to the value observed in 1975–1980 with an upper limit of 1.054, which is based on the average value in 1975–1980 of non-African countries without sex discrimination. Variations in pre-1980 SRBs are minor across countries, with the exception of sub-Saharan Africa where we estimate the average SRB at 1.03.[14] We also assume that sex-selective abortion was not practiced until 1980.

Limitations. Our analysis depends on a set of hypotheses and population estimates. There are a number of potential data and estimation issues that we can illustrate by three examples.

We have selected the regression models with the highest correlation coefficient for the 304 equations used. Our models of the log of sex and mortality ratios by life expectancy tend in general to be more accurate for younger and older age groups than models without logging the dependent variables. Younger adult populations are more affected by migration and underenumeration, but mortality is lower and estimation errors are therefore of lesser demographic consequence. Yet, the choice of the final regression model can have a significant bearing on the overall number of estimated missing females.

The estimation of missing females is based on the assumption that sex ratios are not affected by international migration. However, the departure of a significant number of male international migrants could result in an artificial deficit of men in their country of origin that would lead in turn to an underestimation of the male surplus. Recent data from the United Nations (2013b) illustrate this for India. In 2000, India had 1.4 million more male emigrants than female emigrants, but this male surplus among migrants rose to 3.5 million in 2010. Therefore 2 million more males than females left India in 2000–2010, and this corresponds to a parallel underestimate of India's missing females in 2010. In the absence of disaggregated data by age and period, it was not possible to correct estimates for international migration.

Our estimated number of missing female births is closely linked to SRB estimates. The sensitivity of our estimates is well illustrated by China, the largest contributor in the world to the deficit of female births. According to the United Nations parameters, the average SRB for China was 1.165 in 2000–2009. If we had used the annual estimates by China's National Bureau of Statistics (1.195), we would have found 2.1 million more missing female births during this ten-year period. The estimation of the number of missing female births can therefore be highly sensitive to the quality of original SRB figures.

Future research on the number of missing females based on estimates from *World Population Prospects* would probably benefit from a more systematic measurement of uncertainties linked to both the statistical models used and the sensitivity to SRB and international migration figures.

Comparisons. As noted earlier, our results are close to previous estimates of the stock of missing females in 2000. Other studies provide only flows of newly missing women (Anderson and Ray 2010; World Bank 2012). While based on similar comparative principles, their method for estimating excess female deaths differs significantly from ours since they use in particular the male–female death rate ratios of contemporary high-income countries in 2000 as the single reference for all other countries in the world at any period. Their method estimates excess female death rates due to discrimination *plus* changes in the male–female death rate ratios that accompany declining mortality risks in the absence of discrimination as countries develop.[15] In contrast, the reference mortality ratios by sex used here vary as a function of 1) the life expectancy of the country for which excess deaths are being estimated and 2) the five-year period considered in 1970–2050. This more complicated approach is based on 304 regression models and estimates only excess female deaths due to discrimination. The reason for this different strategy is that we are interested in the number of women who disappeared solely as a result of discrimination—as was true of Sen in 1990 and most of the related literature on missing women. In addition, our method is based on age and sex distributions and mortality rates according to the United Nations 2012 estimates, which we consider the best demographically consistent series of population and mortality estimates.

These differences in measurement strategy explain the variations between estimates for 2000. For instance, our method yields an annual flow of newly missing females in the world of 3.2 million in 2000 (with 1.5 missing births and 1.7 excess deaths). In contrast, Anderson and Ray (2010) put them at 4.9 million (respectively 0.8 and 4.1) and World Bank (2012) at 4.0 (respectively 1.4 and 2.6).[16]

Appendix 2

Missing females, excess female deaths, and missing female births in selected populations, five-year periods 1970–2050

	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
World																	
Missing females	61.0	66.4	72.2	79.3	87.6	96.7	105.9	116.4	125.6	136.2	142.6	147.2	149.5	149.9	148.6	145.4	142.0
Excess female deaths		1.79	1.86	1.90	1.97	1.93	1.71	1.78	1.66	1.65	1.71	1.80	1.92	2.06	2.21	2.39	2.52
Missing female births		0.00	0.00	0.37	0.76	1.23	1.36	1.55	1.71	1.69	1.50	1.28	1.09	0.95	0.81	0.68	0.60
China																	
Missing females	27.2	29.0	31.8	34.6	39.2	44.3	49.5	55.7	62.3	68.4	72.3	74.9	76.4	76.9	76.6	75.1	73.4
Excess female deaths		0.32	0.42	0.50	0.57	0.54	0.45	0.59	0.59	0.59	0.62	0.67	0.74	0.82	0.90	0.97	1.02
Missing female births		0.00	0.00	0.17	0.47	0.68	0.66	0.75	0.89	0.87	0.73	0.59	0.49	0.42	0.36	0.29	0.22
India																	
Missing females	21.8	24.8	27.1	30.2	33.2	36.1	38.9	41.1	43.3	44.9	45.8	46.3	46.0	45.1	43.6	42.0	40.3
Excess female deaths		1.01	0.90	0.95	0.96	0.82	0.72	0.59	0.43	0.38	0.36	0.34	0.32	0.29	0.28	0.30	0.28
Missing female births		0.00	0.00	0.13	0.20	0.44	0.55	0.62	0.63	0.63	0.59	0.54	0.47	0.39	0.32	0.26	0.25
Rest of the world																	
Missing females	12.1	12.5	13.3	14.6	15.2	16.3	17.4	19.5	20.1	22.8	24.5	26.1	27.1	27.9	28.3	28.4	28.3
Excess female deaths		0.46	0.54	0.45	0.44	0.57	0.55	0.59	0.64	0.67	0.72	0.79	0.86	0.95	1.04	1.13	1.21
Missing female births		0.00	0.00	0.07	0.09	0.11	0.15	0.18	0.19	0.19	0.17	0.16	0.14	0.14	0.14	0.13	0.13

