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Counting missing women - A reconciliation of the "flow measure" and the "stock measure"

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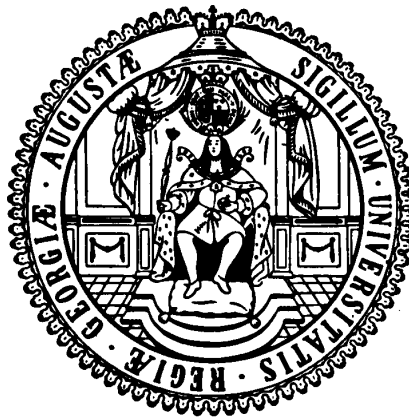
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Counting Missing Women – A Reconciliation of the ‘Flow Measure’ and the ‘Stock Measure’

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Abstract

Existing estimates of the ‘stock of missing women’ suggest that the problem is mostly concentrated in South and East Asia, and often related to sex-selective abortions and post-birth neglect of female children. In contrast, estimates of yearly excess female deaths, referred to as the ‘flow of missing women’, suggest that gender bias in mortality is much larger than previously found (about 4 to 5 million excess female deaths per year vs. around 100 million missing women in total), is as severe among adults as it is among children in India, and is larger in Sub-Saharan Africa than in South and East Asia. We argue that these findings largely rely on the choice of the reference standard for sex-specific mortality and an incomplete correction for different disease environments in the flow measure. When alternative reference standards are used, the results of the flow measure can be reconciled with previous findings of the stock measure.

JEL Codes: J16, D63, I10

Keywords: Missing women, gender bias, mortality, disease, age, Sub-Saharan Africa, China, India

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1. Introduction

The extent of gender bias in mortality in developing countries has been a research topic that sparked substantial controversies in the economic and demographic literature since the time when Amartya Sen first pointed to the millions of 'missing women' in South and East Asia in 1989 (Sen, 1989). This literature focused largely on calculating *stock measures* of missing women. Stock measures compare the actual sex ratio (males/females) using census information in a country with an expected sex ratio that would occur in the absence of gender bias in mortality. These studies on such stock measures, and many more using micro data from individual countries or regions, have converged on two key findings (e.g. Sen, 1989, Coale, 1991; Bannister and Coale, 1994; Das Gupta, 1987, Murthi, Guio and Dreze, 1995; Das Gupta, 2005; Klasen and Wink, 2002, 2003; Das Gupta, Chung, and Shuzhou, 2009). First, the problem of missing women is much more prevalent in China and India than in Sub-Saharan Africa. Second, in China and India, missing women are largely attributable to excess female mortality before birth and/or the first few years of life. The stock estimates of the number of missing women amounted to around 100 million in 2000 in the countries most affected by the problem, i.e. China, India, Pakistan, Bangladesh, the countries of Western Asia and some countries of North Africa (Klasen and Wink, 2003). Compared with a previous census round in 1990, the number of missing women had increased by about 6 million between 1990 and 2000 but fallen as a share of females alive (from 6.5% to 5.7%) (Klasen and Wink, 2003).³

An alternative method to the *stock measure* poses the *flow measure* of missing women as proposed by Anderson and Ray (2010). It compares the ratio of male to female age-specific mortality rates with an expected ratio of male to female age-specific mortality rates from a reference population. It estimates excess female mortality in a given year, opposed to the stock measure's estimates of the total deficit in alive women at one point in time. Using this flow measure method, the World Bank calculated the number of missing women for all developing countries in 1990, 2000, and 2008 in its World Development Report entitled 'Gender Equality and Development' (World Bank, 2012).

Contrary to findings based on the stock measure, estimates of the annual flow of missing women for the year 2000 in China, India, and Sub-Saharan Africa suggest that excess female mortality is (a) as severe among adults as it is among children in India, (b) higher in Sub-Saharan Africa than in China and India and (c) largely due to excess *adult* female mortality in Sub-Saharan Africa (Anderson and Ray, 2010; World Bank, 2012). Altogether, excess female mortality is also much larger than implied by the existing literature on stock measures. In a single year about four to five million women died in excess in India, China, and Sub-Saharan Africa alone. For the 1990s, the stock measure would be consistent with a flow of about one

³ A major controversy about these stock estimates of missing females arose when Oster (2005) claimed that the 'natural' sex ratio at birth in some of these countries was much higher due to the fact that the widespread prevalence of the hepatitis-B-carrier status raised the sex ratio at birth. She claimed that this way some 50-70% of missing females could be accounted for, i.e. their absence was unrelated to discrimination. After an intense debate and further research (Abrevaya, 2009; Das Gupta, 2005, 2006; Lin and Luoh, 2008), Oster retracted the finding in 2009 (Chen and Oster 2010) and the previous estimates of around 100 million were re-instated. See Klasen (2008) for a review of this debate.

million missing women in a given year.⁴ Further, the annual flow of missing women suggests that the United States in 1900 may have had a similar problem of missing women, driven by adult mortality, as Sub-Saharan Africa has today (Anderson and Ray, 2010). Again, this is a new finding in the sense that previous literature had not found such substantial gender bias in mortality the 1900s United States (e.g. Johansson, 1984, 1991; Klasen, 1998, 2003). More recently, the flow measure estimates that excess female mortality is elevated among unmarried women, particularly in the reproductive age (15-49), in developing countries (Anderson and Ray, 2019).

As evident by the World Development Report on 'Gender Equality and Development', the flow of missing women poses a relevant metric to highlight grievances in gender equality in developing countries and therefore to guide policies. Flow estimates are interesting because they allow to directly estimate specific age groups at risk of excess mortality (Anderson and Ray, 2010, 2012, 2019; World Bank, 2012). Further, flow estimates allow for better comparisons of missing women over time and even attributions of deaths to specific disease groups. For example, the World Development Report concludes "Excess female mortality is slowly shifting from early childhood in South Asia to adulthood in Sub-Saharan Africa, declining in all low-income countries except in Sub-Saharan Africa" (World Bank, 2012, p.77). As pointed out above and in the World Development Report itself, some of the results based on the flow measure, were not detected or are even in contrast with earlier stock measure estimates: "Less well known is that excess female mortality is a continuing phenomenon beyond childhood and a growing problem in Sub-Saharan Africa. [...] While missing girls at birth are indeed concentrated in India and China, consistent with the earlier discussion, excess female mortality after birth is highest in Sub-Saharan Africa, the only region where the numbers are going up over time" (World Bank, 2012, pp.118-120).

This paper reconciles critical methodological aspects of the flow measure with those of the stock measure to ultimately enable the reconciliation of the number of missing women based on both measures. Throughout the paper, we refer to the flow measure based on the methods and data used in Anderson and Ray (2010) – the seminal paper on the measurement of the annual flow of missing women – and therefore the number of missing women in 2000. The paper revolves around three key methodological aspects. First, we review the reference standard of high-income countries in 2000 used in flow estimates.⁵ Today's high-income countries are an environment with extremely low overall adult mortality and, therefore, mortality rates are highly sensitive to non-natural causes of death or consequences of sex-specific behavioral patterns such as accidents, violence, suicides and smoking, which affect males much more than females. Second, we discuss that controlling for differences in the disease environment requires to control for sex differences *within* disease groups across countries. For example, the male to female mortality ratio from AIDS is around 4 in high-income countries in 2000 because AIDS mortality was

⁴ Note that flows of missing cannot be calculated as differences in stocks between time periods, i.e. the difference of 6 million in stocks does not imply 600,000 missing women per year. This is due to the fact that some women in a particular age group that have died in excess in a year might not count as missing in a stock measure at the next census if in the time interval some men in that age group have also died due to high overall mortality, i.e. to the extent that an excess female death in a year just advances mortality between two census periods, it would not add to the increase in the stock of missing women at the next census.

⁵ High-income countries refer to the former World Bank country classification 'Established Market Economies' as used by Anderson and Ray (2010), which includes Western Europe, Canada, United States, Australia, New Zealand, and Japan.

confined to male-dominated high-risk groups (gay men and IV drug users), whereas in Sub-Saharan Africa AIDS spread from the beginning to the entire population, with heterosexual transmission playing a key role, and AIDS mortality being more similar for males and females. Thus, using today's high-income countries as a reference standard for AIDS mortality assumes massive excess female mortality in adulthood in AIDS affected countries, which is indeed reflected in the main findings of the World Development Report 2012 showing particularly high rates and increases in excess female mortality in AIDS affected countries of Sub-Saharan Africa (World Bank, 2012). At last, we highlight a general concern that underlies the use of mortality data in Sub-Saharan Africa which is that reliable vital registration data is only available in *one* of 46 countries. For the remaining countries, mortality data have to be estimated.

We use a variety of alternative reference standards for sex-specific mortality and find patterns in the flow of missing women for the year 2000 that are aligned with previous findings on the stock of missing women. We find that excess female mortality is much more serious in India and China than in Sub-Saharan Africa. In China and India, excess female mortality is largely driven by gender bias pre-birth and during the first few years of life. The magnitude of the problem is also much reduced and our estimates suggest that 1.5-1.8 million women die in excess in the three regions in 2000. This number is substantial and worrying but below the number of five million females per year estimated in Anderson and Ray (2010) or 3.3 million below the age of 60 of the World Bank (2012). Our estimate is also lower, but to a lesser extent, than the flow measure estimate by Bongaarts and Guilmoto (2015), who show trends in excess female mortality from 1970 to 2050 using mortality data from 93 countries with different mortality levels to create a reference population.⁶ Bongaarts and Guilmoto (2015) do not provide flow estimates by age such that comparisons of age patterns cannot be made. Further, our calculations confirm severe gender bias in mortality among adults in Sub-Saharan Africa, likely linked to elevated mortality of women due to AIDS, although it is of smaller magnitude than the original flow estimates.

This paper is organized as follows. In section 2, we present the conceptual framework of the flow measure of missing women. In section 3, we discuss the problem of low mortality reference populations and the sex ratio as a functional form of the reference standard. Section 4, presents estimates of missing women using alternative reference standards. In section 5, we discuss the relevance of sex-specific differences within diseases across countries and present estimates of missing women using an alternative reference

⁶ The estimations of Bongaarts and Guilmoto (2015) amount to excess female deaths after birth of 0.54 million in China and 0.82 million in India in 2000. They predict the reference sex ratio of mortality based on a linear regression of the log sex ratio on life expectancy for combinations of different age groups and years (304 separate regressions). The countries included in the computation of the reference population 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.

standard for AIDS. In section 6, we draw attention to the issue of lacking mortality data in Sub-Saharan Africa. Section 7 concludes.

2. The 'flow measure' of missing women

Using the flow measure, excess female mortality (*EFM*) for age group *a* can be calculated the following way:

$$EFM(a) = \left(MR_f(a) - \left(\frac{MR_m(a)}{\widehat{MR}_m(a)/\widehat{MR}_f(a)} \right) \right) * Pop_f(a) \quad (1)$$

$MR_f(a)$ and $MR_m(a)$ refer to the *actual* mortality rates of females and males in age group (*a*), respectively. $\widehat{MR}_f(a)$ and $\widehat{MR}_m(a)$ describe the mortality rates of females and males in age group (*a*) in the *reference population*, respectively. $\widehat{MR}_m(a)/\widehat{MR}_f(a)$ is the male to female sex ratio of the reference population and is used as a correction factor to scale the actual male mortality rate $MR_m(a)$ to account for, for example, differences in risky behavior across sexes or the disease environment. The scaled $MR_m(a)$ provides the *reference mortality rate of females* in age group *a* which is subtracted from *the actual mortality rate of females* to receive the population share of missing women in age group *a*. Multiplying the population share of missing women in age group *a* with the number of women in age group *a*, $Pop_f(a)$, results in the total flow of missing women in age group *a*, $EFM(a)$. Based on equation (1), the essential ingredients to calculate excess female mortality are the age-specific actual mortality rates and the correction factor consisting of the age-specific male to female mortality rate ratio of the reference population. As a reference population, the flow measure of missing women uses high-income countries in 2000. Specifically, the reference standard employs male to female age-specific mortality ratios from high-income countries in 2000.

Table 1: Adult mortality rates (15-59) by sex in 2000

| | (1) Male | (2) Female | (3) Sex Ratio |
|-----------------------|-------------|---------------|------------------|
| Sub-Saharan Africa | 0.511 | 0.454 | 1.125 |
| India | 0.287 | 0.213 | 1.347 |
| China | 0.161 | 0.110 | 1.464 |
| High-income countries | 0.125 | 0.065 | 1.918 |

Notes: Adult mortality rates refer to the likelihood of having died by age 60 if one was alive at age 15. Male refers to the adult (15-59) mortality rate among males. Female refers to the adult (15-59) mortality rate among females. Sex ratio refers to the ratio of columns (1) and (2), i.e. the male to female mortality rate ratios. To derive mortality rates in Sub-Saharan Africa and high-income countries, population (15-59 years old) weighted averages of country specific adult mortality rates were calculated (see supplementary materials). Sub-Saharan African countries include: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, CAR Chad, Comoros, Cote d'Ivoire, DRC Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, South Africa, Swaziland, Tanzania, Togo, Uganda, Zambia, Zimbabwe. High-income countries include: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States.

Sources: Country specific adult mortality rates in 2000 were taken from WHR (2001). Population numbers were taken from The UN World Population Prospect Revision 2000: <https://population.un.org/wpp/Download/Archive/Standard/>, downloaded April 3, 2021.

Table 1 presents the mortality rates for adults aged 15 to 59 by sex for Sub-Saharan Africa, India and China in 2000 as actual mortality rates ($MR_f(15 - 59)$ and $MR_m(15 - 59)$) and for high-income countries in

2000 as reference mortality rates ($\widehat{MR}_m(15 - 59)$ and $\widehat{MR}_f(15 - 59)$). In Sub-Saharan Africa and India, the sex ratios of mortality rates are 1.13 and 1.35, respectively. Adult males thus die at 13-35% higher rates than adult females. The sex ratio in high-income countries in 2000, the reference standard used in the flow measure estimation, is about 1.92. Thus, adult males die at 92% higher rates than adult females. Because the sex ratio in high-income countries constitutes the reference standard of the flow measure, the estimates of missing women will be highly sensitive to this reference standard. Comparing the ratios in Africa and India to that in high-income countries in 2000, suggests that adult females in Sub-Saharan Africa, India and China seem to suffer from a massive relative survival disadvantage.

Following equation (1) and using age-specific sex ratios of mortality and high-income countries in 2000 as a reference standard, Table 2 presents the flow of missing women in Sub-Saharan Africa, India and China in 2000 (Anderson and Ray, 2010).⁷ With this reference standard the problem of missing women as a share of the female population is worst in Sub-Saharan Africa. 0.47% of females died in excess in 2000 in Sub-Saharan Africa, compared to 0.34% in India and 0.31% in China. Table 2 further illustrates that in India there is a massive problem of missing women among adults that is larger than among children. At last, adding the total number of missing women across Sub-Saharan Africa, India and China results in 5 million females that went missing in one year.