NOTES: All figures in millions. Annual excess female deaths and missing female births refer to the preceding five-year period.
SOURCES: Computed by the authors.

Notes

The authors thank Patrick Gerland for his detailed comments on an earlier version of this article.

1 Sen used the term women to include girls as well adult females. To avoid confusion we use the term females.

2 UNDP (2010) updates earlier estimates by Klasen and Wink (2002) for Asian countries.

3 Anderson and Ray (2010) and World Bank (2012) use a comparable method for estimating missing girls at birth and excess female mortality, but based on different data and parameters. In particular, they use 2000 mortality patterns from contemporary high-income countries as a benchmark and use WHO rather than United Nations mortality figures. We describe our methodology in Appendix 1.

4 The sex ratio was 108 among the population aged 5–9 years and 111 among those aged 10–14. These values are clearly above the low sex ratio at birth estimated at 102–103 by Nigeria's latest 2008 and 2013 DHS rounds.

5 Much higher ratios are observed in subnational populations in these two countries.

6 During the entire period from 1970 to 2010, a cumulative total of 72 million excess female deaths occurred worldwide. The age distribution of these deaths is much more skewed than the age distribution of missing females shown in Figure 3. In fact, 38 percent of all excess deaths occurred before age 5 and another 6 percent from ages 5 to 15. A peak occurred among childbearing ages from 15 to 45, which accounts for an additional 23 percent of excess female mortality. A quarter of all excess female deaths occurred above age 60. The presence of excess mortality at all ages explains why the proportion of missing females in a given cohort increases continuously with age as illustrated by Figure 4. It may be added that there are significant regional variations in the distribution of excess deaths. Excess mortality is marked during childhood in South Asia, but is more common among adults in sub-Saharan Africa and among older adults in China. See also Subramanian et al. (2006) on India, Zhao, Chen, and Jin (forthcoming) on China, and World Bank (2012) on Africa.

7 Our figure of 3.3 million is below the 3.9 million estimated by the World Bank (2012) for 2008. See also Appendix 1.

8 The equation used in the demography of missing females is similar to the basic population equation: Missing females at time $t+n$ = survivors at time $t+n$ of missing females at time t + survivors at time $t+n$ of missing female births and excess female deaths occurring between t and $t+n$.

9 This 2050 total could be decomposed as the sum of missing females in 2010 (126 million) and of newly missing births and excess female deaths in 2010–2050 (43 and 81 million respectively), from which we deduce the attrition effect (94 million). This decomposition is less precise than for the 1970–2010 period.

10 The projected percentage of the world's women who are missing rises from 3.66 percent in 2010 to 3.75 in 2015, 3.73 in 2020, and 3.67 in 2025 and is expected to reach 3.00 in 2050.

11 Cases of prenatal sex selection in formerly Communist countries are confined to small countries in the Western Balkans and South Caucasus that belong to Southern Europe or West Asia according to the UN classification.

12 This number is deduced from the apparent number of 14 million "surplus females" found in 2010 for Eastern Europe.

13 We also excluded from our reference category Cambodia in 1975–80 and Rwanda in 1990–95 because of the extremely high mortality levels during these periods.

14 We use 1.03 as reference SRB for sub-Saharan Africa. This number is derived from SRB estimates from DHS surveys as well as from recent census age distributions from Burkina Faso, Ethiopia, Ghana, Kenya, Mali, South Africa, and Tanzania. See also Garenne (2002).

15 Anderson and Ray (2010) note that "if we want to restrict ourselves to defining missing women as the number of females who have died due to discrimination, then the original estimates need to be seriously revised downwards." World Bank (2012) also states that "the literature on 'missing women'

focuses on identifying female mortality solely caused by discrimination [and] tries to control for the overall institutional environment and mortality risks. In contrast, this chapter seeks not to rule out institutional differences but to rule them in." For an extended critique of this method, see Klasen and Vollmer (2013).

16 Estimates from Anderson and Ray (2010) pertain only to China, India, and sub-Saharan Africa, while estimates by the World Bank (2012) refer only to women aged less than 60 and are not available for 2000 (we use here the weighted average of the 2000 and 2008 figures).

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