Table 2: Flow of missing women (in 1000s) by age group in 2000 using today's high-income countries' mortality rates as reference standard

| | (1) Sub-Saharan Africa | (2) India | (3) China |
|--------------------------|---------------------------|--------------|--------------|
| At birth | 0 | 184 | 644 |
| 0-1 | 32 | 146 | 109 |
| 1-4 | 160 | 164 | 23 |
| 5-14 | 70 | 93 | 2 |
| 15-29 | 578 | 258 | 24 |
| 30-44 | 345 | 93 | 73 |
| 45-59 | 84 | 120 | 89 |
| 60-79 | 213 | 541 | 490 |
| 80+ | 44 | 113 | 272 |
| Total | 1526 | 1712 | 1727 |
| Share of females missing | 0.47% | 0.34% | 0.31% |

Note: Numbers do not sum to total because of rounding error.

Sources: Anderson and Ray (2010).

In the following sections, we will more closely review the underlying assumptions and methods of the flow measure estimates presented in Table 2 and reconcile those with the assumptions and methods used in previous stock measure estimations. For this purpose, we rely on the same materials and data used in Anderson and Ray (2010) whenever we can and use the term flow measure when we refer to the methods and results of their paper.

⁷ For example, in Sub-Saharan Africa, the mortality rate for females aged 1-5 is 1.39%, while the male one is 1.27% (Anderson and Ray, 2010, Table 2). Since in high-income countries the male-female sex ratio is 1.25 in that age group (Anderson and Ray, 2010, Table 2), the number of missing females aged 1-5 in Sub-Saharan Africa is $((0.0139 - (0.0127/1.25)) * 42 \text{ m.}) = 0.16$ million as shown in Table 2.

3. The problem of low mortality reference populations and the sex ratio as a functional form of the reference standard

As discussed in detail in Coale (1991), Klasen and Wink (2002, 2003) and Anderson and Ray (2010), the ideal counterfactual for assessing the amount of gender bias in mortality would be a society in which males and females are treated equally and in which there are no sex-based behavioral patterns with significant mortality implications. There is no such society past or present that exhibits this feature so that it is inherently difficult to generate a reference standard that is entirely beyond reproach.

The flow measure of missing women employs male to female age-specific mortality ratios that prevail in high-income countries in 2000 as a reference standard. The main shortcoming of this reference standard is the very low overall mortality in high-income countries. In the adult age group of 15 to 29 year-olds, which accounts for most of the alleged flow of missing women in Sub-Saharan Africa (see Table 2), the female mortality rate in high-income countries in 2000 is 0.42 per thousand whereas that for men is 1.08 per thousand, resulting in a sex ratio of 2.6; i.e. the probability of men dying in this young age group is 160% higher than the corresponding likelihood for women. Thus, even slight differences in the numbers of deaths across sexes generate large sex ratios in low mortality environments, which has large implications for the female reference mortality rate in high mortality environments such as in Sub-Saharan Africa and, consequently, the flow of missing women. This is particular to the flow measure because the stock measure does not rely on the number of deaths but on the number of males and females surviving which make up, of course, much larger numbers.

Figure 1 depicts the male to female mortality ratios by age in high-income countries in 2000. The ratios are particularly high in the age groups between 15 and 35, in which they are above 2. Between the ages of 35 and 55 the mortality ratios are somewhat smaller averaging around 1.86. A final peak arises between the ages of 55 and 70 with mortality rate ratios over 1.94. For older ages the ratio falls sharply, but always remains above 1.

The first peak between 15 and 35 is largely a result of the role of injuries which particularly drives up male mortality rates in these young age groups; in the demographic literature this has sometimes been referred to as the 'testosterone spike' linked to injuries related to the combination of alcohol abuse, dangerous traffic behavior, and violence among young men (Kalben, 2000). Because the overall mortality among 15 to 29 year-olds is very low in high-income countries, deaths from injuries are particularly prominent. In this young age group, injuries make up 71% of all deaths of males (and 51% of females) and the sex ratio of mortality from injuries is 3.7, whereas it is 1.6 for all other deaths. Therefore, the reference standard is heavily affected by this disproportionate importance of injuries in adult mortality for males in high-income countries.

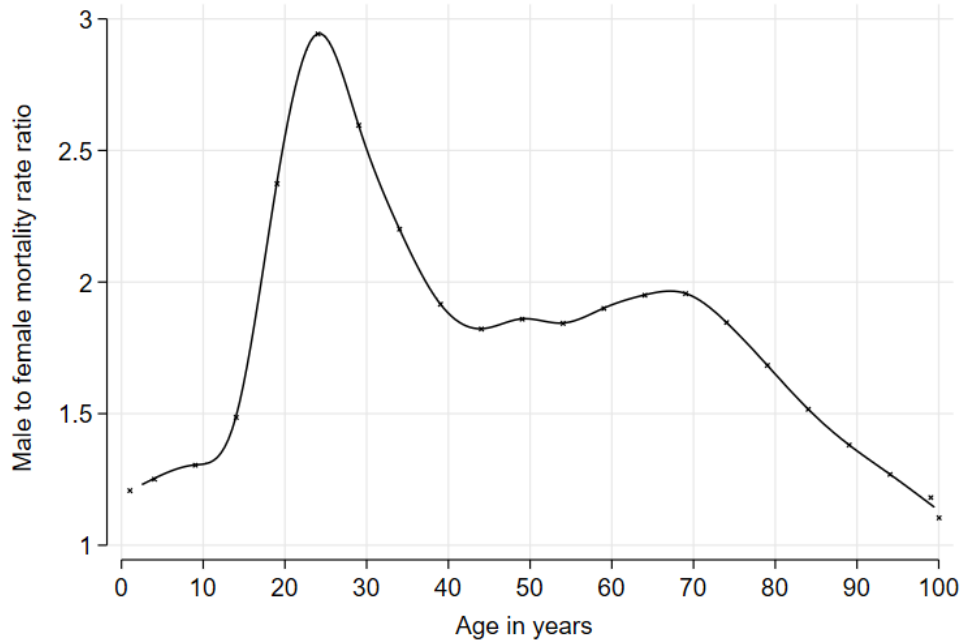


Figure 1: Male to female relative mortality rate ratios by age in high-income countries in 2000

Source: Replicated from supplementary material of Anderson and Ray (2010)

The second peak is heavily affected by the mortality consequences of high rates of smoking among adults. As shown in detail by Crimmins, Preston and Cohen (2011), what matters for mortality are smoking rates two to four decades prior, i.e. smoking prevalence from 1960 to 1980 matters for mortality in 2000. As demonstrated by Deaton (2004) and Crimmins, Preston and Cohen (2011), smoking rates in high-income countries during those times were high, and much higher for males than for females. In fact, Crimmins, Preston and Cohen (2011) estimate that some 20% of all male deaths above age 50 in industrialized countries and less than 10% of all female deaths above age 50 were due to smoking-related diseases. As a result, men lost about 2.2 years of life expectancy due to smoking, compared to 1.2 for women. Many of these deaths (particularly related to lung cancer or cardiovascular diseases of pulmonary diseases) occur in the 55 to 70 age group, leading to the observed high sex ratio of mortality rates among 55 to 70 year-olds in high-income countries.⁸

Assuming such massive *relative* disadvantages in situations of high overall mortality is also inconsistent with the literature on biological and behavioral drivers of sex differentials in mortality (e.g. Rogers et al., 2010; Waldron, 1976, 1982, 1993, 1998; Case and Paxson, 2005; Cawley and Ruhm, 2012; Crimmins, Preston and Cohen, 2011, among many others). Although estimates differ across studies, there is a consensus that most of the survival advantage of females in industrialized countries is due to the sex-

⁸ Since female smoking rates have been rising in high-income countries while overall smoking rates have fallen, the impact of gender gaps in smoking prevalence on sex-specific mortality rates will fall in coming decades. See Pampel (2003) and Crimmins, Preston and Cohen (2011) for a discussion. This also points to another problem of using the actual mortality rates in today's high-income countries as a standard. The number of missing women in Sub-Saharan Africa and India will automatically fall as a result of the greater gender balance in mortality due to smoking in high-income countries.

specific behavioral patterns described above rather than biological differences. As a result, women's biological advantage only amounts to 1-2 years of life expectancy. These biological advantages are most prevalent in infancy and beyond age 50 (e.g. Waldron, 1976, 1982, 1983; 1993; 1998).

Note that this discussion does not suggest that men in other parts of the world do not behave riskier than women, but that because of the overall low mortality environment in high-income countries men's risky behavior affects sex ratios in mortality rates much more in high-income countries than in other parts of the world.

The implications of the substantial relative mortality advantage of women in low mortality environments of high-income countries is reinforced by the choice of the sex *ratio* as a functional form.⁹ As an alternative to the sex ratio, one could use the difference as a functional form. For example, the difference between the male and female mortality rates of 25 to 29 year-olds in high-income countries 0.66 per thousand (=1.08-0.42), considerably lower than the sex ratio of 2.6. To calculate the reference female mortality rate, one could either subtract that difference from the male mortality rate in the country or region of interest (e.g., Sub-Saharan Africa) or divide that male mortality rate by one plus the difference. The first option poses a middle ground between the functional form of ratios used so far and the second option.

4. Use of different reference standards

In this section, we test the sensitivity of the number of missing women based on the flow measure with respect to alternative reference populations and functional forms. These alternatives include (a) the difference, rather than the ratio, in male and female mortality rates as a functional form and (b) the use of Model Life Tables, referring back to the demographic literature for the estimation of missing women based on the stock measure (e.g. Coale, 1991; Klasen, 1994, Klasen, 1998, Klasen and Wink, 2002, 2003).¹⁰ For the difference as a functional form, we subtracts the difference in sex-specific reference population rates from the male mortality rate in the region of interest.

There are various versions of Model Life Tables. The previous literature mostly relied on the Princeton Model Life Tables (Coale, Demeny, and Vaughan, 1983), which are based on comprehensive and high-quality life tables from Europe, North America, and some non-European countries from about 1870 to 1960. These life tables were then combined to generate a set of Model Life Tables for different overall mortality conditions. The use of those Model Life Tables as a reference standard for generating estimates for missing women has several advantages (see Coale, Demeny, and Vaughan, 1983; Coale, 1991; Klasen, 1994; Klasen and Wink, 2002, 2003). First, they provide life tables for high-mortality environments such as Sub-Saharan Africa's but also medium or low mortality environments such as India's or China's.¹¹ Second, and closely related, they reflect the entire spectrum of the epidemiological transition from predominantly

⁹ Anderson and Ray (2010) briefly discuss functional forms, stating that they have a preference for the 'scale neutrality embodied in the use of relative death rates' (Anderson and Ray, 2010: 1290).

¹⁰ Note, we are not recommending the difference as a standard. The absolute difference would underestimate biological differences, particularly in infancy, and might overestimate these differences in older age groups where mortality levels are high. Also, the problem of male-biased injuries dominating the results would still be there (but muted through the functional form).

¹¹ They are less suitable for assessing very low mortality environments such as those prevailing in some industrialized countries today.

communicable to predominantly non-communicable diseases. Third, they come from a time period where the main drivers of high male mortality today, especially related to nicotine abuse and traffic accidents, were much less serious and thus less likely to bias results. Lastly, they come from time periods where the overwhelming historical evidence suggests that gender discrimination in access to resources was comparatively low, certainly when compared to places such as India or China today (UN, 1998; Klasen, 1998; 2003; Johannsson, 1984, 1991; Schofield, 1991; Rosenzweig and Schultz, 1982; Klasen and Wink, 2003; Dyson and Moore, 1984; UN, 1998; Tabutin, 1978).¹² Similarly, the technologies available to produce gender bias, particularly differential access to health care as well as sex-selective abortions, were unavailable or, in the case of health access, much less effective in producing gender differentials in mortality than today (e.g. Asfaw, et al. 2010; Klasen and Wink, 2003; Banister and Coale, 1994; Akbulut-Yuksel and Rosenblum, 2012).

Table 3 summarizes how the results on missing women by age change if one used either the difference in mortality rates in high-income countries (columns (2), (6) and (10)), the sex ratio of mortality rates from the Princeton Model Life Tables West (columns (3), (7) and (11)), or relied on the difference in mortality rates from the Princeton Model Life Tables West.^{13, 14} The findings based on the flow measure using the sex ratios of mortality in high-income countries today are reproduced and shown in columns (1), (5), and (9). The approach for identifying the number of missing women at birth remains the same throughout different reference standards.

Regardless of which alternative reference standard we use, the key findings following from the flow measure when using mortality sex ratios of high-income countries mostly disappear.¹⁵ The first key finding, that the missing women problem is more severe in Sub-Saharan Africa than in India or China, reverses using alternative reference standards. The total and percentage flows of missing women are now much larger in India and China, compared to Sub Saharan Africa. Using sex ratios as a functional form and Princeton Model Life Tables West as the reference population (column (3)), 0.07% of females die in excess

¹² There is a literature that has examined gender bias in mortality in historical Europe and that literature has indeed identified small episodes of such gender bias; but most episodes refer to the early 19th century, before the time period covered in the Model Life Tables; also the one episode in the late 19th century was focused on girls (aged 1-14) and has been linked to a particularly serious episode of tuberculosis that particularly affected them. But the presumed excess amounted to never more than 5-10% above expected mortality in this one age group and was very small in Scandinavia and the UK (and larger in Ireland). For a survey, see for example, Klasen (1998, 2003), Johannsson (1984, 1991), among others.

¹³ In a robustness check, we also use the Princeton Model Life Tables 'North' with virtually identical results. They are available on request. Note that Anderson and Ray (2010) also report on results using model life tables in appendix B and also find that most missing women disappear in Sub-Saharan Africa but do not place any emphasis on these results in the text.

¹⁴ We also used the sex ratio of mortality prevailing in Latin America as a robustness check and the results are available on request. Note that using Latin America does little to solve the problem as mortality rates in Latin America today are much lower than in Africa or India and in fact relatively close to high-income countries; the sex ratio of mortality in Latin America is even higher in some young adult age groups, related to particularly high male mortality rates due to injuries. So, the same concerns apply to this standard.

¹⁵ Note that using the difference of mortality rates as the reference standard leads to negative numbers of missing females in Sub-Saharan Africa. But this is mostly driven by the 0-1 age group. Here the epidemiological literature (e.g. Waldron 1983, 1998) is quite clear that the disadvantage in infancy appears to be a relative one (not an absolute one) so that one should treat the results with caution.

every year in Sub-Saharan Africa, compared to 0.14% in India and China, respectively. Using the difference in mortality rates as a functional form leads to very similar findings in Sub-Saharan Africa and India as far as size and distribution of gender bias are concerned.¹⁶

Table 3: Number of missing women (in 1000s) by age group using alternative reference standard

| | Sub-Saharan Africa | | | | India | | | | China | | | |
|--------------|--------------------|-------------|--------------|--------------|-------------|-------------|--------------|--------------|-------------|-------------|--------------|--------------|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) |
| | RC Ratio | RC Diff. | MLT Ratio | MLT Diff. | RC Ratio | RC Diff. | MLT Ratio | MLT Diff. | RC Ratio | RC Diff. | MLT Ratio | MLT Diff. |
| At birth | 0 | 0 | 0 | 0 | 184 | 184 | 184 | 184 | 644 | 644 | 644 | 644 |
| 0-1 | 32 | -235 | 22 | 13 | 146 | 8 | 181 | 156 | 109 | 65 | 148 | 119 |
| 1-4 | 160 | 55 | 55 | 56 | 164 | 121 | 140 | 141 | 23 | 13 | 29 | 20 |
| 5-14 | 70 | 18 | 5 | 2 | 93 | 53 | 71 | 69 | 2 | -9 | 12 | 4 |
| 15-29 | 578 | 279 | 241 | 237 | 258 | 127 | 111 | 113 | 24 | -9 | -9 | -37 |
| 30-44 | 345 | -56 | -3 | -51 | 93 | -63 | -70 | -80 | 73 | 53 | -2 | -16 |
| 45-59 | 84 | -144 | -55 | -93 | 120 | -114 | -39 | -75 | 89 | 15 | -9 | -26 |
| 60-79 | 213 | -18 | -40 | -40 | 541 | 103 | 76 | 41 | 490 | 170 | 27 | 12 |
| 80+ | 44 | 10 | -10 | -8 | 113 | 84 | 21 | 39 | 272 | 165 | 64 | 64 |
| Total | 1526 | -91 | 213 | 116 | 1712 | 503 | 674 | 590 | 1727 | 1107 | 903 | 783 |
| % of females | 0.47 | -0.03 | 0.07 | 0.04 | 0.35 | 0.10 | 0.14 | 0.12 | 0.28 | 0.18 | 0.14 | 0.13 |

Note: Ratios refer to reference standards that are based on sex ratios of age-specific mortality rates, difference to absolute differences. RC refers to high-income countries in 2000, MLT are Princeton Model Life Tables West.

Source: Anderson and Ray (2010) for population sizes and male and female deaths in Sub-Saharan Africa, India, China and high-income countries (referred to as EME) in 2000; Coale, Demeny, and Vaughan (1983) for Princeton Model Life Tables West.

The second key finding, that the problem of missing females in India is as much a problem among adults as it is among children, has also almost entirely vanished. The vast share of missing females in India emerges pre-birth and in the first few years of life. Using the Princeton Model Life Tables West as a reference population, the share of missing women accounted for by sex-selective abortions and elevated mortality rates in infancy and early childhood (<age 5) is over 70% compared to less than 30% when using high-income countries as a reference population (compare column (5) to columns (7) and (8)).

The third key finding, that the massive problem of gender bias in Sub-Saharan Africa is driven by excess mortality among adults, is also much reduced. But it remains the case that the largest *share* of missing women in Sub-Saharan Africa appears to go missing in the 15-29 year old age group.

The distribution of missing women by age changes the least for China when the alternative reference standards are used. China already has a rather low mortality environment and thus the biases generated by using the ratios of mortality from high-income countries are less severe.

¹⁶ Using the difference also shows qualitatively the same result; in fact, there are no more missing females in Sub-Saharan Africa. For reasons stated above, we consider the Princeton Model Life Tables and the expert standard to be the most reliable reference standard.

To summarize, using today's male to female mortality rate ratios in high-income countries likely overstates the flow of missing women in Africa and Asia. The total flow of missing women using the sex ratio in high-income countries as the reference standard is about 5 million which reduces to around 1.5-1.8 million per year when alternative reference standards are used. The estimates based on the alternative reference standards confirm previous estimates of missing women based on the *stock measure*; specifically, that the problem of missing women is more severe in India and China than in Sub-Saharan Africa and that it is largely driven by gender bias pre-birth and in young ages in India and China. Additionally, the alternative reference standards confirm that young adult women have a mortality disadvantage relative to other age groups in Sub-Saharan Africa.

5. Controlling for the Disease Environment

a. AIDS mortality

The disease environment in high-mortality regions such as Sub-Saharan Africa and, to a lesser extent, India is dramatically different from the disease environment in today's high-income countries. In Sub-Saharan Africa communicable diseases account for over 50% of all deaths.¹⁷ On the contrary, in today's high-income countries, communicable diseases account for less than 5% of total deaths, whereas non-communicable diseases drive mortality in older ages and injuries in younger ages. But not only does the distribution of causes of death differ across countries, but also the distribution of deaths by sex across causes of death. For example, in high-income countries in 2000 the sex ratio of deaths from AIDS was on average 4 across adult age groups, i.e. men died at four times the rate of women from AIDS. In contrast, in Sub-Saharan Africa, the male to female ratio of deaths from AIDS was between 1 and 1.6 in most adult age groups, but only about 0.53 in the 15-29 age group. Thus, young adult women have higher mortality from AIDS than men. The stark difference in sex ratios of AIDS mortality across regions emerges because AIDS incidence and fatalities in high-income countries are mostly driven by gay men and IV drug users (also predominantly men), whereas heterosexual transmission plays a significant role in Sub-Saharan Africa (World Bank, 1997). When estimating excess female mortality, it is critical to control for differences in the sex-specific disease environments between the population of interest and the reference population.

To account for differences in disease environments, the flow measure neglects sex-specific differences and builds up the number of missing women disease group by disease group. Specifically, the flow of missing women is calculated for each age and disease group, using the sex ratio of age-specific mortality rates for that disease group in high-income countries as the reference standard, and sums these flows over all ages and diseases to achieve the total number of missing women in a year.¹⁸ Building up the flow of missing women disease-by-disease, only has minor implications for the estimated total number of missing women. In Sub-Saharan Africa, the number of missing women who die annually falls from 1.526 million to 1.385

¹⁷ The discussion is based on numbers of death by disease, age and region reported in the web appendix and online supplementary material of Anderson and Ray (2010).

¹⁸ Formally, Anderson and Ray (2010) do the following: For disease i , $Missing_i = (MR_{fai} - (MR_{mai}/(MR_{mri}/MR_{fri}))*Pop_f$ where MR_{fai} is the actual female mortality rate in an age group from a particular disease, m , f are males and females, and ri the mortality rate in the reference population, i.e. high-income countries, from that particular disease, while Pop is the population by sex in that age bracket. The total number of missing women in an age group is simply the sum of missing women from these individual diseases in that age group (and those are summed to the total number of missing women).

million, in India from 1.712 to 1.637 million, and in China from 1.727 to 1.592 million (Anderson and Ray, 2010). The key findings of the overall high magnitude (4.6 million per year), the preponderance among adults, and the larger share of missing women in Africa, are not affected significantly by this disease correction.

The counterfactual used in this disease correction presumes that without gender bias, AIDS in Sub-Saharan Africa would have also been primarily a disease affecting gay men and IV drug users and suggests that 58% of all adult missing women in Sub-Saharan Africa die from AIDS (see Table 5, column (3)). This counterfactual is likely false. AIDS in Africa has been a disease that has spread mostly through heterosexual intercourse (and mother to child transmission) due to the early emergence of the disease in Africa and its spread among heterosexual couples long before it was identified as a disease, together with a very high incidence of STDs (Iliffe, 2006; World Bank, 1997; Oster, 2005). It is likely to be true that the particularly high incidence and fatality of AIDS among young women is to some extent due to gender discrimination (e.g. unwanted sexual intercourse with older men), but this is not the *main* reason why AIDS is a disease affecting mostly heterosexual people. Most certainly, assuming the ratio from high-income countries as a reference standard vastly overstates the relevance of AIDS in causing missing women.

Comparing the mortality sex ratios in heavily AIDS affected and largely AIDS unaffected countries of Sub-Saharan Africa supports that death from AIDS affects men and women similarly. In comparison to AIDS unaffected countries, the sex specific mortality rates among adults in AIDS affected countries would be unfavorable towards women if excess female mortality due to AIDS was so important. In Table 4, we present these ratios. In AIDS-affected countries the male-female ratio of adult mortality is indeed slightly lower at 1.107, whereas in non-AIDS affected countries the ratio is 1.157.¹⁹ However, the difference is small and the sex ratio of mortality in AIDS unaffected countries is far off the sex ratio of 1.9 prevailing in high-income countries. This is not only true on average, but for individual countries as well. For example, in two countries little affected by AIDS, Mali and Nigeria, the ratios in 2000 were 1.161 and 1.127, respectively, whereas in the two countries most affected by AIDS, Botswana and Lesotho, they were 1.051 and 1.059 (World Health Organization, 2001). If excess female mortality was so high and AIDS such an important driver of missing women, the differences between AIDS affected and AIDS unaffected countries in these sex ratios of mortality should be much larger. Further, the sex ratio of mortality in AIDS unaffected countries should be much closer to the sex ratio of 1.9 prevailing in high-income countries given that 58% of missing women in AIDS affected countries were estimated to die from AIDS based on the flow measure.

¹⁹AIDS affected countries refer to countries with a HIV prevalence of more than 5%. The countries included are Botswana, Burundi, Central African Republic, Cote d'Ivoire, Democratic Republic of the Congo, Eritrea, Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Tanzania, Uganda, Zambia, Zimbabwe. Non-AIDS affected countries refer to countries with an HIV prevalence rate of less than 5%. The countries included are Algeria, Angola, Benin, Burkina Faso, Cameroon, Cape Verde, Chad, Comoros, Congo, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Madagascar, Mali, Mauritania, Mauritius, Niger, Nigeria, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Togo.

Table 4: Adult mortality rates by sex (15-59) and sex ratios in AIDS affected and AIDS unaffected countries of Sub-Saharan Africa

| | (1) Male | (2) Female | (3) Sex Ratio |
|--|-------------|---------------|------------------|
| Sub Saharan Africa 2000, total | 0.511 | 0.454 | 1.125 |
| Sub Saharan Africa, AIDS affected countries 2000 | 0.599 | 0.541 | 1.107 |
| Sub Saharan Africa, non-Aids affected countries 2000 | 0.409 | 0.354 | 1.157 |
| High-income countries 2000 | 0.125 | 0.065 | 1.918 |

Notes: Adult mortality rates refer to the likelihood of having died by age 60 if one was alive at age 15. Male refers to the adult (15-59) mortality rate among males. Female refers to the adult (15-59) mortality rate among females. Sex ratio refers to the ratio of columns (1) and (2). To derive mortality rates in AIDS affected and non-AIDS affected countries, population (15-59 years old) weighted averages of country specific adult mortality rates were calculated (see supplementary materials). AIDS affected countries refer to countries with a HIV prevalence of more than 5%. The countries included are Botswana, Burundi, Central African Republic, Cote d'Ivoire, Democratic Republic of the Congo, Eritrea, Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Namibia, Rwanda, South Africa, Swaziland, Tanzania, Uganda, Zambia, Zimbabwe. Non-AIDS affected countries refer to countries with an HIV prevalence rate of less than 5%. The countries included are Algeria, Angola, Benin, Burkina Faso, Cameroon, Cape Verde, Chad, Comoros, Congo, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Madagascar, Mali, Mauritania, Mauritius, Niger, Nigeria, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Togo.

Sources: Country specific adult mortality rates in 2000 were taken from WHR (2001). Population numbers were taken from The UN World Population Prospect Revision 2000: <https://population.un.org/wpp/Download/Archive/Standard/>, downloaded April 3, 2021.

An alternative assumption for an AIDS-specific reference standard in environments with a predominantly heterosexual transmission path, could be a sex ratio of mortality in high-income countries that weights mortality rates by the share of hetero- and homosexual populations. For example, the sex ratio of HIV among heterosexual men (84.1%) and women (86.9%) as well as homosexual men and women (defined as those who are not heterosexual) in the US, as one of the established market economies, is around 1 (Lansky et al., 2015; Centers for Disease Control and Prevention, 2019).²⁰ This number is much smaller than the actual male to female mortality ratio from AIDS of 4 prevailing in most adult age groups of high-income countries in 2000. The sex ratio of AIDS mortality of 1 would still allow for high female mortality from AIDS in the 15-29 age group -- in which gender discrimination in the transmission of AIDS through forced sexual intercourse likely matters -- as the male to female ratio of deaths from AIDS among 15 to 29 year-olds is only 0.5 in Sub-Saharan Africa.²¹

Table 5 presents the flow of missing women from AIDS using a sex ratio of mortality from AIDS of 1 in columns (4) and (5) and a sex ratio of 1.2 as a more conservative reference standard for AIDS in columns (6) and (7). The flow of missing women from AIDS reduces by about 400,000 to 600,000 women to 19,000-170,000 excess female deaths, essentially all accruing in the 15-29 age group. Further, the share of adult women that go missing due to AIDS reduces from 58% to a more realistic percentage share of 2 to 16%, depending on the reference standard.

²⁰ Specifically, the sex ratio is calculated as $sex\ ratio =$

$$\frac{(share\ hetero.\ men * HIV\ cases\ per\ 100,000\ hetero.\ men) + (share\ homo.\ men * HIV\ cases\ per\ 100,000\ homo.\ men)}{(share\ hetero.\ women * HIV\ cases\ per\ 100,000\ hetero.\ women) + (share\ homo.\ women * HIV\ cases\ per\ 100,000\ hetero.\ women)}$$

²¹ While partly this high mortality could indeed be due to discrimination linked to unwanted sexual intercourse of young women with older men, part of the high female mortality could also be due to earlier voluntary sexual activities of females (and thus earlier AIDS risks) which is observable in most countries of the world, including high-income countries; see World Bank (2012) for a discussion.

Table 5: Number of missing women from AIDS (in 1000s) by age group using alternative reference standards

| Sub-Saharan Africa: Flow of missing women... | | | | | | | |
|--|--|---|----------|---------------------------|----------|-----------------------------|----------|
| | ...total | ... from AIDS | | | | | |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| | Reference: Sex ratio, high-income countries Method: disease-by-disease group | Reference: Sex ratio, high-income countries | | Reference: Sex ratio=1 | | Reference: Sex ratio=1.2 | |
| Age | Total | Total | % of (1) | Total | % of (1) | Total | % of (1) |
| 15-29 | 406 | 277 | 68% | 180 | 44% | 253 | 62% |
| 30-44 | 278 | 240 | 86% | -91 | -- | -55 | -- |
| 45-59 | 134 | 78 | 58% | -58 | -- | -112 | -- |
| 60-79 | 217 | 15 | 7% | -11 | -- | 6 | -- |
| 80+ | 25 | 0 | -- | 0 | -- | 7 | -- |
| Total | 1,060 | 611 | 58% | 19 | 2% | 171 | 16% |

Note: Column (1) presents the total number of missing women when calculated disease group by disease group as presented in Table 6 of Anderson and Ray (2010). Columns (2) to (7) refer to different reference standards that were applied in the estimation of missing women from AIDS. Figures in columns (1), (2), (4) and (6) are rounded to the nearest thousand. Percentage shares in columns (3), (5) and (7) are based on numbers rounded to nearest thousand in columns (1), (2), (4) and (6).

Source: Anderson and Ray (2010) Table 6 for column (1) and Anderson and Ray (2010) supplementary material for population sizes and male and female deaths from AIDS in Sub-Saharan Africa and high-income countries (referred to as EME) in 2000.

b. Maternal mortality, injuries and suicide

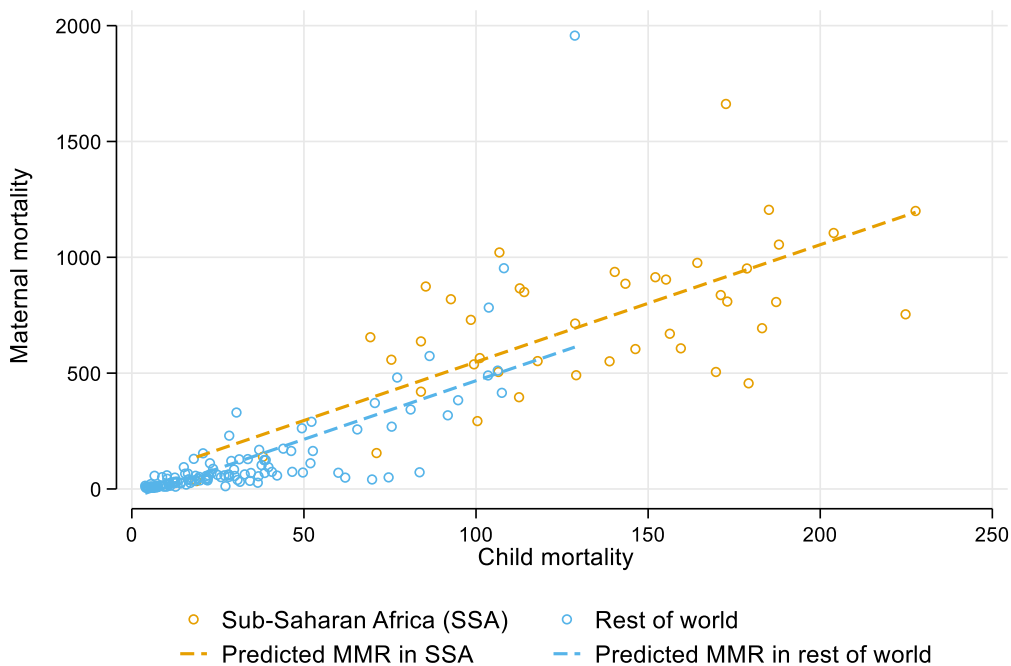
When the sex ratio of mortality in today's high-income countries is used as a reference standard there are numerous other diseases in addition to AIDS that require attention because disease patterns by sex differ between high- and low-mortality environments. In addition, some diseases are particularly rare in high-income countries, which often renders the disease-specific sex ratio of mortality prevailing in high-income countries an unsuitable reference standard.

As there is no such thing as paternal mortality that can be used to derive expected maternal mortality, the flow measure of missing women assumes that *any* maternal death above the rate prevailing in high-income countries is an excess death. Because maternal mortality is rare in high-income countries maternal mortality among 15 to 45 year-olds accounts for the second most excess deaths in Sub-Saharan Africa (after AIDS, which would change if the alternative reference standards for AIDS were used) and for most excess deaths in India. Hence, the assumption of all maternal deaths being excess female deaths is a determining factor for the total number of missing women and the distribution of missing women across age groups in Sub-Saharan Africa and India.

Maternal mortality is often related to the poor overall health conditions and services prevailing in many Sub-Saharan African countries and India. Figure 2 presents the relationship between child mortality rates of both sexes, which is an indicator of overall health conditions in a country, and the maternal mortality ratio. Child and maternal mortality show a close fit, indicating that maternal mortality goes hand-in-hand with poor overall health. If Sub-Saharan African countries were outliers in this relationship, then this might

be due to gender inequality in health access that goes beyond poor overall health conditions. The dashed lines in Figure 2 present the predicted maternal mortality ratios based on a simple linear regression model of maternal mortality on child mortality and a dummy for Sub-Saharan Africa. The results suggest that on average about 11-16% of the maternal mortality in Sub Saharan Africa is not explained by poor health conditions and might be due to gender bias.²² Thus, a small number of deaths from maternal mortality - around 22-32,000 rather than all 200,000 maternal deaths - might indeed be due to gender inequality.

Figure 2: Cross-country relationship between child mortality (x-axis) and maternal mortality (y-axis)



Notes: Child mortality is measured as the probability of dying between birth and exact age 5, expressed per 1,000 live births, while the maternal mortality ratio (MMR) is the number of maternal deaths per 100,000 live births. Predicted maternal mortality ratio is based on a linear prediction of maternal mortality on child mortality and a Sub-Saharan Africa dummy (both predictions result from the same model).

Source: UN Inter-agency Group for Child Mortality Estimation (UNICEF, WHO, World Bank, UN DESA Population Division; at childmortality.org) for child mortality and Hogan et al. (2010) for maternal mortality ratio.

Another noteworthy cause of death are injuries, specifically suicides and fires, for which differences in the distribution of deaths by sex potentially account for a substantial number of missing women. The sex ratio of deaths from suicides in India is relatively balanced and likely driven by economic hardship of families (especially in rural areas), whereas deaths from suicides in high-income countries is male biased and driven by psychiatric conditions (e.g. Aditjanyee, 1986; Hiroeh et al., 2001; Mortensen et al., 2000; Nordentoft et al., 1993; Qin et al., 2000). Similarly, death from fires is heavily male-biased in high-income countries (sex ratio of adult mortality (15-59) of 2.1), whereas in India fires afflict relatively more women (sex ratio of adult mortality (15-59) of 0.44). An estimated 106,000 out of 163,000 fire related deaths in India in 2001

²² 11-16% is the confidence interval of the mean of the Sub-Saharan Africa fixed effect (81 deaths) divided by the predicted maternal mortality ratio (mean=13.5%, CI=10.8-16.2%).

accrued to women (Sanghavi et al., 2009; Bhalla et al., 2020). It was further estimated that more women died from fires than giving birth and at a rate 20 times more than in the rest of the world. These fire-related deaths are said to be due to the use of open fires, candles, and kerosene during domestic chores as well as self-immolation and domestic violence (Sanghavi et al., 2009). Thus, a considerable share of fire related missing women is likely due to gender bias.²³ Yet, the flow of adult (>15 years) missing women from fires using the sex ratio from high-income countries as a reference standard is 72,000 in India, which make up over 50% of missing women from unintentional injuries and 80% of all fire related death of adult women would have to be due to gender discrimination, which is unlikely.

The discussion illustrates that when using the sex ratio of mortality prevailing in today's high-income countries as a reference standard in the estimation of missing women, disease corrections must address the differences in the sex-specific disease environments between high-income countries and China, India, and Sub-Saharan Africa. Differences in disease environments may be based on different structures within disease groups (as in AIDS or injuries) or can be largely a result of the overall worse disease environment in developing countries (as is the case with maternal mortality). Overall, the necessity for a detailed disease correction depends on the chosen reference standard. The more appropriate the general reference standard is, the less is such a disease correction required. For example, estimates using the Princeton Model Life Tables are much more similar to the within-disease corrected flow of missing women using high-income countries as a reference standard already.

6. General concerns about mortality data from Sub-Saharan Africa

Putting the methodological question of appropriate reference standards aside, an important reason why flow estimates of missing women have not been produced before is the lack of reliable data on age-specific mortality rates by sex in many developing countries. Disease-specific data are even harder to come by as they require a complete vital registration system.

Our analysis follows previous estimations of the flow of missing women and uses mortality data for the year 2000 from the World Health Organization's 2002 Global Burden of Disease estimates (Anderson and Ray, 2010; World Bank, 2012).²⁴ A detailed description of data sources and methods used in the derivation of the WHO mortality data are provided in Mathers et al. (2004, see text, Table 4, Annex Table 6 and Annex Table 7). While the majority of countries have fairly recent data on infant and child mortality from DHS and related surveys (the modal time period being 1995-99, see Mathers et al. Table 3), data to estimate adult mortality are often lacking. In Sub-Saharan Africa, adult mortality estimates for 2000 are based on observations from only 4 out of 46 countries, two each for the early and the late 1990s (see Mathers et al., 2004, Table 4). In fact, reliable vital registration data are available for only *one* country in Sub-Saharan Africa, which is the island of Mauritius (see Mathers et al., 2004, Annex Table 6). Although China and India also lack full vital registration systems, in China age specific deaths could be estimated from a sample vital

²³ Due to death from interpersonal violence and women would also be less likely to conduct household chores if the division of domestic and wage work was equal across sexes.

²⁴ We directly use the age- and disease-specific mortality data of Anderson and Ray (2010) as provided in their supplementary materials.

registration and the 2000 census, and in India data from a project vital registration system was available (see Mathers et al., 2004, pp.10/11 and Annex Table 6).

Since the Global Burden of Disease estimates in 2002, there have been multiple revisions and updates of the WHO life tables, the latest update being from December 2019. However, the availability of quality vital registration data has not changed a bit since 2002.²⁵ Although a few more countries, for example Cabo Verde and South Africa, now collect and report vital registration data to the World Health Organization, they were excluded due to insufficient quality (World Health Organization, 2020 a,b). In consequence, even the most recent WHO mortality data for Sub-Saharan Africa only include high-quality vital registration data for Mauritius.

In the absence of vital registration data, age- and disease-specific mortality rates for Sub-Saharan Africa have to be estimated. This requires accurate calculations of overall age-specific mortality rates to provide the 'envelope' for total deaths that can then be attributed to different disease categories (Mathers et al., 2004). When data on child mortality (the likelihood of reaching age five) and adult mortality (the likelihood of reaching age 60 given that one has reached age 15) are available, modified logit life tables can be used to estimate mortality rates for all age groups (Murray et al., 2003 a, b). Murray et al. (2003a, b) demonstrate that the prediction method performs well in simulations if reliable data on child mortality and adult mortality for each sex are available; as the relationship between child and adult mortality differs between countries and across regions (see also Coale, Demeny and Vaughan, 1983), these two pieces of information are crucial to generate the full set of age-sex specific mortality rates.

Because only child mortality data was available for the year of 2000 in Sub-Saharan Africa, the corresponding levels of adult mortality were essentially assumed, using historical model life tables, as explained by Mathers et al. (2004, p.11): "Based on the predicted level of child mortality in 2002, the most likely corresponding level of adult mortality (excluding HIV/AIDS deaths where necessary) was selected, along with uncertainty ranges, based on regression models of child versus adult mortality as observed in a set of almost 2000 life tables judged to be of good quality."²⁶ There is no independent way of confirming these adult mortality rates generated by the life tables, let alone the relationship between male and female adult mortality rates.

In more recent years there has been some progress in the estimation of adult mortality rates (15-59). Since 2012, sex-specific adult mortality estimates of the Global Burden of Disease studies are based on sibling survival data in countries where no vital registration data are available, which in the case of Sub-Saharan Africa mostly come from Demographic and Health Surveys (Obermeyer et al., 2010; Wang et al., 2020, see supplementary appendix 1, section 2.3 and appendix table 3; World Health Organization, 2020 a,b). Albeit not perfect, these adult mortality estimates are based on actual data from Africa and therefore allow for

²⁵ See <https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates/download-the-raw-data-files-of-the-who-mortality-database> for "Availability Contains an Excel file with the list of countries-years available for the mortality and population data. Last updated: 15 December 2019."

²⁶ Note that the 2000 life tables referred to here and lower down in the paper by Murray et al. (2003 a, b) are from all over the world, not from Africa alone.

a more reliable estimation of age-specific mortality rates using modified logit model life tables (Murray et al., 2003a,b; Wang et al., 2020; Wang et al. 2012, 2014; World Health Organization, 2020a,b).

Yet, the complete absence of vital registration systems makes it impossible to come up with precise age-specific mortality rates. In contrast, the stock estimates of missing women using the much more widely available (and reliable) census information appears and continues to be the more reliable way to study the issue of missing women.

7. Conclusions

The *flow measure* of missing women calculates excess female mortality that occurs in a certain time period, whereas the previous literature focused largely on calculating the *stock measure* of missing women, i.e. the deficit among alive women at one point in time. Estimations of excess female mortality by Anderson and Ray (2010) and World Bank (2012) suggest that gender bias in mortality is much larger than previously found (about 4 to 5 million excess female deaths per year vs. around 100 million missing women in total in 2000), is as severe among adults as it is among children in India, and is larger in Sub-Saharan Africa than in China and India. However, these estimates depend on particular methodological choices with respect to the reference standard and the method of disease correction. If alternative, potentially better suited, reference standards are applied the results are much more aligned with those of the previous literature on the stock measure of missing women. The stock measure results show that much more women are missing in China and India than in Sub-Saharan Africa and that, in China and India, missing women are largely attributable to excess female mortality before birth and/or the first few years of live. In addition to the discussion on an appropriate reference standard, estimations based on mortality data are less reliable per se because in most low income countries vital registration data is lacking and age and disease specific adult mortality need to be estimated.

Gender bias in mortality is a serious issue that deserves urgent attention by policy makers. According to our calculations, 1.5 to 1.8 million females perish in excess every year. Although, this number is much lower than the previous estimates of 4 to 5 million yearly excess female deaths, our results suggest that the focus of the literature and associated policy proposals on South Asia and China, and on pre-birth and young children, is largely correct.

One new finding from the flow measure that remains is the excess female mortality in Sub-Saharan Africa, mainly among young adults driven by excess mortality from AIDS and maternal mortality. In this age group, female mortality is higher than suggested by the overall disease environment and the expected mortality rate in a mainly heterosexual AIDS transmission channel. Although, excess female mortality during adulthood is much smaller than initially estimated, the result provides some intriguing further detail to the issue of gender bias in mortality in Sub-Saharan Africa studied so far (e.g. Klasen, 1996a, b; Svedberg, 1996; Klasen and Wink, 2002; 2003; World Bank, 1997). Further investigating this issue would surely be worthwhile, as would be continuing efforts to improve vital data from developing countries to be able to assess flow measures of gender bias in mortality more accurately in the future.

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